Stefano Zaffagnini
David Dejour
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Editors

Patellofemoral Pain, Instability, and Arthritis

Clinical Presentation, Imaging, and Treatment

ESSKA

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Foreword

A new look at the patellofemoral joint and a new book by ESSKA members!

The patellofemoral joint (p-f joint) has been called “the spine for the sports medicine physician” presumably due to the difficulty in finding the etiology of pain from the p-f joint. Every third youth suffers from anterior knee pain showing the scope of the clinical problem. The rationale for treatment is to correct unbalanced tracking of the patella. The most commonly recommended treatment is strengthening of the quadriceps along with avoidance of painful activities. Recently, the focus in orthopedic sports medicine has been on patella instability as the cause of the pain and many new procedures have been published over the last few years. With the arrival of new, young sports physicians and surgeons and not the least physiotherapists with profound interest in the field, old dogmas are being torn apart and new algorithms are being proposed.

This book was initiated by Stefano Zaffagnini and David Dejour with major input from Elizabeth Arendt and originates from an ESSKA supported meeting in May 09 where the authors reviewed current concepts in this important field. Chapters were assigned and more than 35 authors have contributed significantly to this book which covers the p-f joint from the young child to the old athlete. The book will be handed out to all the participants at the biannual ESSKA meeting in Oslo (June 2010) and should thus set the standard for standard terminology, evidenced based analysis, examination, and treatment of problems in the p-f joint. We, as ESSKA leadership, are extremely grateful to the initiators as well as to the authors who with this book will heighten the standards for p-f analysis and treatment.

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Preface

ESSKA has given the arthroscopy committee a fantastic opportunity: to compile an international reflection on patellofemoral (PF) disorders.

In creating this book we invited orthopedic surgeons, physiotherapists, and researchers from Europe and the USA to provide their personal point of view on various topics of interest and concern related to patellofemoral disorders. This was followed by group discussions and debate at a consensus meeting where all authors discussed each chapter of this book. This work is a collection of information and differing points of view resulting in what we hope is a homogenous product to the reader. Its goal was to construct a global overview of the pathology and treatment options for patellofemoral disorders for the young child to the old athlete.

Patellofemoral pathology is a frequent reason for consulting a knee physician; it is also a leading cause of iatrogenic surgery.

Current literature is difficult to interpret due to confusion over terminology and definitions associated with this pathology, a plethora of surgical procedures for the same pathology, and a paucity of well-executed outcome studies to help define treatment algorithms. It is sometimes difficult to define what is normal and what is pathological in a given patient. Precise definitions and clear terminology are needed in order to ensure everyone is interpreting what is being discussed in the same manner; this is a necessary first step for comparing and compiling global clinical results.

The phylogenesis of the human gait evolved from a quadruped mammal to bipedal locomotion, making the constraint of the extensor mechanism increasingly more important. The shape of the patellofemoral joint changed over the years to support this necessary constraint and yet allow upright bipedal ambulation. The patella, housed within the extensor mechanism, is the lower limb restraint mechanism. In each phase of evolution the development of a specific problem could occur. The family genetic influence is strong within this joint; the difference between pain and instability or dislocation has to be strongly individualized. The link is strong from the child to the elderly because all the factors which lead to dislocation and pain are the same factors which can lead to degenerative disease and osteoarthritis.

In the evaluation of PF disorders, there are elements that are objective others that are subjective. Clinical history and examination is important and should be standardized. The use of objective data to quantify findings on x-rays, CT scan, and MRI are necessary to allow orthopedic surgeons, sport-medicine doctors, and physiotherapists to speak the same language.

This was the goal of our team; this was the goal of ESSKA: to promote a unique, but open point of view on this controversial topic.

We hope this book has utility for all clinicians interested in the patellofemoral joint and its disorders. We hope this book will be a reference in the future for our youngest to our oldest colleagues.

Bologna, Italy — Stefano Zaffagnini
Lyon, France — David Dejour
Minneapolis, Minnesota, USA — Elizabeth A. Arendt

Acknowledgement

The editors acknowledge Silvia Bassini for her contribution of iconographic material and for the logo appearing on the cover page.

Contents

1 Pathophysiology of Anterior Knee Pain

Vicente Sanchis-Alfonso

1.1 Introduction

Anterior knee pain, diagnosed as patellofemoral pain syndrome (PFPS), is one of the most common musculoskeletal disorders [61]. It is of high socioeconomic relevance as it occurs most frequently in young and active patients. The rate is around 15–33% in an active adult population and 21–45% in adolescents [36]. However, in spite of its high incidence and abundance of clinical and basic science research, its pathogenesis is still an enigma ("The Black Hole of Orthopaedics"). The numerous treatment regimes that exist for PFPS highlight the lack of knowledge regarding the etiology of pain. The present review synthesizes our research on pathophysiology [53–62] of anterior knee pain in the young patient.

1.2 Background: Chondromalacia Patellae, Patellofemoral Malalignment Tissue Homeostasis Theory

Until the end of the 1960s anterior knee pain was attributed to chondromalacia patellae, a concept from the beginnings of the twentieth century that, from a clinical point of view, is of no value, and ought to be abandoned, given that it has no diagnostic, therapeutic, or prognostic implications. In fact, many authors have failed to find a connection between anterior knee pain and chondromalacia [52, 61]. Currently, however, there is growing evidence that a subgroup of patients with chondral lesions may have a component of their pain related to that lesion due to the overload of the subchondral bone interface which is richly innervated.

In the 1970s anterior knee pain was related to the presence of patellofemoral malaligment (PFM) [14, 24, 26, 40]. We define patellofemoral malalignment as an abnormality of patellar tracking in the sense of lateral displacement of the patella, lateral tilt of the patella, or both, in extension, that reduces in flexion. Excessive lateral pressure syndrome (ELPS) would be a type of PFM. Although it is more common to use the term malalignment as a malposition of the patella on the femur some authors, as Robert Teitge, use the term malalignment as a malposition of the knee joint between the body and the foot with the subsequent effect on the patellofemoral mechanics [61]. For many years, PFM has been widely accepted as an explanation for the genesis of anterior knee pain in the young patient. Moreover, this theory had a great influence on orthopedic surgeons, who developed several surgical procedures to "correct the malalignment." Unfortunately, when PFM was diagnosed it was treated too often by means of surgery. Currently, however, PFM concept is questioned by many, and is not universally accepted to account for the presence of anterior knee pain. In fact, the number of realignment surgeries has dropped dramatically in recent years, due to a reassessment of the paradigm of PFM.

Obviously, there are patients in whom PFM is the primary cause of their anterior knee pain but they represent in my clinical practice a small percentage of all patients with PFPS. Moreover, in my experience most of these patients were iatrogenically malaligned, that is, patients with multiple structurally/biomechanical – oriented surgeries [62]. PFM may cause pain due to cyclical soft tissue and/or bone overload.

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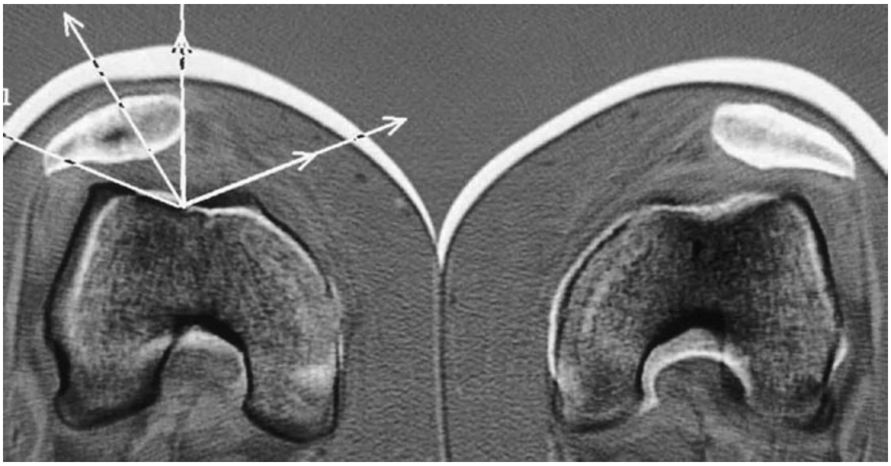

Fig. 1.1 Computed tomography (CT) at 0° from a patient with anterior knee pain in the right knee, however, the left knee is completely asymptomatic. In both knees the PFM is symmetric (Reprinted from [61]. With kind permission of Springer Science + Business)

The great problem of the PFM concept is that not all malalignments, even of significant proportions, are symptomatic. A person with PFM may never experience pain if the joint is never stressed to the point in which the tissues are irritated. Such individuals probably learn early that "my knee hurts when I do sport"; therefore learn to stop being active. Even more, one knee may be symptomatic and the other not, even though the underlying malalignment is entirely symmetrical (Fig. 1.1). On the other hand, patients with normal patellofemoral alignment on computed tomography (CT) can also suffer from anterior knee pain. Therefore, although biomechanically appealing, the malalignment theory has failed to explain the presence of anterior knee pain in many patients; so other pathophysiologic processes must exist. Moreover, PFM theory cannot adequately explain the variability of symptoms experienced by patients with PFPS (especially rest pain).

Finally, we must also remember that it has been demonstrated that there are significant differences between subchondral bone morphology and geometry of the articular cartilage surface of the patellofemoral joint, both in the axial and sagittal planes [71]. Therefore, a radiographical PFM may not be real and it could induce us to indicate a realignment surgery than could provoke involuntarily an iatrogenic PFM leading to a worsening of preoperative symptoms. This would be another point against the universal acceptance of the PFM theory. Moreover, this could explain also the lack of predictability of operative results of realignment surgery.

In the 1990s, Scott F. Dye, of the University of California, San Francisco, and his research group, came up with the tissue homeostasis theory [13]. According to Dye, the loss of both osseous and soft tissue of the peripatellar region homeostasis is more important in the genesis of anterior knee pain than biomechanical/structural characteristics. He suggests that patients with PFPS are often symptomatic due to supraphysiologic loading of anatomically normal knees components. In fact, patients with anterior knee pain often lack an easily identifiable structural abnormality to account for the symptoms. According to Dye's theory of envelope of load acceptance, overuse or cyclical overload of soft tissue or bone areas may explain anterior knee pain in some patients.

1.2.1 Patellofemoral Malalignment Versus Tissue Homeostasis Theory

From a biomechanical point of view, there are two factors that can contribute to pain: (1) PFM and (2) joint loading, that depends on intensity and duration of activity. Thus, the presence of PFM would reduce the person's envelope of loading potential; that is to say, a person with PFM and minimal to moderate joint loading can have the same overloading of the subchondral bone, which is richly innervated, as someone without PFM and high loading. Presumably, this is because PFM, reduces patellofemoral contact area which in turn would results in elevated stress across the joint [61]. Moreover, certain positions that are adopted in sports, such as maintained knee flexion and knee valgus, will contribute to increasing the overload of the subchondral bone due to the increment of the patellofemoral joint reaction (PFJR) and Q angle [61]. In the same sense, a maintained flexion contracture of the knee will contribute to increasing the overload of the subchondral bone due to the increment of the PFJR [61]. This flexion contracture could be responsible for pain [73].

In essence, the proponents of tissue homeostasis theory look at PFM as representing internal load shifting within the patellofemoral joint that may lower the threshold (i.e., decrease of the Envelope of Function) for the initiation and persistence of loss of tissue homeostasis leading to the perception of patellofemoral pain. Pain always denotes loss of tissue homeostasis. From this perspective, there is not an inherent conflict between both theories. However, these are not two co-equal theories. Tissue homeostasis theory easily incorporates and properly assesses the clinical importance of possible factors of PFM, whereas the opposite is not true.

We truly believe that both theories, are not exclusive, but complementary. In our experience, a knee with PFM can exist happily within its envelope of function, but once it is out, for example by overuse, training error, patterns of faulty sports movements or traumatism, it can be harder to get back within it, and realignment surgery could be necessary in very selected cases when nonoperative measures fail. The objective of surgery is to restore balance in a way that normalizes loading of both retinacular and osseous structures without creating other aberrant or harmful effects.

1.3 Overload in the Genesis of Anterior Knee Pain. Posterior Knee Pain in Patellofemoral Disorders. Kinetic and Kinematic Analysis Help to Improve Understanding

Powers and colleagues [48] have demonstrated by means of kinetic and kinematic analysis that female patients with PFPS presented a significant reduction in the peak vertical ground reaction force compared to the control subjects in both free walking and fast walking. They have also observed a slower gait velocity during the free and fast trials and a decrease of the stance phase knee flexion during fast walking. The reduction in knee flexion at the beginning of the stance phase could be a strategy to avoid quadriceps contraction in order to decrease the loading on the patellofemoral joint**.** Therefore, we can conclude that pain cannot be attributed to excessive lower limb loading during gait.

However, we have demonstrated that PFM could provoke, in some cases, an overload as a consequence of a modification of the gait pattern as a defense mechanism. In this sense we have found that some patients with iatrogenic medial patellar instability adopt a knee extension gait pattern to avoid an increment of the medial displacement of the patella with knee flexion, which implies an increment in the vertical ground reaction force [62]. This knee extension gait pattern obligate posterior muscles to work in a chronic manner in an eccentric condition and this situation could be responsible for posterior knee pain in some patients with patellofemoral disorders.

It is well known that from a functional point of view ascending and descending stairs is one of the most painful activities of daily living for subjects with PFPS. Moreover, it is universally accepted that walking down stairs is more challenging than step ascent due to the level of eccentric control required during step descent.

In the healthy subject, during walking down stairs, the knee joint starts from a relatively stable extended position and flexes towards an increasingly unstable position. The increased joint flexion causes a progressive increment in the knee flexion moment which is matched by progressively increasing eccentric muscle contraction in order to prevent collapse. In doing so, the knee extensor moment increases during walking down stairs as knee flexion occurs. As the PFJR is dependent on the magnitude of the quadriceps force and knee flexion angle, the compressive force acting between the patella and femoral trochlea during stair descent would be expected to be significant.

On the contrary, in the young patient with PFPS there is a statistically significant reduction in the knee extensor moment during walking down stairs compared to healthy control subjects. This reduction of the knee extensor moment could be a compensatory strategy used by patients with PFPS to minimize pain aggravation during activities such as walking down stairs. The reduction of the knee extensor moment, with the subsequent smaller quadriceps contraction, will provoke a decrease of the PFJR and a decrease of the loading on the patellofemoral joint during pain-provoking activities such as walking down stairs. Moreover, the decrease of the active shock absorption through quadriceps muscle contraction supposes greater shock absorption through the bone and cartilage that could explain tibiofemoral pain and predispose one to osteoarthritis of the knee.

One factor that could contribute to the knee extensor moment reduction could be the decrease of the stance time duration. Another strategy for reducing knee extensor moment in subjects with PFPS could be the decrease of knee flexion angles during the stance phase of stair ambulation compared to control healthy subjects. With a lesser knee flexion, the lever arm of the ground reaction force is shortened and consequently the knee extensor moment is reduced, equilibrium being achieve by fewer quadriceps contractions. This knee extension walking down stairs pattern obligates posterior muscles to work in a chronic manner in an eccentric condition and this situation could be responsible for posterior knee pain in some patients with PFPS. A decrease of the vertical ground reaction force was also observed compared to the healthy extremity. This could reflect an apprehension to load the knee joint at the beginning of the stance phase and could contribute to the knee extensor moment reduction.

PFPS patients use strategies to diminish patellofemoral joint loading during walking down stairs when compared to a pain-free control group. Therefore, we can conclude that anterior knee pain cannot be attributed to excessive lower limb loading during walking down stairs.

1.4 Critical Analysis of Realignment Surgery, What Have We Learned? In Criticism of PFM Concept. Is PFM Crucial for the Genesis of Anterior Knee Pain?

As occurs with many surgical techniques, and realignment surgery is not an exception, after wide usage, surgeons may question the basic tenets and may devise clinical research to test the underlying hypothesis, in our case the PFM concept. In this way we evaluated retrospectively 40 Insall's proximal realignments (IPR) performed on 29 patients with an average follow-up after surgery of 8 years (range: 5–13 years). One of the objectives of this study was to analyze whether there was a relationship or not between the presence of PFM and the presence of anterior knee pain [61].

In our experience IPR provides a satisfactory centralization of the patella into the femoral trochlea in the short-term follow-up, that it is associated with resolution of patellofemoral pain [53]. This fact is said to support the malalignment theory. However, the success of realignment surgery may be due to factors independent of relative patellofemoral position such as denervation of the patella, postoperative extensive rest (unload), and postoperative physical therapy. In this sense, as shown by Wojtys and colleagues [77], there are authors who have failed to show objective improvements of malalignment after isolated lateral release despite the fact that this procedure frequently lessens pain. The satisfactory centralization of the patella observed in our series is lost in the CT scans performed in the long-term follow-up in almost 57% of the cases (Fig. 1.2). That is, IPR does not provide a permanent correction of patellofemoral congruence in all the cases [61]. Nonetheless, this loss of centralization does not correlate with a worsening of clinical results [61]. Furthermore, we have not found, in the long-term follow-up, a relation between the result, satisfactory versus nonsatisfactory, and the presence or absence of postoperative PFM [61]. However, if according to some authors the presence of PFM is crucial for the genesis of anterior knee pain, why we have not found differences at long-term follow-up between the result (satisfactory vs nonsatisfactory) and the presence or absence of PFM? We postulate that PFM could influence the homeostasis negatively, and that realignment surgery could allow the restoring of joint homeostasis when nonoperative treatment of symptomatic PFM fails. Realignment surgery temporarily would unload peripatellar tissues, rather than permanently modify PFM. Once we have achieved joint homeostasis, these PFM knees can exist happily within the envelope of function without symptoms.

Moreover, in our series, 12 patients presented with unilateral symptoms [61]. In nine of them the contralateral asymptomatic knee presented a PFM and only in three cases was there a satisfactory centralization of the patella into the femoral trochlea [61]. Therefore, if the presence of PFM is crucial in the genesis of anterior knee pain, how can we account for unilateral symptoms in patients with similar morphologic characteristics of their patellofemoral joints? With regards to unilateral pain in the presence of bilateral PFM, it is well known that subjects preferentially load one limb more than the other (usually the dominant limb) with high demanding activities as occurs in sports. This loading difference could be enough to cause unilateral pain. Moreover, when one knee starts to hurt, overall activity tends to decrease. Perhaps the loading on the

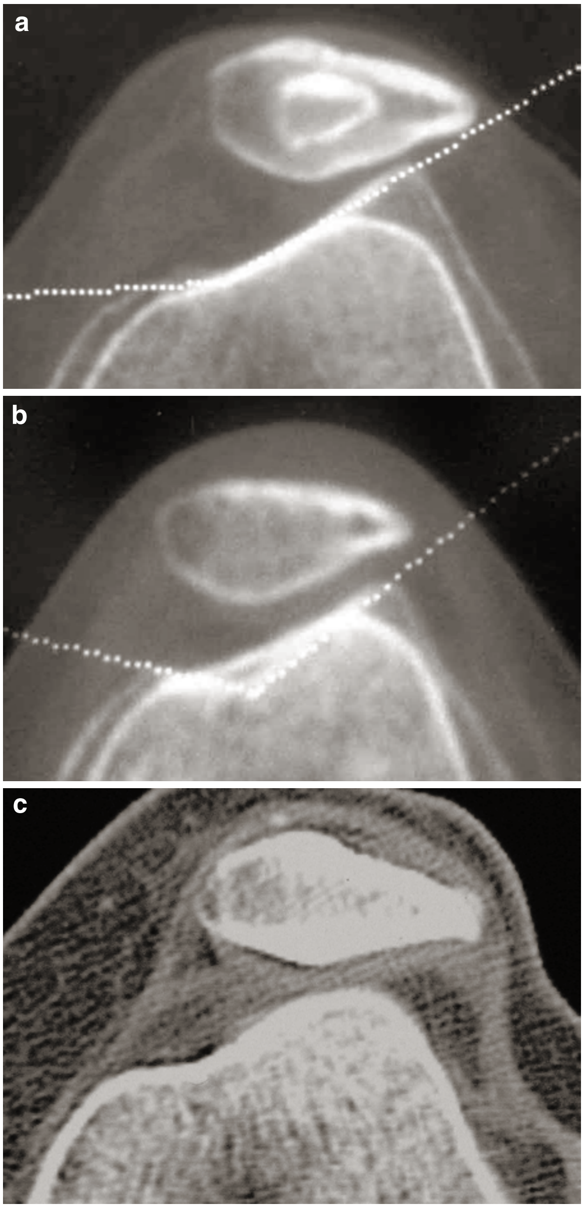

Fig. 1.2 Loss of patellar centralization at long-term follow-up in a patient with clinically excellent result at 13 years follow-up. (**a**) Pre-op (Reprinted with permission from SLACK Incorporated [55]), (**b**) Post-op 6 months, (**c**) Post-op 13 years (Reprinted from [55] (**b**) and [61] (**c**). With kind permission of Springer Science + Business Media)

other side is insufficient to reach the pain threshold. However, we have not found a relationship between the lateral dominance and the affected side in the cases with unilateral pain.

Finally, in six patients with bilateral symptoms operated on of the most symptomatic knee the contralateral knee was pain-free in the follow-up. Moreover, in my experience 91% of patients with primary PFPS improve with conservative treatment. So, if the presence of PFM is crucial in the genesis of anterior knee pain, why do symptoms disappear without any change in the patellofemoral alignment? We believe that loss of both tissue and bone homeostasis is more important than structural characteristics in the genesis of anterior knee pain.

According to Grelsamer PFM is a predisposing factor that requires a yet-unknown intermediary to trigger the pain [20]. However, we have observed that not all patellofemoral malaligned knees show symptoms, which is not surprising, as there are numerous examples of asymptomatic anatomic variations. What is more, we have demonstrated that PFM is not a sufficient condition for the onset of symptoms. Moreover, it is not crucial for the genesis of PFPS given that there are many patients with PFPS without PFM. We can conclude that the pain generator is not the malalignment. Thus, no imaging study should give us an indication for surgery. History, physical exam, and differential injection, must point towards surgery and imaging only to allow us to confirm clinical impression.

To think of anterior knee pain as somehow being necessarily tied to PFM is an oversimplification that has positively stultified progress toward better diagnosis and treatment. The great danger in using PFM as a diagnosis is that the unsophisticated or unwary orthopedic surgeon may think that he or she has a license or "green light" to correct it with misguided surgical procedures that very often make the patients' pain worse. In my experience the worst cases of anterior knee pain are those patients that have had multiple, structurally oriented operative procedures, for symptoms that initially were only mild and intermittent.

1.5 Neuroanatomical Bases for Anterior Knee Pain in the Young Patient: "Neural Model"

Based on our histological studies [54, 56, 57, 60], we have developed what we call "Neural Model" as an explanation for the genesis of anterior knee pain in the young patient.

We are fully aware that anterior knee pain cannot be imputed to one single factor, but a multiplicity of factors are involved [7, 8, 17, 19, 30, 54, 56, 57, 60, 74]. The origin of pain could be in: lateral retinaculum, medial retinaculum, infrapatellar fat pad, synovium, and subchondral bone. Moreover, we must also consider some influencing factors such as: overload, instability, psychological factors, and gender. Moreover, it is likely that different subgroups of PFPS exist.

Our studies on anterior knee pain pathophysiology [54, 56, 57, 60] have been focused on the lateral retinaculum (67 specimens analyzed) retrieved during patellofemoral realignment surgery because there is clinical support to think that this anatomical structure plays a key role in the genesis of anterior knee pain in the young patient [8, 17, 19, 30, 54, 56, 57, 60, 77]. According to Fulkerson [16], in patients with PFM there is an adaptative shortening of the lateral retinaculum as a consequence of the lateral displacement of the patella. With knee flexion, the patella migrates medially into the femoral trochlea [53], which produces a recurrent stretching on the shortened lateral retinaculum that may cause nerve changes such as neuromas and neural myxoid degeneration [16, 17]. Moreover, in some cases we have also performed histological studies of the medial retinaculum (13 specimens).

Patients with patellar symptoms can be divided into two groups: those with anterior knee pain and those with patellar instability. To obtain a homogeneous population we have included in our study group only those patients who had: (1) tenderness over the lateral retinaculum and excessive lateral tightness in the cases in which the main symptom was pain, and instability in the lateral direction in the cases in which the main symptom was instability, (2) PFM demonstrated with CT, (3) no previous knee surgery, (4) no peripatellar tendinosis and bursitis, and (5) no associated intra-articular pathology (synovitis, meniscal tears, ACL/PCL tears, osteoarthritis) confirmed arthroscopically. Given that our objective was to study "pain" patellar instability group was used as control group.

1.5.1 Morphologic Neural Changes into the Lateral Retinaculum

Some studies have implicated neural damage into the lateral retinaculum as a possible source of pain in the young patient. In 1985, Fulkerson and colleagues [17] described for the first time nerve damage (demyelination and fibrosis) in the lateral retinaculum of patients with intractable patellofemoral pain requiring lateral retinacular release or realignment of the patellofemoral joint. The changes observed by these authors in the retinacular nerves resembled the histopathologic picture of Morton's interdigital neuroma. Later, in 1991, Mori and colleagues [43] found degenerative neuropathy into the lateral retinaculum in patients with anterior knee pain. Like theses authors, we [54, 60] have also observed in many cases, into the lateral retinaculum, chronic degenerative nonspecific changes in nerve fibers, with myxoid degeneration of the endoneurium, retraction of the axonal component and perineural fibrosis (Fig. 1.3a). Likewise, a smaller group of specimens presented nerve fibers mimicking amputation neuromas seen in other parts of the body [54, 60] (Fig. 1.3b). Regarding neuromas, we have seen a clear relationship between their presence and anterior knee pain. In contrast, we have found no relationship between neural myxoid degeneration and pain.

Nerve damage occurs diffusely in the affected retinaculum, and therefore one must consider the possibility of multiple neurologic sequelae in the peripatellar region. A possible consequence of this nerve damage

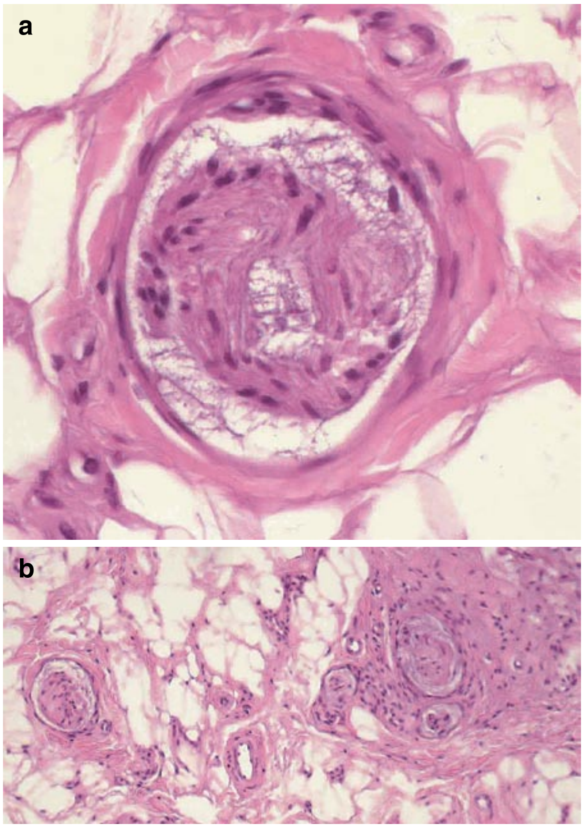

Fig. 1.3 Histologic features of a nerve with neural myxoid degeneration (**a**), and a tissular neuroma (**b**) in the lateral retinaculum. (Hematoxylin-Eosin stain). (Reprinted from [54]. With permission; first publication by SAGE/SOCIETY)

could be an altered proprioceptive innervation [17]. Baker and colleagues [28] observed abnormal knee joint position sense (proprioception) in subjects with PFPS. This is in agreement with the clinical study of Jerosch and Prymka in 1996 [29], that revealed a highly significant reduction in knee proprioception after patellar dislocation, explained by the damage of neuroproprioceptive fibers [29, 75].

Current research shows the importance of proprioceptive information from joint mechanoreceptors for proper knee function. Connective tissues, in addition to their mechanical function, play an important role in transmitting specific somatosensory afferent signals to the spinal and cerebral regulatory systems. Thus, the giving-way in patients with PFPS can be explained, at least in part, because of the alteration or loss of joint afferent information concerning proprioception due to the nerve damage of ascendent proprioception pathway or decrease of healthy nerve fibers capable of transmitting proprioceptory stimuli [54]. In conclusion, it seems likely that, to a certain degree, the instability in patients with PFPS depends not only on mechanical factors (such as Patella Alta, soft tissue dysplasia, and patellar and trochlear dysplasia) but also on neural factors (proprioceptive deficit both in the sense of position, and in slowing or diminution of stabilizing and protective reflexes) [20, 29, 75]. Jensen and colleagues [28] demonstrated an abnormal sensory function in the painful and nonpainful knee in some subjects with long lasting unilateral PFPS. A dysfunction of the peripheral and/or the central nervous system may cause neuropathic pain in some individuals with PFPS.

1.5.2 Hyperinnervation into the Lateral Retinaculum and Anterior Knee Pain. Immunohistochemical Analysis for Neural Markers

Our studies have implicated hyperinnervation into the lateral retinaculum as a possible source of anterior knee pain in the young patient [54, 60]. Thus, we found an increase in the number of nerves in the lateral retinaculum of patients with painful PFM, there being higher values in those with severe pain compared with those with moderate or light pain [60]. Moreover, we have seen that the lateral retinaculum of the patients with pain as the predominant symptom showed a higher innervation pattern than the medial retinaculum or the lateral retinaculum of patients with patellar instability [56]. This nerve ingrowth, consisted of myelinated and unmyelinated nerve fibers (Fig. 1.4) with a predominant nociceptive component [56].

The nociceptive properties of at least some of these nerves are evidenced by their substance P (SP) immunoreactivity. SP, which is found in primary sensory

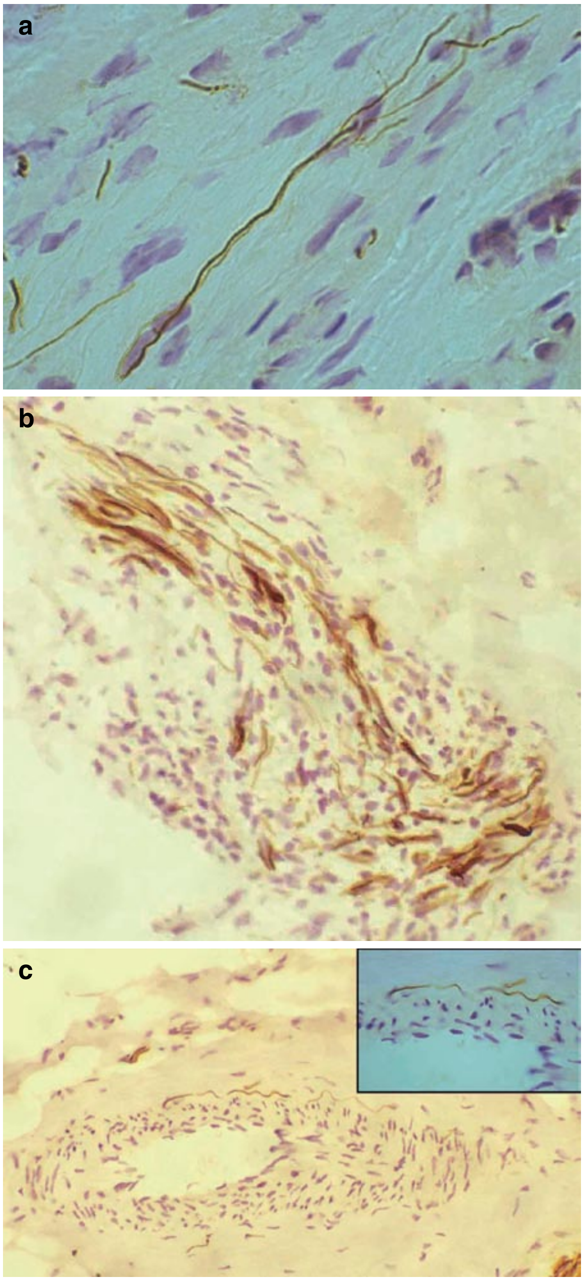

Fig. 1.4 Free nerve endings (**a**). Neuroma showing the richness in free nerve endings (**b**). Vascular innervation (**c**) (Neurofilaments, hematoxylin counterstained) (Reprinted from [56]. With permission; first publication by SAGE/SOCIETY)

neurons and C fibers (slow-chronic pain pathway), is involved in the neurotransmission pathways of nociceptive signals [2, 4–6, 11, 15, 22, 32–34, 47, 76, 77]. SP was detected in the axons of big nerve fibers, in free nerve endings, and in the vessel walls in some patients with pain as predominant symptom [56] (Fig. 1.5). Nociceptive fibers, that is, neural fibers with intra-axonal SP, were in a lower number than NF fibers, indicating that not all the tiny perivascular or interstitial nerves were nociceptive [56]. Interestingly, our finding that SP fibers were more abundant in the lateral retinaculum than in its medial counterpart reinforce the role of the lateral retinaculum as a main source of pain in these patients [56]. Moreover, we have observed that the number of these nociceptive fibers was higher in PFM patients suffering from pain as main symptom than in those with instability as predominant symptom (with little or no pain between instability episodes) [56].

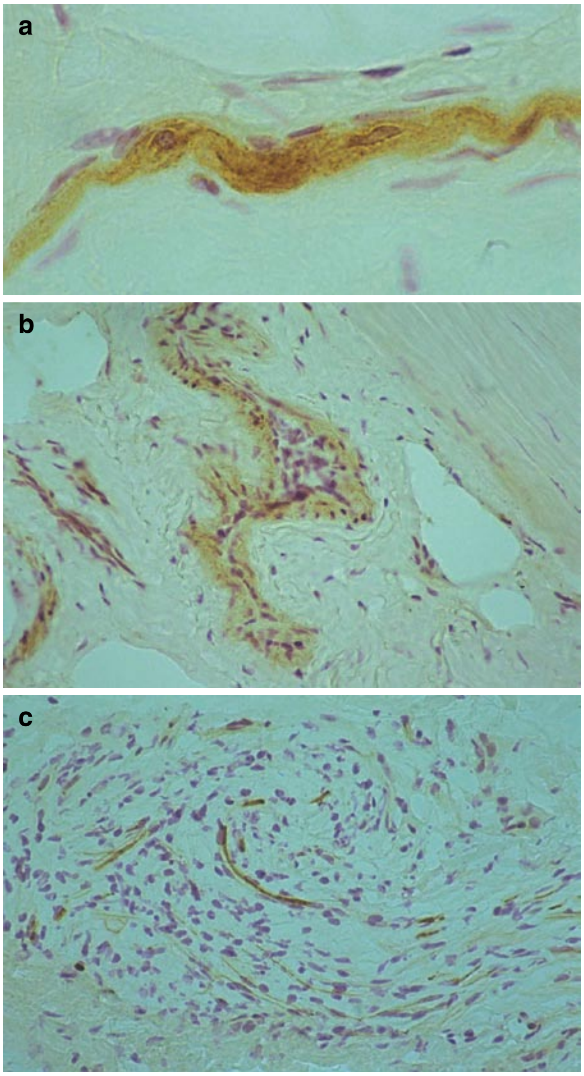

Fig. 1.5 Substance P is present in the axons of the nerves and in the free nerve endings with a granular pattern (**a**), and can be observed in the vessel walls in some patients with a painful clinic (**b**). Neuromas are rich in nociceptive axons, as can be demonstrated studying substance P (**c**). (Immunohistochemistry for Substance P. Frozen sections). (Reprinted from [56]. With permission; first publication by SAGE/SOCIETY)

Nerve ingrowth is mostly located within and around vessels [56, 60] (Fig. 1.6). Thus, we have seen, into the lateral retinaculum of patients with painful PFM, S-100 positive fibers in the adventitial and within the muscular layer of medium and small arteries, resembling a necklace. S-100 protein is a good marker when studying nerves, because of its ability to identify Schwann cells that accompany the axons in their myelinated part. It is well known that myelinated fibers lose their myelin sheath before entering into the muscular arterial wall, but this was not the case in our patients. Since we were studying by S-100 immunostaining only the myelinated fibers, and the myelin sheath is supposed to be lost before the nerve enters the muscular arterial wall, we were surprised by the identification of S-100-positive fibers within the muscular layer of medium and small arteries. Therefore, our findings may be considered as an increase in vascular innervation. We have demonstrated that vascular innervation was more prominent (94%) in patients with severe pain, whereas we found this type of hyperinnervation in only 30% of the patients with light or moderate pain [60]. Our findings are in agreement with the statement of Byers that postulated in 1968, that pain in the osteoid osteoma could be generated and transmitted by vascular pressure-sensitive autonomic nerves [9].

In reviewing the literature, we have seen that hyperinnervation is also a factor implicated in the pathophysiology of pain in other orthopedic abnormalities such as chronic back pain, and jumper's knee [11, 15]. On the other hand, pain has also been related with vascular innervation in some pathologies as is the case in osteoid osteoma [23], where the authors found an increase in perivascular innervation in all their cases, postulating that pain was more related with this innervation than with the release of prostaglandin E_2. Grönblad and colleagues [21] have also found similar findings in the lumbar pain of the facet syndrome. Finally, Alfredson and colleagues [3] related pain in Achilles tendinosis with vasculo-neural ingrowth.

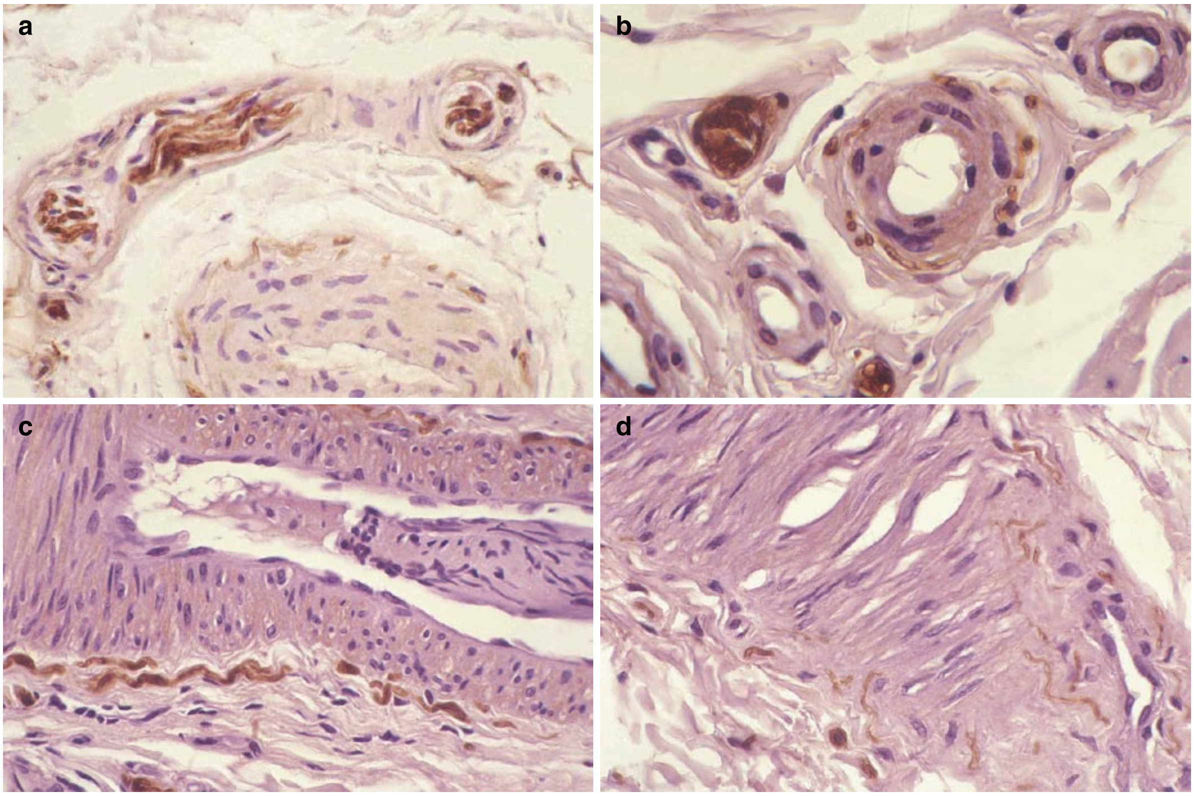

Fig. 1.6 An increase in periadventitial innervation is detectable in our patients expressed as a rich vascular network made up of tiny myelinated fibers that, from the arterial adventitia, enter into the outer muscular layer, conforming a necklace. (Immunohistochemistry for protein S-100) (Reprinted from [54]. With permission; first publication by SAGE/SOCIETY)

We have demonstrated that hyperinnervation is associated with the release of neural growth factor (NGF), a polypeptide that stimulates axonogenesis [57]. NGF adopted a granular pattern in the cytoplasm of Schwann cells of the thick nerve fibers and in the muscular wall of the arterial vessels and the amount of staining for this neurotrophin was related with increased perivascular innervation [56]. NGF has two biologically active precursors: a long form of approximately 34 kD of molecular weight, and a short form of 27 kD [12]. We have found, in the lateral retinaculum of patients with painful PFM, the 34 kD precursor. The fact that some of the nerve fibers of the lateral retinaculum express NGF means that these nerve fibers must still be in a proliferative phase [57]. As expected, we found that NGF is higher in patients with pain that in those with instability as the main symptom [57]. Gigante and colleagues [19] have also found NGF and TrkA (the NGF receptor) expression into the lateral retinaculum of patients with PFM, but not in patients with jumper's knee or meniscal tears.

However, NGF is related not only to neural proliferation in vessels and perivascular tissue but also to the release of nociceptive transmitters, such as substance P [38]. We postulate that both mechanisms are involved in the pathogenesis of anterior knee pain in patients with PFM. Thus, we suggest that two pathobiological mechanisms may lead to symptomatic PFM: (1) pain as the main symptom, with detectable levels of NGF that cause hyperinnervation and stimulus of SP release, and (2) instability as the predominant symptom, with lower levels of local NGF release, less neural proliferation and less nociceptive stimulus [57]. This means that there must be other factors acting on a PFM to conduct it versus pain or instability as the main symptom. Maybe, PFM may not have anything to do with the appearance of pain (PFM = "nonparticipating guest"). In other words, symptoms appear to be related to multiple factors with variable clinical expression, and our imperfect understanding of these factors may explain the all-too-frequent failure to achieve adequate symptom relief with the use of realignment procedures.

The question is: which are the mechanisms that stimulate NGF release in these patients? We hypothesize that periodic short episodes of ischemia could be the primary mechanism of NGF release, hyperinnervation, and therefore could be implicated in pain, at least in a subgroup of patients with PFPS.

1.6 Which is the Basic Cause of the Disease? Role of Ischemia in the Genesis of Anterior Knee Pain. "Loss of Vascular Homeostasis"

Despite the numerous publications concerning PFPS, the basic cause of the disease, that is the pain-provoking mechanism, is controversial. Rethinking the pathogenesis of PFPS and exploring new pain mechanisms could lead to changes in the assessment and management of this syndrome. The findings in our studies are in agreement with the biologically orientated perspective of the genesis of pain proposed by Scott Dye. Our results indicate that vascular problems also affect the tissue homeostasis. We propose the loss of vascular homeostasis as an intrinsic mechanism of pain in a subgroup of anterior knee pain patients.

1.6.1 Definition of Tissue Homeostasis, Ischemia, and Hypoxia

The term homeostasis is defined to mean the maintenance of constant conditions in the internal environment. The concept of tissue homeostasis involves all the molecular and biochemical processes that result in the normal maintenance of living structures and which restores in an automatic biologic process homeostasis (healing) following a perturbing event or series of events (overuse). At present, osseous homeostasis can be sensitively and geographically manifested by the use of PET scans (Positron Emission Tomography) with the use of flourine.[18] However, no method exists to sensitively and geographically manifest soft tissue homeostasis. Clinically, the presence of musculoskeletal soft tissue homeostasis is manifested by the absence of pain, tenderness, warmth, or swelling, while the loss of musculoskeletal soft tissue homeostasis is most often indicated by the presence of pain, tenderness, warmth, and swelling, etc., the classical signs of inflammation.

Hypoxia is a pathological condition in which the body as a whole (generalized hypoxia) or in part (tissue hypoxia) is deprived of an adequate supply of oxygen. It could be the result of a reduced supply of arterial blood or venous stasis (ischemic hypoxia), insufficient oxygen saturation (hypoxic hypoxia), or low hemoglobin (anemic hypoxia). Ischemia is an absolute or relative shortage of blood supply caused by vasoconstriction or blockage of the blood vessels supplying or draining the tissue.

1.6.2 Basic Science

According to some authors NGF synthesis can be induced by ischemia [1, 35, 78]. Moreover, it has been shown that NGF stimulates neural sprouting and hastens neural proliferation in vessels walls [25, 31], and it is just the pattern of hyperinnervation that is seen in the lateral retinaculum of patients with painful PFM [54, 56, 60]. Similar changes have been studied in animal models and are present in the coronary innervation of patients with myocardial infarcts and brain ischemia [1, 31, 35]. Thus, we hypothesize that short episodes of tissular ischemia, due to a mechanism of vascular torsion or vascular bending, may be the main problem in painful PFM [56, 57, 60]. Vascular bending could be induced mechanically by medial traction over the retracted lateral retinaculum, due to PFM, with knee flexion.

We have demonstrated histologic retinacular changes associated with hypoxia in painful PFM [60]. In this way, we find lesions that can lead to tissular anoxia such as arterial vessels with obliterated lumina and thick muscular walls [60] and, in addition, we find other lesions that are a consequence of ischemia such as infarcted foci of the connective tissue, myxoid stromal degeneration, and ultrastructural findings related with anoxia (degenerated fibroblasts with autophagic intracytoplasmic vacuoles, endothelial cells with reduplication of the basal lamina, young vessels with endothelial cells containing active nuclei and conspicuous nucleoli and neural sprouting) [51, 60, 68]. We ought to bear in mind that, at experimental level, it has been found that neural sprouting finishes when NGF infusion ends [25].

Another phenomenon related with ischemia is angiogenesis, given that chronic ischemia leads to VEGF-release, inducing hypervascularization in order to satisfy the needs of the tissue [67]. We have

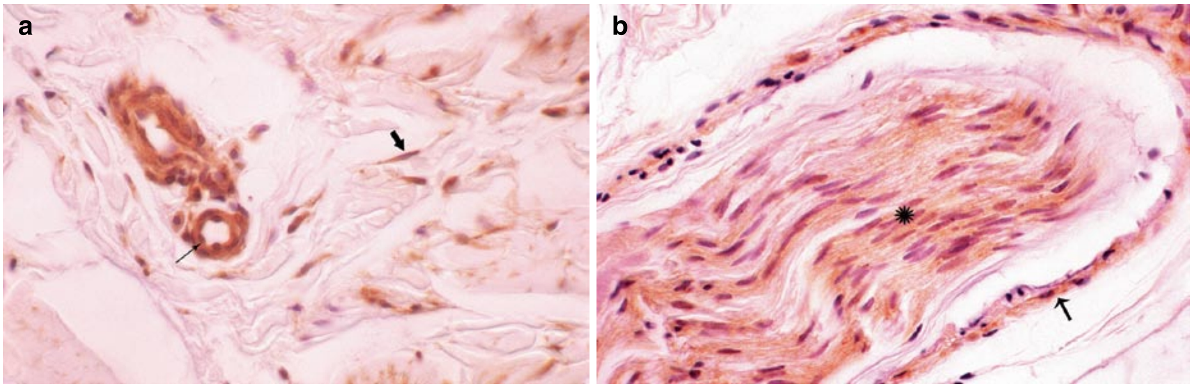

Fig. 1.7 (**a**) VEGF is present in small vessels (wall and endothelium) (*thin arrow*) and in perivascular fibroblasts (*thick arrow*) in patients with moderate-severe pain. (**b**) Some cases have VEGF expression even in the perineural shift (*thin arrow*) and inside the axons (*asterisk*) (Immunohistochemistry for VEGF) (Reprinted from [61]. With kind permission of Springer Science + Business Media)

performed a quantitative analysis of vascularization into the lateral retinaculum excised at the time of surgical patellofemoral realignments using a pan-vascular marker, anti-Factor VIII-related antigen [60]. Thus, we found an increase in the number of vessels in the lateral retinaculum of patients with painful PFM, there being higher values in the severe pain group compared with those of moderate or light pain [60]. Moreover, as expected, we found a positive linear correlation between number of vessels and number of nerves [60].

Tissular ischemia induces vascular endothelial growth factor (VEGF) release by fibroblasts, synovial cells, mast cells, or even endothelial cells [37, 41, 44, 80]. Following these principles, we performed a study of VEGF expression into the lateral retinaculum of patients with PFM by immunohistochemistry and immunoblot [60]. VEGF is a potent hypoxia-inducible angiogenic factor that causes hypervascularization [27, 37, 39, 41, 50, 67, 72]. VEGF release begins 8 h after hypoxia and the peptide disappears in 24 h, if the ischemic crisis is over [60, 61]. Therefore, VEGF positivity reflects that, at this moment, we face an ischemic process, or better said, we are between 8 and 24 h from the onset of the transitory ischemic episode. However, given the fact that the average life of VEGF is very short, its negativity has no significance regarding the presence or not of a transitory ischemic process.

Although this process has been well documented in joints affected by rheumatoid arthritis and osteoarthritis [27, 44, 49, 80] it has never been documented in PFM until our study [60]. In our series, VEGF production was seen in stromal fibroblasts, vessel walls, certain endothelial cells, and even nerve fibers, as much in axons as in perineurum [60] (Fig. 1.7). We complemented immunohistochemistry to identify and locate VEGF with immunoblotting so as to detect even minimal expression of VEGF. Our immunohistochemical findings were confirmed by immunoblot analysis. VEGF levels were higher in patients with severe pain than in those with light-moderate pain whereas the protein was barely detectable in two cases with light pain [60] (Fig. 1.8).

VEGF expression is absent in normal joints [27] although inflammatory processes can stimulate its release [27, 49]. In such cases, synovial hypoxia secondary to articular inflammation is supposed to trigger VEGF production [27]. However, we have not observed inflammatory changes into the lateral retinacum in our cases [54, 60]. Furthermore, it has been reported that peripheral nervous system hypoxia can simultaneously trigger VEGF and NGF synthesis via neurons [10]

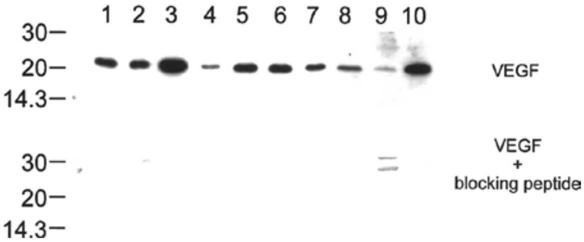

Fig. 1.8 Immunoblotting detection of VEGF, showing a thicker band in cases with severe pain, whereas it is hardly expressed in two patients in whom instability and not pain was the main problem (severe pain: cases 2, 3, 10; moderate pain: cases 1, 5, 8, and light pain: cases 4, 6, 7, 9) (Reprinted from [61]. With kind permission of Springer Science + Business Media)

inflammatory or stromal cells [1, 35, 78]. VEGF induces hypervascularization and NGF induces hyperinnervation. Both facts have been observed in our cases [54, 60]. We have concluded that ischemia could be the main trigger for the pain in PFPS, at least in a subgroup of patients with PFPS.

1.6.3 Clinical Studies

We believe that PFPS may be attributable to vascular disturbance. However, the role of vascular insufficiency in PFPS has not been studied extensively from a clinical point of view. In fact, up to now only few clinical papers allude to the possibility of hypoxia as a factor in the pathogenesis of anterior knee pain.

Sandow and Goodfellow [63] investigated the natural history of anterior knee pain in adolescents. They observed in a study sample of 54 adolescent girls that 9 out of 54 (16.7%) had pain that was aggravated by cold weather. According to Selfe and colleagues [64], the proximal part of the rete patellae is very superficial, and therefore it is vulnerable to thermal environmental stress, resulting in greater hypoxia during cold weather. More recently, Selfe and colleagues [65] studied the clinical outcome in a sample of patients categorized as hypoxic, that is to say PFPS patients with "cold knees" (his/her legs felt cold even in warm surroundings). Fourteen out of 77 (18%) of the patients were classed as "cold sufferers" (a percentage very similar to that of Sandow and Goodfellow). They studied local hypothermia by means of infrared thermography. The authors concluded that the patients categorized as hypoxic reported greater pain levels and responded worse to an exercise based treatment than nonhypoxic patients. Gelfer and colleagues [18], using single-photon emission computed tomography (SPECT), also found a relationship between transient patellar ischemia following total knee replacement and clinical symptoms of anterior knee pain. In the same sense Naslund [45] also observed, using photoplethysmography, which is a reliable technique for estimating blood flow in bone tissue, that an ischemic mechanism (decreased blood flow in the patellar bone) is involved in the pathogenesis of pain in PFPS. Moreover, Naslund [45] also observed in half of PFPS patients an accelerated bone remodeling in any of the bony compartments of the knee joint that may be due to a dysfunctioning sympathetic nervous system and cause intermittent ischemia and pain. Selfe and colleagues [64] classified anterior knee pain syndrome patients into three groups: hypoxic, inflammatory, and mechanical. However, ischemia may be the pain-provoking factor in all three groups given that inflammatory changes can develop not only after ischemia but also after mechanical damage to the vascular system [45, 79]. Ischemia could be caused by higher intraosseous pressure, redundant axial loading, or decreased arterial blood flow [45].

1.7 Author's Proposed Anterior Knee Pain Pathophysiology (See Fig. 1.9)

We hypothesize that short and repetitive episodes of tissular ischemia, due maybe to a mechanism of vascular torsion or vascular bending, which could be induced by a medial traction over a retracted lateral retinaculum, could trigger release of NGF and VEGF on PFM. Once NGF is present in the tissues, it induces hyperinnervation, attraction of mastocytes, and substance P release by free nerve endings [38]. In addition, VEGF induces hypervascularization and plays also a role increasing neural proliferation.

Free nerve endings, slowly adapting receptors that mediate nociception, are activated in response to deformation of tissues resulting from abnormal tensile and compressive forces generated during flexoextension of the knee, or in response to the stimulus of chemical agents such as histamine, bradykinin, prostaglandins, and leukotrienes [32, 69, 70]. Therefore, SP is released

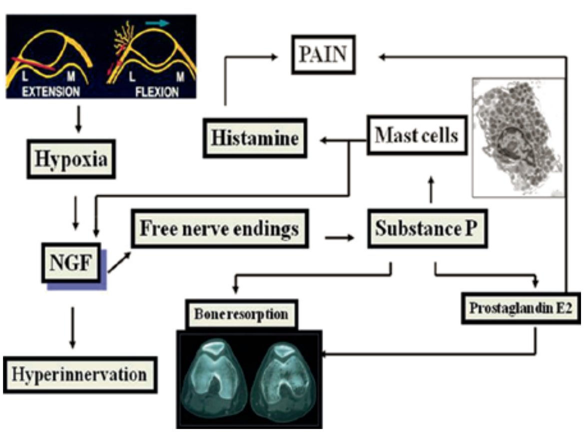

Fig. 1.9 Pathophysiology of anterior knee pain

from peripheral endings of nociceptive afferents as a result of noxious chemical or mechanical stimulation. The nociceptive information relayed by these free nerve endings is responsible, at least in part, for the pain.

Once SP is liberated on the connective tissue, the neuropeptide induces as well the release of prostaglandin E2, one of the biochemical agents known to stimulate nociceptors [2]. The activation of nociceptive pathways by prostaglandins could be one of the many mechanisms involved in the transmission of pain from knees with PFM. Moreover, SP stimulates mast cells, facilitating a degranulation process, which can liberate in the media another nonneurogenic pain mediator, the histamine [22]. Numerous mast cells have been identified into the lateral retinaculum of our patients [61]. Mast cells have been also related with the release of NGF [46, 56], contributing to the hyperinnervation and indirectly provoking more pain. Furthermore, SP has been shown to induce the release of collagenase, interleukin-1, and tumor necrosis factor-alpha (TNF-α) from synoviocytes, fibroblasts, and macrophages, that could participate in the genesis of patellar instability by degradation of soft tissues [2, 5]. SP has recently been implicated as well in bone resorption both in vitro and in vivo, which can explain at least in part the osteoporosis associated in many cases of anterior knee pain [66]. Finally, SP and VEGF stimulate endothelial cell proliferation and migration [6], which are essential in the development of a new vascular network that may promote tissue repair, but indirectly maintain the vicious circle.

Woolf [79] described from a clinical point of view four types of pain: (1) Nociceptive pain – transient pain in response to noxious stimulus, (2) homeostatic pain – pain that promotes the healing of injured tissue, that is the cascade of events that participate in the reestablishment of homeostasis, (3) Neuropathic pain – spontaneous pain and hypersensitivity to stimulus in association with damage of the nervous system, and (4) Functional pain – pain resulting from abnormal central processing of normal input. Homeostatic pain may include specific symptoms such as allodynia – pain due to stimulus that does not normally provoke pain – and hyperalgesia – a heightened response to a stimulus that is normally painful. The phenomenon of rest pain in PFPS ("movie sign") might be an example of allodynia, that is, pain arising from nonnociceptive afferent activity due to central sensitization and can be induced by ischemia [42]. All these mechanisms are involved in the pathophysiology of pain in PFPS.

1.8 Clinical Relevance

Anterior knee pain depends not only on mechanical factors, but also on neural factors that are involved in this process. Our findings provide support for the clinical observation that lateral retinaculae play an important role in anterior knee pain syndrome. The resolution of pain by realignment surgery, as we have seen in our series [53], does not necessarily mean that PFM caused theses symptoms. We believe that pain relief after realignment surgery may be attributed in part to dennervation. In the same sense, Vega and colleagues [74] in 2006, described electrosurgical arthroscopic patellar dennervation for the treatment of patients with intractable anterior knee pain and no or minimal malalignment.

Moreover, realignment surgery would not only achieve the effect of denervation mentioned above, but it would also eliminate the tensile and compressive forces that are produced in the lateral retinaculum with knee flexoextension, that stimulate free nerve endings (a type of nociceptor) [32], and would break the ischemia – hyperinnervation – pain circle.

If the "neural model" of anterior knee pain proves to have certain validity, it would lead in many cases to therapeutic recommendations to alleviate pain more effective and safer than the attempts to correct "malalignment." Thus, specific unloading, a selective pharmaceutical approach, that is to say medications that affect neural pain transmission (e.g., drug inhibitors of synthesis and release of SP, or SP receptor antagonists), could be of interest in the treatment of pain in these patients. Finally, if we demonstrate that regional anoxia plays a key role in the genesis of pain, topical periferic vasorelaxant drugs could also be of special interest in the treatment of pain in these patients as well as protecting the knees from decrease in blood flow by means of limitations in time spent with knee in flexion as well as protecting the knees from a cold environment. Moreover, ice application in these patients may cause increasing of symptoms due to a significant diminution of blood flow following it.

We are now at a turning point. Nowadays, medicine in its entirety is being reassessed at sub-cellular level, and this is precisely the line of thought we are following in the approach to PFPS. Still to be seen are the implications that this change of mentality will have in the treatment of PFPS in the future, but we are sure that these new currents of thought will open for us the doors to new and exciting perspectives that could potentially revolutionize the management of this troublesome pathologic condition in the new millennium we have just entered. Clearly, we are only at the beginning of the road that will lead to understanding where anterior knee pain comes from.

1.9 Conclusions

We have demonstrated a neuroanatomical basis for PFPS in the young patient and the clinical observation that the lateral retinaculum may have a key role in the origin of this pain. Our findings, however, do not preclude the possibility of pain arising in other anatomical structures.

We hypothesize that periodic short episodes of ischemia could be implicated in the pathogenesis of anterior knee pain by triggering neural proliferation of nociceptive axons (SP-positive nerves), mainly in a perivascular location. Our findings are in line with the homeostasis perspective proposed by Dye. We believe that loss of vascular homeostasis in the knee region (e.g., hypervascularity, ischemia, osseous hypertension) may be associated with PFPS. Moreover, we believe that instability in patients with PFPS can be explained, at least in part, because of the damage of nerves of the lateral retinaculum which can be related with proprioception.

1.10 Summary

- We review the development in the field of pathophysiology of anterior knee pain in the young patient to its current status.
- We have developed what we call the "Neural Model" as an explanation for the genesis of anterior knee pain.
- We hypothesize that periodic short episodes of ischemia into the lateral retinaculum could be implicated in the pathogenesis of anterior knee pain, at least in a subgroup of anterior knee pain patients, by triggering neural proliferation of nociceptive axons (substance P-positive nerves), mainly in a perivascular location.
- Our findings are compatible with the tissue homeostasis theory widely accepted currently to explain the genesis of anterior knee pain.
- If the "neural model" of anterior knee pain proves to have certain validity, it would lead in many cases to therapeutic recommendations to alleviate pain more effective and safer than the attempts to correct "malalignment."

Part of this chapter has been published in a similar manner in the book "Anterior Knee Pain and Patellar Instability," Sanchis-Alfonso V. (ed), Springer-Verlag, London, 2005 and in Orthopade: "Patellofemorale Schmerzen," Sanchis-Alfonso V, Springer-Verlag, Berlin, 2008.

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2 Pathophysiology of Lateral Patellar Dislocation

Stefano Zaffagnini, Giovanni Giordano, Danilo Bruni, Giulio Maria Marcheggiani Muccioli, and Maurilio Marcacci

2.1 Introduction

Patellofemoral disorders represent 20–40% of all knee problems and can be one of the most common complaints in sports related injuries. These disorders are a major cause of disability, particularly in females, and in extreme cases may contribute to termination of athlete's career and could lead to degenerative arthritic changes of the knee joint. For these reasons, disorders and in particular patellar instability often pose a diagnostic and therapeutic dilemma for the orthopedic surgeon. This dilemma implies that usually no single pathophysiology or therapeutic approach can fully explain and solve patellofemoral instability. In fact the patellofemoral joint is biomechanically one of the most complex human articulations with different anatomical components like bone shape, capsuloligament structures, and muscle that could alone or in combination be responsible for patellar instability. These factors are often present in combination in one patient, but the severity of each pathology can be different resulting in variable patterns of instability and pain that determine that each patient is almost unique; thus the characterization in a classification is a simplification of a very complex issue. Moreover the multifactoriality and variability of pathogenesis has determined in the past numerous misunderstanding. These misconceptions have been responsible for the high variety of surgical procedures proposed to treat patellofemoral instability, leading to less than completely satisfactory clinical results also related to iatrogenic cause.

Central to the development of a rational therapy for these patients is a complete and deep knowledge of the various anatomical abnormalities that can be responsible for patellofemoral instability. For a true comprehension of the influence on patellar instability by each risk factor it is fundamental to clearly understand the biomechanical rule on which the normal physiology of the patellofemoral joint is based.

The "valgus law" underlines the prevalence of the lateral structures with respect to the medial ones [23]. The lateral knee compartment of the patellofemoral joint is normally wider than the medial one. In fact the lateral condyle is larger than the medial one with an external part of the patellar groove higher, wider, and forward with respect to the medial compartment. The external patellar facet is larger in respect to the medial facet. At the capsular level is present a prevalence of the lateral retinaculum that is stronger and wider with respect to the medial one (Fig. 2.1).

The patella is the largest sesamoid bone in the body, and resides within biarticular muscles (the quadriceps and patellar tendons). The patella functions both as a lever and a pulley. As a lever, the patella magnifies the forces exerted by the quadriceps on knee extension. As a pulley, the patella redirects the quadriceps force as it undergoes normal lateral tracking during flexion.

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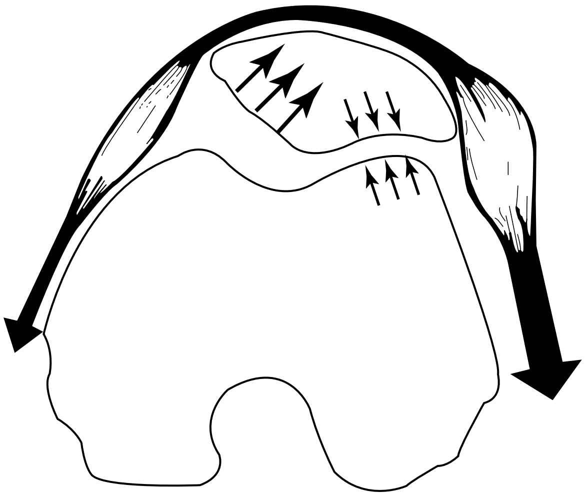

Fig. 2.1 A VMO dysplasia, a tightening of the lateral structure or a coordination defect between the two structures determine a stress concentration on lateral patellar facet and at the same time a maltracking with lateral patellar subluxation

Considering these anatomical features it is easy to understand how the complex and delicate equilibrium between bony, ligamentous, and capsular structures can be easily compromised altering the forces exerted on the patella, with external forces that overcome the medial forces.

So far the comprehension and treatment of patellofemoral disorders has suffered from the lack of a generally accepted classification. In fact a clear definition of anatomopathologic categories is fundamental to avoid using symptoms or objective signs to make a diagnosis.

Dejour [12] has developed a classification of patellofemoral disorders based on anatomopathologic features and on the severity of clinical findings, in order to standardize treatment. Three major groups can be identified: patellar dislocation, pain, and pain plus anatomical disorders. The first group includes three categories where instability is associated with anatomical abnormalities, while the second group includes all the patients with patellar symptoms but without anatomical alterations. This classification clearly facilitates the treatment choices, and moreover permits one to differentiate these three populations.

Instability of the patellofemoral joint is a multifactorial problem with great variability and severity of anatomical deformities that are difficult to be clearly understood and evaluated by the clinician.

Patellofemoral instability can result from soft tissue abnormalities, such as a torn static stabilizer like the medial patellofemoral ligament or a weakened dynamic stabilizer like the distal oblique portion of the vastus medialis. Generalized ligamentous laxity must also be considered as a risk factor, especially in nontraumatic instability, but this is not yet demonstrated.

The other fundamental risk factors are the osseous abnormalities such as Patella Alta, trochlea and patellar dysplasia, rotational and axial deformities of the lower limb, with alteration of Q angle.

2.2 Soft Tissue Abnormalities

Extensor muscle dysplasia is often responsible for patellar symptoms. In fact the delicate and complex muscular mechanism that controls the joint kinematics is extremely sensible to small variation.

Ficat and Hungerford [23] in the late 1970s have considered lateral patellar compression syndrome one of the major causes of patellar symptoms and instability as well as a risk for degenerative joint disease of the patellofemoral joint. The augmented tension on the lateral retinacula increases the stress on the lateral patellar facet and simultaneously predisposes to patellar malalignment and instability, but no objective data have documented this theory. Terry [55] more recently has underlined that the iliotibial band has attachments to the patellar and quadriceps tendons. Therefore excessive tension in the iliotibial band causes the patella to track in a more lateral position and predispose one to patellar dislocation.

Insall [35] and Fox [25] in the 1980s have underlined that a real hypoplasia of the vastus medialis and its altered insertion on the patella can lead to unbalanced patellar kinematics. These anatomical observations were more consistently studied in an experimental set up by Farahmand [21]. He observed in vitro that the vastus medialis obliquus has a mean orientation that deviates 47° ± 5° medially from the femoral axis, and the vastus lateralis has a mean orientation that deviates 35° ± 4° laterally from the axis [21]. He also found a different cross-sectional area between the vastus medialis and lateralis and a higher variation of this in the vastus lateralis. Therefore an imbalance in strength caused by different cross sections or different fiber orientations may lead to instability.

Vastus medialis relaxation reduces lateral patellar stability at all flexion angles. Goh [29] found lateral stability to be reduced by 30% when the vastus medialis obliquus was relaxed at 20° of knee flexion with a lateral patellar displacement of 4 mm.

A VMO dysplasia does not guarantee the force necessary to compensate the force exerted from the lateral structure to stabilize the patella in the trochlea groove. In this type of dysplasia the absence of the oblique muscle fibers causes a worse lever arm. The consequences are usually an increased patellar tilt or a tendency to patellar subluxation.

Voight [60] also has demonstrated that although the medial and lateral muscle structures are normal, a defect in the muscular coordination, can determine an opposite recruitment order between vastus medialis and lateralis originating in patellar instability.

Passive stabilizers in the patellofemoral joint include patellofemoral and patellotibial ligaments and the retinacula. Warren and Marshall describe the MPFL as an extracapsular structure [64]. The size and thickness of the ligament varies considerably among individuals, but it is relatively constant within a given person [65]. The MPFL acts as a static check rein to resist lateral translation of the patella.

Desio [16] reported that the MPFL contributes 60% of the total restraining force against lateral patellar displacement with the patellomeniscal ligament the second most important medial stabilizer contributing an average of 22% of the total restraining force. Senavongse [49] found that 20° of knee flexion was the position when 10 mm displacement occurred at the lowest restraining force. However the patella was more resistant to medial than lateral 10 mm displacement. Again Senavongse and Amis [48] tried to demonstrate the relative effects of various abnormalities on patellar stability. They found that a relaxed VMO reduced by 30% the force to displace the patella laterally in 20°–90° flexion range, while only by 14% in extension. If the MPFL was ruptured the force required to displace the patella laterally was reduced by 50% in the extended knee, decreasing while the knee flexed. Interestingly abnormal trochlear geometry reduced the lateral stability by 70% at 30° of flexion.

General hyperlaxity can also be a cause of patellofemoral instability related to the insufficiency in controlling lateral patellar displacement.

Carson and James [8], evaluating lateral patellar displacement in response to applied load at full extension, found a significantly greater lateral patellar mobility in symptomatic and hyperlaxity patient. The same observation was performed by Fithian [24] at 30° of flexion.

Nomura in 2006 [44], in a case series, showed that a hypermobile patella and generalized joint laxity were significantly important in the recurrent patellar dislocation group compared to the control group, with hypermobile patella as a predisposing factor for dislocation. Christoforakis [9] still in 2006 has shown that release of the lateral retinaculum reduces at 10° and 20° of flexion the force required to displace the patella by 20%. These findings underline the importance of medial structures like the VMO and MPFL.

2.3 Bone Abnormalities

One of the most important anatomical abnormalities originating in patellar symptoms is the trochlear dysplasia. This pathology has often been underestimated and initially considered secondary to patellar dislocation [13,15,16]. Instead intraoperative observations have confirmed that the intercondylar groove can be found completely flat or even convex [17, 18].

The normal trochlea is concave and strictly correlated to the bony contour and depth of the overlying cartilage [49, 50]. Trochlear dysplasia is defined as a groove with a proximal flat articular zone and a distal shallow zone. [15] Trochlear dysplasia was first described many years ago by Richerand [38]. This author, in 1802, described an abnormal lateral condyle in patients with recurrent patellar dislocations.

In the presence of dysplasia, the intercondylar groove may be flattened or even convex. [17, 45] This convexity presents the articular cartilage being thicker centrally than laterally and medially. [49, 50]. These findings have been confirmed from other authors [56, 61] utilizing standard x-ray and CT images. In patients with recurrent patellar dislocation Yamada et al. [68] found the convex groove to extend twice as far during flexion as in controls. In the presence of trochlear eminence, the patella has to surmount the bump during the early flexion of the knee. [13, 15] The inadequate depth of the intercondylar groove can be total or focal, when affecting only the upper part [14].

Flattening of the groove does not allow the patella to fit into the trochlea during range of motion. Imbalance of the patellofemoral joint with risk of patellar dislocation is created by this lack of centration, especially in the first degrees of flexion that allows the lateral structure to overtake easily the medial ones. In the presence of this deformity, the stresses are prevalently distributed on the lateral facet instead of the entire groove, originating as long term arthritic degenerative changes of the joint [13, 15]. Quantitatively the convexity (bump or boss) is pathological above 3 mm or more, the depth is abnormal at 4 mm or less [15] (Fig. 2.2). The geometry of the trochlear groove has great influence on patellofemoral joint stability. The trochlear dysplasia is strongly linked with objective patellar instability, because there is a lack of congruence between the groove and the patella [15]. Recurrent patellar dislocation without surgical treatment is associated with a high incidence of the patellofemoral arthrosis [42]. There is a direct link between objective patellar instability and lateral patellofemoral osteoarthritis [11,15]. The qualitative definition of trochlear dysplasia by H. Dejour in 1990 is based on the "intersection sign" on the lateral view [14] (Fig. 2.3). D. Dejour created a classification using four grades. In Dejour and Le Countre, comparing 143 radiographs of patients and 190 control radiographs, they showed that 85% of patients with a history of patellar dislocation had evidence of trochlear dysplasia [11]. Amis et al. [2] in an in vitro study, found that trochlear dysplasia led the patella to become less stable laterally, while the trochleoplasty increased stability not significantly different from a normal knee. The importance of the lateral facet of the trochlea in resisting the lateral force is logical and widely accepted [1, 3, 48, 49]. The first author who described this concept has been Brattstrom in 1964 [7]. He studied qualitatively and quantitatively the shape of the intercondylar groove describing the trochlear dysplasia as an increase of the sulcus angle in relationship to developing defects of the trochlear profile. He found the lateral condyle to be significantly lower in patients with habitual patellar dislocation. Amis [3] in another in vitro study, showed that

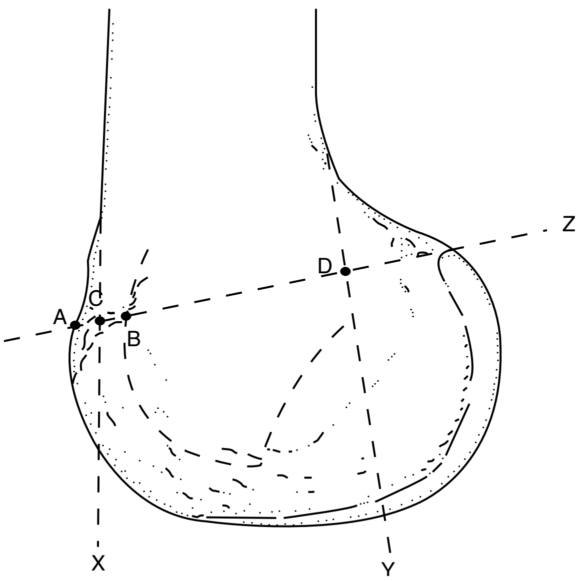

Fig. 2.2 Measurement of the trochlear boss: the distance BC (Dejour-Neyret and Gilles method; reproduced by permission from "Factors of patellar instability: an anatomic radiographic study" [15])

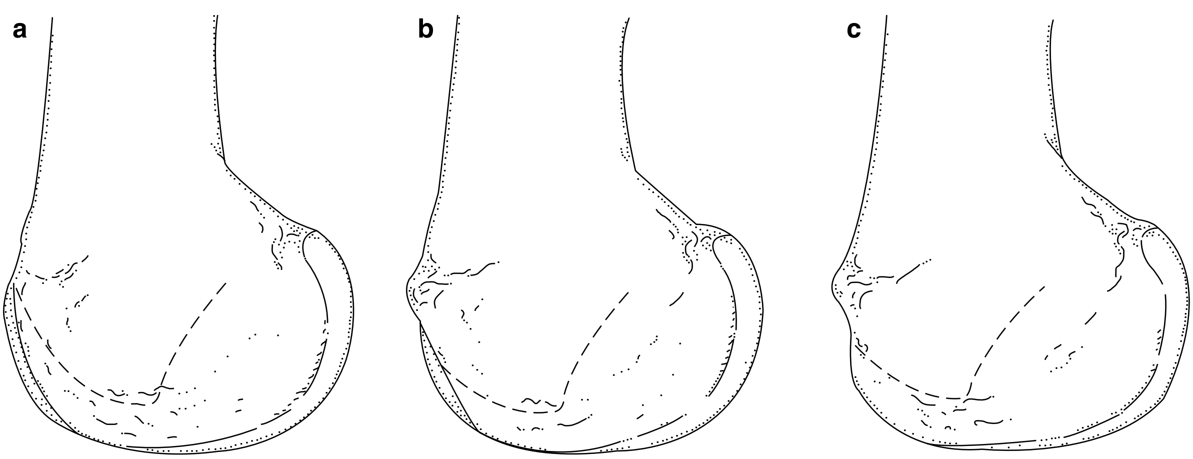

Fig. 2.3 Definition of trochlear dysplasia: the intersection of the line of the bottom of the trochlea with the two condyles allows the determination of a typology of dysplasia: (**a**) Type I; (**b**) Type II; (**c**) Type III), minor in Type I, major in Type III (Reproduced by permission from "Factors of patellar instability: an anatomic radiographic study" [15])

flattening the lateral groove had more influence on patellar laxity than dysfunction of VMO and MPFL. It has been found that the patellar shape could change in trochlear dysplasia. The distal medial facet in dysplastic knee does not articulate well with the trochlea, becoming smaller than normal. [4, 26] Fucentese et al., in a comparative MRI study, proposed that the patellar morphology may be not only a result of missing medial patellofemoral pressure in trochlear dysplastic knees, but a decreased medial patellofemoral traction. They found hypotrophic medial patellofemoral restraints and increased lateral patellar tilt in the dysplastic knees. Wiberg [67] has classified radiographically the shape of the patella determining three types of patellar hypoplasia that can originate from patellar symptoms. Ficat [22, 23] has underlined that the severe dysplasia of the internal facet implies a reduction of the weight-bearing internal area with a surface incongruence and an automatic stress concentration on lateral side that can start the degenerative phenomena.

A similar instability mechanism is encountered when Patella Alta is found. The patellar height is defined by the Insall-Salvati Ratio [37] (Fig. 2.4). Patella Alta is characterized by a more proximal position of the patella (i.e., high-riding patella). This condition has been correlated with patellofemoral dysfunction [36] and is one of the risk factors for patellar instability [39]. Dejour found in the objective patellar instability cases 24% had Patella Alta and 90% had patellar tilt [15]. High-riding patella, in fact, is strongly associated with patellar dislocation and subluxation.

Insall [36] and Blackburne [5] have underlined the role of Patella Alta as a cause of patellar instability. When the patellar tendon is longer than normal, during quadriceps contraction, the patella goes proximal and completely above the corresponding femoral surface without any lateral bony support preventing lateral dislocation. During flexion there is a delay in centration of the patella in the trochlea groove. In this condition the lateral structures do not find any bony resistance to lateral traction of the patella, due to the normal prevalence of the lateral structures with respect to the medial ones. Patella Alta, modifying the lever arm between quadriceps and patellar tendons, increases the compression forces in patellofemoral joint leading to cartilage damage. In patient with Patella Alta, Dejour has often found stiffness of the rectus femoris, supposing that Patella Alta may be a rectus femoris dysplasia [15].

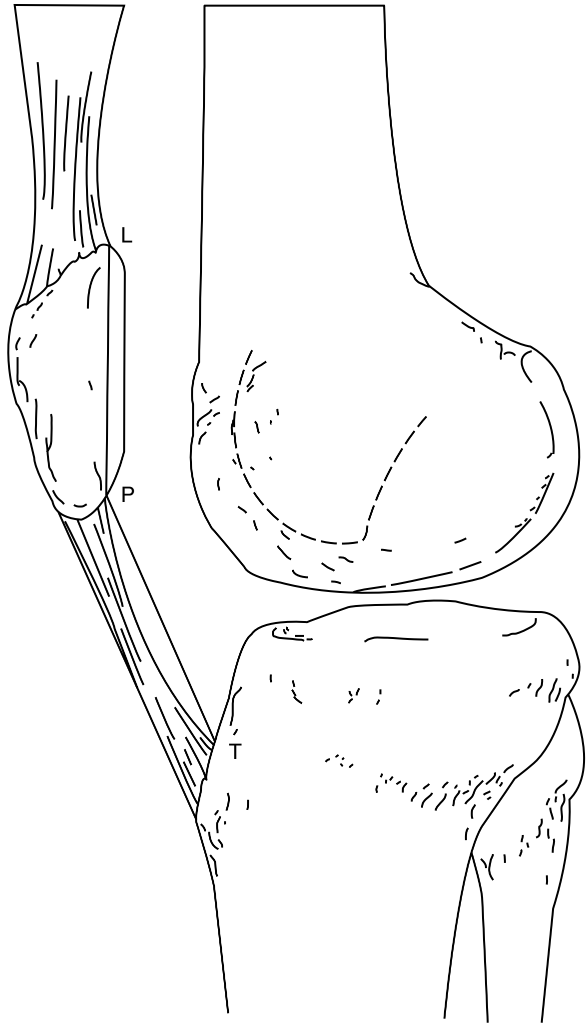

Fig. 2.4 The Insall-Salvati ratio is defined by the relation LP/LT (*LP* length of the patella, *LT* length of the patellar tendon): the normal value is between 0.8 and 1.2 (Modified and reproduced by permission from "Factors of patellar instability: an anatomic radiographic study" [15])

Biomechanically the patellofemoral joint is a lever system. The patella is the fulcrum of this system and contributes significantly to the torque in knee extension by increasing the lever arm of the quadriceps and transmitting the forces from the quadriceps tendon to the patellar tendon. In the normal knee, the patellofemoral total contact area increases from extension to flexion and reaches a maximum at 90°, reducing the contact stress in deeper flexion. The cartilage layer is thicker in the high load area of the joint. Although in the literature some authors [33, 62, 69] have suggested that Patella Alta may altered the mechanics of knee extension, there is no consensus on the real effect of Patella Alta on patellofemoral force, contact area, and contact pressure. Singerman, Davy, and Goldberg [51] reported, in an in vitro study, that the patellofemoral contact force, and its point of application on the patella, depended on patellar height. In a high-riding patella the magnitude of the PF contact increases with increasing flexion angle. They report also no increases from 0° to 60° of knee flexion and a significant rising at 90° in PFJ reaction force with Patella Alta. Luyckx [41], using a dynamic knee simulator, reported that the patellofemoral contact force is the sum of the patellar tendon force and the quadriceps tendon forces. In Patella Alta he showed the lowest PF contact force in initial flexion (35–70°) and a higher contact force in deeper flexion (70–120°) than in normal conditions. In this way he demonstrated a direct association between patellar height and maximal contact force. He also found that Patella Alta caused the greatest maximal contact force and pressure. In normal conditions the effective moment arm of the quadriceps tendon is greater than that of the patellar tendon because of the distal contact point of the patella during initial flexion [30, 58]. Yamaguchi and Zajac [69], moreover, by a mathematical simulation of Patella Alta to calculate a quadriceps moment arm, reported that modified lengthening of the patella or patellar tendon caused alteration of force transmission from quadriceps to patellar tendon. They showed a considerable increasing of moment arm and joint reaction force at flexion above 25–30°, with the Patella Alta condition. It seems that Patella Alta creates a more efficient knee extensor mechanism by a more distal contact point in initial flexion (0–60°), whereas, in deeper flexion, it is considered a biomechanical disadvantage [41].

Ward et al. [62, 63] demonstrated in two MRI studies that Patella Alta is correlated with a significantly larger quadriceps and smaller patellar ligament moment arm than in normal conditions, with a greater transmission force from quadriceps to patellar ligament. They showed 19% less contact area than normal between 0° and 60° of flexion, with lateral displacement and lateral tilt of the patella at 0° of flexion. Patients with Patella Alta and pain have elevated PFJ stress because of smaller PFJ contact areas and interrelate with patellofemoral cartilaginous breakdown and degeneration, dysfunction, and subsequent pain. [32, 39] No correlation could be found between malalignment and the reduced contact areas [41].

Rotational and axial deformity of the entire leg can play a role in patellar instability.

Increased femoral anteversion and/or increased tibial torsion can determine patellofemoral disorders. Smillie [52], Blaimont and Schoon [6] in the 1970s with observational studies have underlined the importance of rotational deformities in determination of patellar symptoms. Weber [66] found a frequent combination of femoral anteversion with condromalaciae and patellar instability. Eckhoff [20] and Lee [40] have demonstrated that increased femoral anteversion determined increased patellar tilt and promoted lateral patellar subluxation. Eckhoff has suggested correction of excessive femoral anteversion in young patients to prevent these phenomena. Takai [53] has documented that patients with increased femoral anteversion have an increased incidence of osteoarthritis. Femoral anteversion increases compression forces on the lateral compartment of the patellofemoral joint by bringing the lower femoral extremity in internal rotation resulting in the clinical appearance of "squinting patellae" (Fig. 2.5).

The association between distal femoral internal rotation and tibial external rotation alters the Q angle.

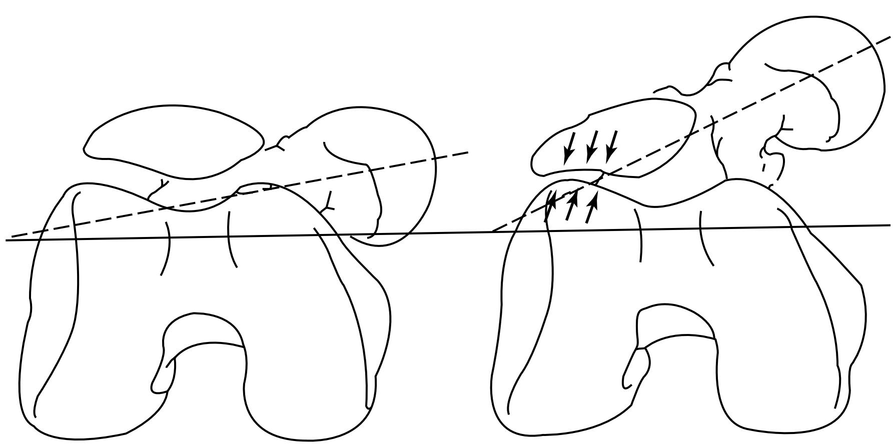

Fig. 2.5 An increased femoral anteversion increasing patellar tilt and subluxation determine higher compressive forces on external compartment of patellofemoral joint, with increased risk of chondral damage

Brattstrom [7] described the Q angle as the angle formed by the line of pull of the quadriceps and that of the patellar tendon as they intersect at the center of the patella. The Q angle is largest in extension in relation to the screw home mechanism of the knee. For this measurement to be accurate the patella should be centered on the trochlea. In males the Q angle is normally about 8–10° in females 15 plus or minus 5°. It should be noted that the relationship between the Q angle and clinical signs and symptoms has not always been consistent. A possible reason for the lack of association is related to the fact that there has been no consensus with respect to how this measurement should be taken, but more important is the fact that this measurement is taken statically, therefore, the contribution of abnormal segmental motions and muscle activation to the Q angle during dynamic activities may not be appreciated.

The Q angle is an expression of patellar kinematic that is guided by the static bony restraints and by dynamic muscle vectors. Therefore the analysis of the static deformities that can alter the patellar kinematic are better evaluated with CT scan taking into consideration femoral neck anteversion, distal femoral rotation, and tibial rotation. Patellar centration is more reliably evaluated by the measurement of TT-TG that considers femoral rotation as well as the rotation of tibial tuberosity (Fig. 2.6).

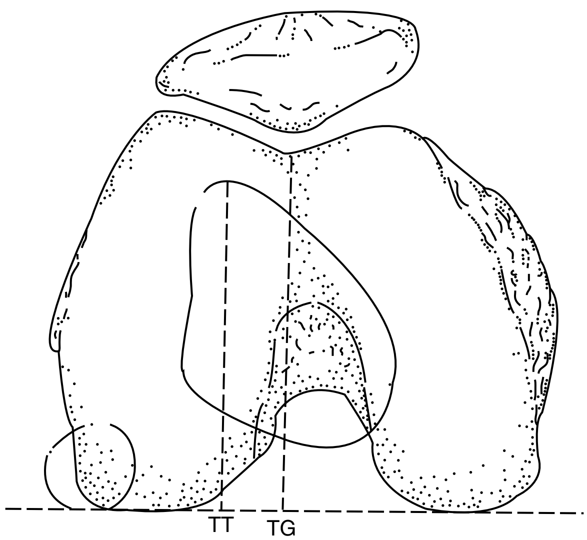

Fig. 2.6 Patellar centration evaluation with measurement of TT-TG displacement (*TT* tibial tuberosity, *TG* trochlear groove): a value greater than 20 mm is pathological (Reproduced by permission from "Factors of patellar instability: an anatomic radiographic study" [15])

Lee in 1994 [40] has demonstrated in vitro that fixed rotational deformities of the distal femur increase patellofemoral contact pressure with higher risk of joint degeneration and patellar dislocation. Powers [46] and Tennant [54] have shown that femoral internal rotation influences patellar alignment and kinematic. Powers using dynamic MRI in patient with patellar instability demonstrated that the primary contributor to patellar tilt and displacement was femoral internal rotation and not patellar motion. This phenomena was more pronounced in the last 10° of extension.

Many authors have suggested that patellofemoral symptoms are often associated with excessive primary or secondary tibial torsion [19, 25, 28]. Turner [57] has demonstrated that an excessive external tibial torsion determines a modification of the Q angle and that tibial external rotation was significantly different in patient with patellar instability. This alteration creates a less favorable lever arm for quadriceps muscle that during contraction moves the patella laterally increasing instability (Fig. 2.7).

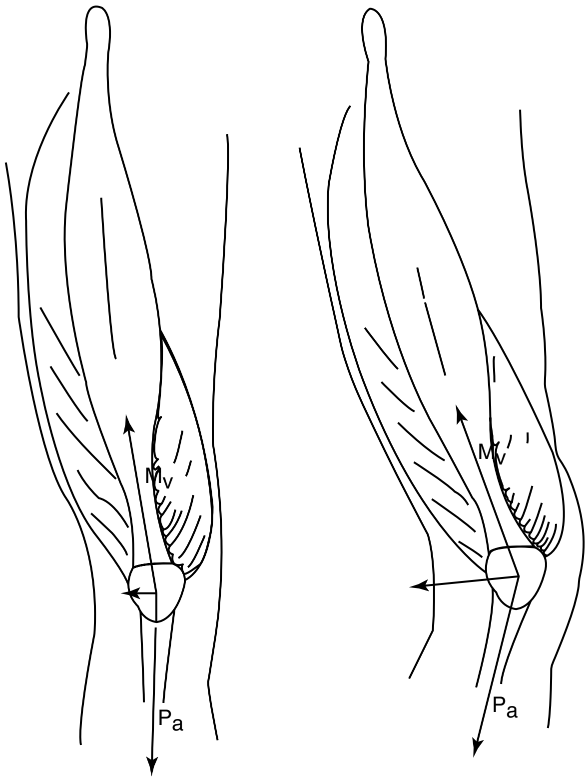

Fig. 2.7 An excessive external tibial torsion determine Q angle alteration, with a less favorable lever arm for quadriceps muscles. During contraction the forces that move the patella laterally are higher increasing instability

Van Kampen and Huiskes [59], Nagamine [43], and Sakai [47] examined the effect of tibial rotation on patellar three-dimensional movement. Hefzy [31] also studied the change of patellofemoral contact area with tibial rotation.

Apart from abnormal rotations in the transverse plane, excessive frontal plane malalignment can also influence patellofemoral joint.

Fujikawa et al. [27] observed that in varus deformity the patella displaces laterally and the lateral facet is hyperstressed with the increased risk of patellar instability. They also observed an association of proximal tibial rotation with varus deformity.

Similar combinations of varus and tibial torsion have been described by Coscia [10] in 1983. In these patients there is an increased risk of patellar instability, moreover the screw home mechanism is reduced or missed and this can originate in degenerative changes of the medial femorotibial compartment and of the lateral patellofemoral joint.

Ficat described this phenomena as a cruciate arthritis.

A valgus knee alters the Q angle and can be responsible for dynamic patellar instability. Old observational studies have underlined that an excessive valgus knee alignment associated with external tibial rotation determines especially close to extension a lateral patellar displacement especially during quadriceps contraction that increases the risk of patellar instability [22, 23].

Coscia [10] has also observed that in a valgus knee it is difficult to achieve knee extension stability due to excessive internal rotation. Therefore these knees remain unstable. During time this pathological situation leads to medial capsular distension further increasing knee laxity. In severe valgus articular stability is lacking due to the difficulties in controlling external rotation and the screw home mechanism (Fig. 2.8).

As underlined by Powers [46] a valgus knee is not only determined by static osseous abnormalities but

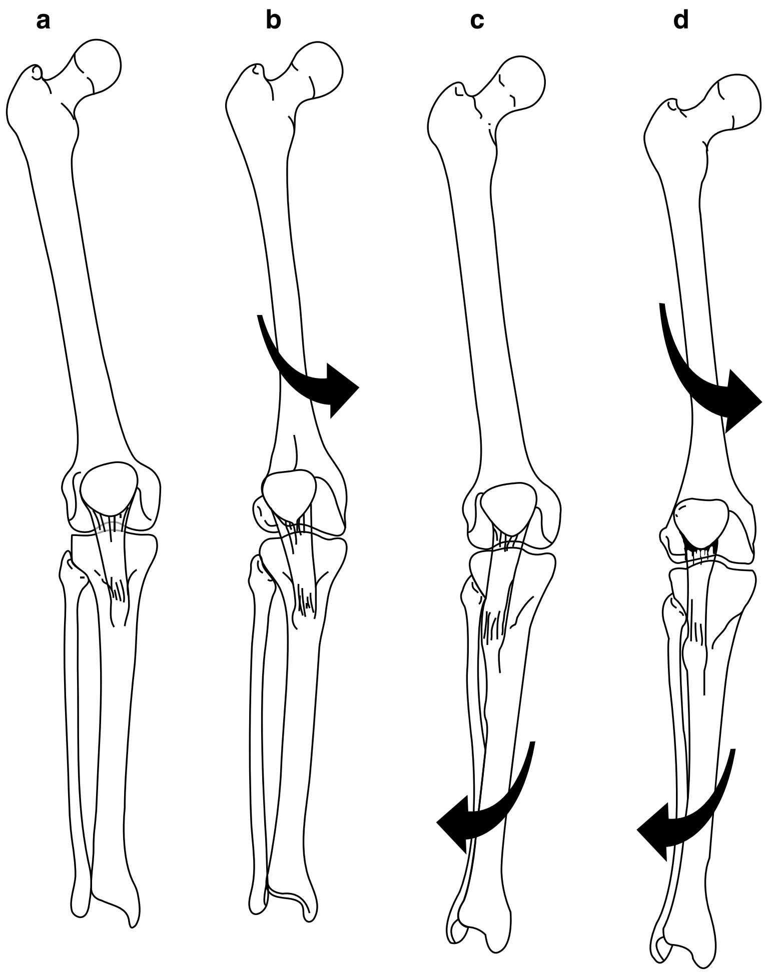

Fig. 2.8 Summary of alterations of lower limb that can originate patellar symptoms: (**a**) normal limb alignment; (**b**) increased femoral anteversion with internal rotation of femoral condyle causing higher patellar stress and instability; (**c**) external tibial torsion promotes increased compressive forces on lateral patellar facet with subluxation; (**d**) limb alterations can be combined in a same patient, with consequently a severe clinical picture and a technically demanding solution

also dynamically during certain activities as a result of femoral, tibial, or combined adduction moment. These can results from muscle weakness or imbalance, or abnormalities at the level of the hip and pelvis as well as of the foot.

Torsional defect of the lower extremity can be found often together with different patient penetration originating in a wide variety of clinical aspects that are really difficult to be globally understood.

In all these studies, a pathological value for varus/valgus or rotational deformity that is correlated to clinical symptoms has not been detected.

As we have shown the anatomical alterations that can be present with different penetration in each patient are various and complex and create several clinical aspects. Therefore the treatment options should be chosen in relation to the etiologic factors responsible for clinical symptoms in each patient.

A rational treatment of these disorders must foresee the execution of different surgical procedures in the same patient when the symptoms have a multifactorial origin in a manner to completely modify the joint physiology and kinematic.

Even if the surgical procedure acts mostly on passive and static stabilizers of the patella it is fundamental to achieve during surgery a dynamic patellar equilibrium with correct patellar tracking during the whole range of motion. Hughston [34] in 1989 has underlined the importance of dynamic stability of patellofemoral joint.

2.4 Summary

Patellofemoral instability:

- Subjective instability with anatomical abnormalities
- Traumatic dislocation without anatomical abnormalities
- Dislocation with anatomical abnormalities
- Patellofemoral pain

Patellofemoral instability:

- Soft tissue abnormalities
- Osseous abnormalities
- Soft tissue and osseous abnormalities

Soft tissue abnormalities:

- Extensor muscle dysplasia
- Ipoplasia of the vastus medialis
- Patellofemoral, patellotibial ligaments, and retinacula disorders
- General hyperlaxity

Osseous abnormalities:

- Trochlear dysplasia
- Patella Alta
- Rotational and axial deformity of lower limb
- Patellar dysplasia

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3 Natural History of Patellofemoral Dislocations

Justin J. Gent and Donald C. Fithian

3.1 Introduction

Harilainen et al. reported that acute patellar dislocations were the second most common injury noted among patients presenting with acute knee hemarthrosis [17]. Recurrent patellofemoral pain and giving-way can cause disability after an acute patellar dislocation. Historically, MacNab noted a 15% redislocation rate and a 33% overall frequency of symptoms following a first-time dislocation [26]. Hawkins et al., Cofield and Bryan, and others have reported that sequelae of patellar dislocation affect up to one half of patients who present with a first-time dislocation and no prior history of patellofemoral complaints [8, 18].

Although there is a large body of literature on patellar dislocation, the clinical characteristics of these patients and their prognosis following injury are surprisingly ill-defined. Most of the literature is retrospective and has analyzed mixed groups of patients with a primary dislocation and patients with prior history of patellofemoral pain, subluxation, or dislocation [4, 28, 37], patients presenting with pain and/or instability [21, 36], patients with chronic symptoms [14, 24, 33], and patient populations gleaned from surgical logs [4, 10, 22, 23] or hospital records [6, 8, 9, 19]. Understanding the causes, the consequences, and the types of patients who suffer from the disease will help us better care for our patients.

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3.2 Etiology

Several studies have suggested that congenital or developmental factors may contribute to an increased risk of recurrence after initial patellar dislocation [6, 27, 31], or failure after surgical treatment [28]. Recurrent patellar instability has been shown to be associated with four major factors. These factors are trochlear dysplasia, Patella Alta, lateralization of the tibial tuberosity relative to the trochlear groove (so-called TT-TG offset), and insufficient medial retinacular restraint [13]. A high rate of patellofemoral dysplasia has been reported among patellar dislocators [11, 12]. However, in prospective studies it has been difficult to link specific anatomic features with greater risk of recurrent instability following primary patellar dislocation [15]. So while it is apparent that anatomic deficiencies which reduce trochlear and retinacular constraint increase the likelihood of recurrent instability, at this time it is very difficult to predict which patients will experience recurrence after a single dislocation.

The familiar stereotype of the overweight adolescent female has been challenged by some studies [3, 6], and there remains considerable uncertainty over who is at risk for poor outcomes [18, 25, 29–31]. In a prospective study at our institution, a large group of patellar instability patients were followed for a minimum of 2 years [15]. Table 3.1 displays mean annual risk of dislocation by age and gender for both first-time dislocators and patients with a prior history of subluxation or dislocation. In both groups, females ages 10–17 years were at highest risk for patellar dislocation. The prior subluxation/dislocation group ($N = 64$) was older (median = 21, range 8–65) ($p < .001$), and consisted of more females (70%) ($p < .05$) than the first-time dislocation group ($N = 125$) (median

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Table 3.1 Average annual risk for patellar dislocations (per 100,000 members)

	Female		Male		Both	
First-time dislocator group	Risk	95% CI	Risk	95% CI	Risk	95% CI
10–17	33	11	25	9	29	8
18–29	7	4	10	8	9	5
30 and older	1	1	1	1	1	1
Overall					5.8	1
Prior subluxation/dislocation Group	Risk	95% CI	Risk	95% CI	Risk	95% CI
10–17	18	8	6	8	12	7
18–29	11	6	12	5	11	5
30 and older	3	1	0	1	2	1
Overall					3.8	2

Table 3.2 Index knee physical exam data by gender and patient group

		First-time dislocation group		Prior subuxation/dislocation group	
		Mean	Range	Mean	Range
Standing alignment (°)	Males	6	3–8	6	5–7
	Females	6	3–9	6	5–10
Thumb to forearm (cm)	Males*	5	0–9	5	0–10
	Females	3	0–8	3	0–7
Q angle (0°)	Males*	10	6–15	10	6–15
	Females**	12	9–18	14	10–19
Q angle (30°)	Males*	13	10–19	13	9–19
	Females**	16	10–24	18	13–25
Foot thigh angle (°)	Males	5	2–10	5	4–6
Females	Females	5	2–30	5	2–8
Internal hip axial rotation	Males*	31	10–60	34	20–65
(°)	Females	43	20–70	43	25–60
External hip axial rotation	Males*	27	10–45	23	10–35
(°)	Females	23	5–45	25	10–45

*Significant difference between males and females

**Significant difference between females in primary and prior history group

age = 16, range 9–67, females = 52%). In a recent review of the literature a male to female ratio of first-time dislocators was found to be 46% males to 54% females [42]. In our study, 61% of first-time dislocations occurred during sporting activities, and an additional 9% occurred while patients were dancing. In comparison, 55% of Nietosvaara's sample from Finland was injured in sporting activities [34]. These results indicate that primary patellar dislocation is an injury of young, athletically active persons. Table 3.2 summarizes physical measurements of each group which indicate small but significant increases in extensor mechanism malalignment among females in both groups, with the highest degrees of malalignment being observed among females who reported previous histories of patellar pain or instability at the time of

Table 3.3 Index knee radiographic parameters at time of injury

Parameter	First-time dislocation group			Prior subluxation/dislocation group (index knee PF problems only)		
	Mean	Range	% Abnormal	Mean	Range	% Abnormal
Patella Alta	1.0	.4–1.59	45% > 1.0	1.17	.8–4.6	50% > 1.0
Sulcus angle	140	120–163	14% ≥ 150°	141	123–170	11% ≥ 150°
Congruence angle	12.1	−28–59	78% > 0°	16.5	−37–49	81% > 0°
Laurin angle	2.6	−24–20	38% ≤ 0°	2.4	−17–19	36% ≤ 0°
Lateral overhang	6.5	−10–25	78% > 0 mm	7.5	−2–17	92% > 0 mm

presentation, while Table 3.3 condenses the index knee radiographic parameters at the time of injury.

3.3 Family History

Crosby and Insall noted a family history of patellar instability in 15% of the patients surveyed in their study, which coincided with Maenpaa's reports of 15.6% [9, 28]. Reider et al. noted a family history of knee disorders in half of their patients, though this included pain without dislocation [36]. Also in the study from our institution, patients with a family history of PF problems (adjusted OR = 3.7, p <.05) and those who reported factors associated with Developmental Dysplasia of the Hip at the time of birth or delivery by Caesarian section (adjusted OR = 15, p <.001) were more likely to have a non-index knee subluxation or dislocation during follow-up (Table 3.4). Because a control group in this study was not used, it was not possible to compare the prevalence of these DDH risk factors in patellar dislocation and nonpatient populations. It has also been noted trochlear dysplasia is associated with a family history of patellar instability [11].

Table 3.4 Logistic regression odds ratios for subsequent subluxation/dislocation

	Odds ratio (95% CI)	Model X^2
Index knee		24.5**
Age	.93 (.88,.98)*	
Gender	1.0 (.45, 2.4)	
Prior history of PF dislocation/subluxation	6.6 (2.7, 16.1)**	
Family history of PF dislocation/subluxation	.85 (.31, 2.3)	
DDH risk factors	.51 (.01, 2.7)	
Non-index knee		32.8**
Age	.92 (.84, 1.0)	
Gender	1.2 (.40, 3.6)	
Prior history of PF dislocation/subluxation	6.4 (2.1, 19.7)**	
Family history of PF dislocation/subluxation	3.7 (1.2, 11.7)*	
DDH risk factors	14.7 (3.3, 64.8)**	

*p <.05
**p <.01
**p <.001

3.4 Recurrence Rate

In our study logistic regression analysis showed that a previous history of patellofemoral subluxation or dislocation is the strongest predictor of future patellar instability (Table 3.4). Only 17% of primary dislocators suffered a second event over the subsequent 2–5 years, compared to a rate of 49% in the same time period among patients with prior history of instability [15]. Young age at presentation also was a significant factor associated with future subluxation or dislocation of the index patella. This finding is consistent with other studies [8, 25].

The method of nonoperative treatment may influence the risk of redislocation. One study found that patients immobilized for 6 weeks had lower recurrence rates than those who were braced and allowed full motion [31].

The trauma associated with a primary dislocation is frequently debated as a risk factor for recurrent instability. As we have seen, there is a well established link between recurrent instability and preexisting anatomic factors that reduce constraint of the patella [11–13]. Maenpaa noted that a lower degree of trauma was predictive not only of failure of conservative treatment [31], but of surgical management as well [28]. Generalized hypermobility has also been implicated as a cause of patellar instability [41]. These studies support the idea that predisposition to a primary dislocation (due to inherently low patellar constraint) predisposes to subsequent dislocations.

But retinacular injury at the first dislocation also has been found to be a predictor of recurrence. Hinton reported that palpable defects in the VMO, adductor mechanism, medial patellofemoral ligament (MPFL), and a grossly dislocatable patella were prognostic factors for poor nonoperative outcomes [20]. In a study of instrumented measurement of patellar mobility, we found greater laxity in the dislocating patella than in the opposite patella, despite similar underlying bony anatomy and physiologic laxity profiles [14]. These findings support the idea that retinacular laxity in the injured knee is a factor in recurrence.

3.5 Treatment

There have been several retrospective studies of nonoperative care of primary (first-time, unilateral) patellar dislocators as a distinct group [3, 6, 18, 25, 29–32, 34, 41]. Maenpaa et al. compared 100 patients treated with a cast, a posterior splint, or a bandage/brace. Patients exhibited fewer redislocations, less loss of range of motion, and better Kujala scores who were treated in a posterior splint for 2–3 weeks [31]. In a retrospective analysis of a 3-year period, Garth et al. treated 58 young active patients with 69 knees that had either primary or recurrent patellofemoral dislocation with functional rehabilitation and a laterally padded knee sleeve[16]. They reported at follow-up of a minimum of 2 years that 72% of patients stated they were satisfied with their knee, but 26% had a redislocation, and patients with a unilateral and primary dislocations seemed to do better than bilateral and recurrent instability patients [16].

Cofield and Bryan suggested that young, active individuals are particularly prone to develop sequelae which impair function [8]. Concern over late disability and recurrence led Hawkins [18] and others [1, 38, 43] to recommended immediate surgery after the initial dislocation event. Two prospective studies have documented recurrence and late disability following conservative management of acute primary patellar dislocation [25, 35]. Though both studies documented the presence of predisposing factors at the time of presentation, they were unable to link those factors to outcomes, possibly because of low statistical power due to small sample size.

A recent retrospective MRI study found that MPFL avulsion from its femoral attachment at the time of primary dislocation was associated with higher recurrent instability [40]. That study reviewed 53 young adult males; unfortunately of the 11 patients who were lost to follow-up 10 were in the femoral avulsion group. But of the 43 patients with follow-up Sillanpaa reported that a significantly greater number of patients who had an avulsion of the MPFL at it femoral attachment, compared with patellar avulsions or midsubstance tears, had recurrence of patellofemoral instability and that those patients were less likely to regain their preinjury activity level [40].

Early surgical repair has become fashionable, despite a distinct lack of evidence to support this approach. Numerous comparative studies have failed to demonstrate that surgical treatment results in improved outcomes [2, 7, 9, 30, 35, 39]. We are aware of only one prospective study in which direct repair of a localized MPFL tear resulted in superior outcomes among surgically treated patients compared to patients treated without repair [5]. At this time, nonoperative care, consisting of a short period of immobilization followed by functional rehabilitation and a laterally padded knee sleeve, of first-time dislocators is recommended. If surgery is contemplated, then preoperative MRI should document a single, specific, localized avulsion of the MPFL femoral attachment [5, 40].

3.6 Development of Arthritis

In the study from our institution, neither the first time dislocators nor those with a prior history of instability demonstrated significant radiographic or scintigraphic evidence of degenerative joint disease at 2–5 years follow-up. This may be due to the short follow-up time.

In a retrospective review of 85 patients who had undergone nonoperative initial management of first-time patellar dislocation, Maenpaa et al. [29] reported degenerative changes in 22% of the index knees and 11% of the non-index knees at follow-up of 6–26 years. Of patients who underwent late surgery for recurrent instability or pain, 35% showed arthritic changes. Interestingly, degenerative changes were less common among patients with occasional recurrences than among patients with stable patellae. Crosby and Insall [9] reported that degenerative changes were uncommon after patellar dislocation. Arnbjornsson et al. reported on a series of patients that had bilateral patellar dislocations, but only had surgery on one knee [2]. At mean follow-up of 14 years, patellofemoral arthritis was seen in 15 of 20 (75%) of operative knees while only 6 (29%) of nonoperative knees had patellofemoral arthritis.

3.7 Conclusion

- Patellofemoral dislocation is a disease of young and athletic people.
- Dislocation recurs in only 17% of first-time dislocators, but once a patient has a second dislocation the recurrence rate jumps to nearly 50%.
- Recurrent patellofemoral instability is associated with previous patellofemoral instability, a young age at the time of first dislocation, and preexisting deformities such as trochlear dysplasia and Patella Alta which reduce constraint.
- If surgical treatment is undertaken, medial laxity must be addressed; additional procedures might be necessary to improve engagement between the patella and trochlea.
- We recommend nonoperative management of first-time dislocators and surgical management including MPFL reconstruction with or without tibial tubercle displacement osteotomy for recurrent instability.

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4 Clinical Presentation of Patellofemoral Disorders

Ricardo Varatojo

4.1 Anterior Knee Pain

When evaluating a clinical setting of anterior knee pain, the patient's history often elicits an underlying supraphysiologic loading event, or series of events that leads to the development of symptoms [13]. Pain commonly begins insidiously, and we must search for a history of overuse. Overuse may result from beginning a new activity or from ill-advised increases in the duration, frequency, or intensity of a patient's usual work or recreation activities [36].

Report of certain activities of daily living associated with high patellofemoral loads, such as rising out of a chair, going up or down stairs, kneeling, squatting, or sitting for prolonged periods of time with the knee flexed have become symptomatic.

Characteristics of the patient pain that should be specifically addressed include quality, radiation, and exacerbating and relieving factors.

Anterior knee pain is frequently reported by patients to be achy, poorly localized, positional, and activity related. Patients commonly present with symptoms that are vague, chronic in duration, sometimes bilateral, and insidious in onset.

Patellofemoral pain usually increases with activity and decreases with rest. The pain is rarely constant and asymptomatic periods are common.

Classical teaching also has it that pain is worse going down stairs, but pain going up stairs is just as common [4, 19]. Complaints are also aggravated with running or walking on incline.

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Consistent with this complaint is the patient's difficulty getting out of a low chair. Patients rarely volunteer this information. It has to be elicited [19].

Patients often complain of anterior knee pain with prolonged sitting, the classic "movie theater sign," and it is usually relieved by passive extension. The cause for pain exacerbation with flexion seems an increase tension in the extensor mechanism as well as the posterior and lateral forces imparted by the retinacular attachments of the iliotibial band, which are posterior to the knee axis in flexion greater than 30°.

The history of a patient with patellar pain is usually nonspecific, occasionally the pain is directly anterior, and they will often place a hand over the anterior knee when asked about the location of their pain, but most often not. It is commonly medial or lateral to the patella.

The pain can be directly over the medial or lateral joint line in which case it can mimic a torn meniscus [24, 31]. Investigators believe that this is related directly or indirectly to the patellomeniscal/patellotibial ligaments.

Pain can even be popliteal [1, 37], possibly secondary to hamstrings tightness or spasm.

Pain near the inferior pole of the patella can be confusing. It can be a reflection of patella malalignment, but can also be related to an inflammation of the fat pad or to patellar tendinosis [14, 28].

Patient-drawn pain diagrams correlate well with tenderness and can sometimes direct attention to the heart of the problem. In patients with anterior knee pain, 86% of negative patient's zones accurately predicted a negative examination [33].

Initial onset of pain can be acute after a traumatic episode.

In contrast, pain that is constant and/or not related to activity or knee positions should make the clinician

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suspicious of referred pain (hip, spine), neurogenic pain, postoperative neuroma, reflex sympathetic dystrophy (RSD), or symptom magnification for secondary gain. More rarely, pain at rest can be associated with a patellar tumor, an infection, or a stress fracture.

It is extremely common for patients with knee pain to consider their knee to be swollen. Although it can indeed be swollen, very often objectively this is not the case. The painful knee may feel heavy, stiff, and irritated, which may translate into an impression of swelling.

Many patients report heat about the knee. This heat is usually not observed by the examiner.

Noisy knees are common and not necessarily a cause of concern. Crepitus or a grinding sensation under the kneecap that hurts is pathological and has not been determined exactly what causes the noise. Articular cartilage, synovium, or other soft tissues can be the cause.

History taking should always include current and desired activity levels and work requirements. To increase patient satisfaction, be sure that patient has realistic goals [32].

Special attention must be taken to associated psychiatric pathology or psychological conflicts, especially in teenagers. Clinical evolution can be extremely complex.

4.2 Patellar Instability

Patellar instability is generally defined as an abnormal movement of the patella with respect to the trochlear groove off the femur [15].

It is important to determine if this feeling of instability is related to the extensor mechanism or secondary to ligament insufficiency. However lack of knee trauma will usually rule out cruciate or collateral ligament pathology.

The patient may complain of “goes out” or “giving way” episodes for either the reflex quadriceps inhibition because of sudden pain and/or muscular atrophy or the true momentary patellar dislocation. Try to elicit a description in the patient’s own words that the patella either clearly dislocated (requiring a reduction maneuver) or subluxed laterally (partial dislocation with spontaneous reduction). Episodes of instability are usually associated with weight-bearing and twisting injury [32].

In addition, these patients frequently complain of clicking, popping, and grinding within the knee joint.

This is usually seen in the young athlete, with a female predominance [3, 17].

The degree of functional instability, interference with daily nonsports tasks, is ascertained. Symptoms of the opposite knee and both hips are investigated [38].

The onset of symptoms can be acute/traumatic or chronic/atraumatic including overuse. The lack of a traumatic event can effectively rule out causes of patellofemoral pain such as fracture, chondral injury, or bone bruise.

Traumatic instability or patellar dislocations usually described as the kneecap “going out/of the side” is a dramatic, memorable event and the patient will frequently describe having to extend the knee for the patella to reduce spontaneously or require manipulation [23].

More commonly, the patient will describe an indirect mechanism consisting of a strong eccentric quadriceps contraction, a flexed and valgus knee position, and internal rotation of the femur or an externally rotated tibia [9]. It may occur from a rapid, noncontact deceleration or change of direction maneuver. The precipitating force should be categorized as major or minor. This episode can result in chondral injury to the distal medial patella and the lateral trochlea.

This is the most severe form of patellar instability, which cannot occur unless the patella is hypermobile [15].

Direct patellar trauma (such as dashboard injuries) occurs more often with the knee in greater degrees of flexion, thus affecting the patella more proximally and the trochlea more centrally. In cases of direct injury to the anterior knee, remember to look carefully for PCL deficiency, another well-known cause of anterior knee pain [25].

The clinical manifestation of a primary dislocation of the patella varies from a massive swollen knee to a nearly painless knee. In the chronic setting sharp intermittent pain suggests the possibility of loose bodies or unstable chondral pathology.

The direction of the instability or subluxation the patient will describe is more frequently lateral [3].

Two common mechanism of first-time dislocation are sports (61%) and dance (9%) injuries [16]. In the sample of Nietosvaara et al., 55% occurred during sports activity.

The average annual incidence of primary patellar dislocation is 5.8 per 100,000 [16]. This incidence increases to 29 per 100,000 in the 10–17-year age group, somewhat lower than that reported by Nietosvaara et al. [31] for the pediatric population (0–16 years old).

Contrary to previous belief, the most commonly affected demographic is not obese, inactive females but instead is actually young athletes of either gender [16].

The "Lyon School" refers to it as objective patellar instability (OPI) as a synonym for patellar dislocations [11].

More appropriate to describe the population of interest would be the term episodic patellar dislocation because it describes the patient who complains primarily of the disability associated with occasional sudden displacement of the patella out of the trochlea [15].

Chronic instability may occur with minor activities such as ascending or descending stairs, twisting the knee to externally rotate the tibia on the femur may produce subluxation or dislocation by increasing the valgus force on the patella.

Recurrent dislocation rates vary between 17% and 44% after conservative treatment. Failure to return to previous levels of sports activity is reported to be as high as 55% [6, 22, 35, 39].

Causes of such a dismal outcome include persistent instability, recurrent anterior knee pain, and unrecognized intra-articular injury, and many patients continue to be symptomatic following their dislocation episode, resulting in significant disability.

Sequelae of patellar dislocation affect up to one half of patients after injury [6, 22, 27]. At 6 months postinjury 58% of patients continue to have limitations with strenuous activity [2].

Particular care should be taken to determine whether the patient has had a previous patellar dislocation on the index or contralateral knee. A history of contralateral patellar dislocation would increase the risk of recurrence sixfold, as much as a previous dislocation event on the index knee [16]. Patellar dislocators with prior patellar subluxation or dislocations are significantly older and more predominately female than first-time dislocators [16].

Only 17% of first-time dislocators suffered a second dislocation within the next 2–5 years [16]. Patients presenting with recurrent patellar instability are much more likely to continue experiencing dislocations than patients who have had only one dislocation episode. In contrast the risk of an additional dislocation within 2–5 years is around 50% if the patient presents with a history of prior patellar instability [16].

Overall, a previous history of patellofemoral subluxation or dislocation is the strongest predictor of future patellar instability [16].Young age at presentation also was a significant factor associated with future subluxation or dislocation of the index patella [2, 6].

4.3 Patellofemoral Arthritis

Isolated patellofemoral arthritis is a rare condition (incidence less than 1%) [21], a female predominance (72%) and often bilateral, because 51% of the patients have complaints referred to the other knee [10].

This arthritis can be caused by trauma in 9% of the cases (intra-articular patellar fractures), chondrocalcinosis (8%), patellar dislocation (33%). In 49% of the cases isolated patellofemoral arthritis is classified as idiopathic or essential [10].

Patients with isolated patellofemoral arthritis associated with instability are operated sooner, at a mean 54 years, than posttraumatic (55 years). Idiopathic arthritis have surgical procedures done later, around 58 years, and chondrocalcinosis at 72 [10].

The most important anatomical factor is patellofemoral dysplasia, and 78% of the patients have trochlear dysplasia [10, 21].

This arthritis is seen at earlier ages, it begins at 45 years of age and surgery is performed at a mean age of 58 years and first consultation at 57 years [10, 21].

Radiological progression is slow, since the evolution from grade I to IV, takes a mean period of 18 years [10, 21]. Well tolerated, only 10% of the patients perform surgery during 9 years evolution. The progression to the femorotibial compartment is rare, representing less than 20% of the cases in a period of 9 years, but normally comes with a clinical progression [21].

The prevalence of patellofemoral joint space narrowing, in patients older than 60 years is 32.7% in men and 36.1% in women, and isolated patellofemoral compartment degeneration occurs in 15.4% of men and 13.6% of women [8].

The degenerative changes of the patellofemoral joint, became here symptomatic and patients typically complain of pain felt at the front of the knee, and less frequent on the popliteal area. This is typically worse with exercise, kneeling, squatting, and stairs. However the patients typically state that going upstairs is more difficult than going downstairs [12].

In a study Dejour and Allain noted that 65% of the patients have limitations on stairs, 15% even do not use them anymore, 88% have difficulty on kneeling and 92% need some help getting out from a chair [10].

Iwano et al. [26] in a study on the clinical presentation on patients with patellofemoral osteoarthritis stated that all knees displayed crepitation by movement or grinding and 45% had peripatellar pain. In the isolated patellofemoral osteoarthritis group patients had great difficulty on squatting, running with short steps, and sitting with a fully flexed knee. No patients had problems getting up from a low chair. More patients had difficulty going downstairs than upstairs. Their ADL score did not correlate with the severity of arthritis on x-ray.

The pain is diminished when the subject walks on level ground, but 80% have a walking range of less than 1 km [10].

Pain is associated with a grinding or crackling sensation (crepitus) and the knee may be stiff. There may be pseudolocking due to "kissing" lesions between the patella and the trochlea groove, when exposed bone rubs on exposed bone. True locking may exist from osteophytes in the intercondylar notch obstructing the anterior cruciate ligament.

Younger patients tend to be obese [5, 10], and this condition aggravates symptoms, since there is a statistical correlation between degree of complaints and weight [10].

A history of swelling, attributable to an effusion, suggests intra-articular pathology. It frequently arises insidiously and indicates inflammation, as a reaction to articular cartilage debris and inflammatory cytokines.

4.4 Previous Treatments

It is helpful to know what prior treatment patients received (bracing, taping, NSAIDS, injections, physical therapy) for their knee problems and whether or not the interventions were successful.

If physical therapy has been tried, it is important to investigate precisely what was done to determine if it was appropriately prescribed and followed through by the patient and therapist.

If the patient underwent previous surgery, a copy of the operative report, or ideally arthroscopic photos should be obtained. The patient should be asked if the procedure had any effect on his or her symptoms, and particularly, if there was a change in the nature and location of the pain.

If preoperative complaints were primarily pain, but instability becomes prominent postoperatively, suspect that unnecessary or excessive realignment surgery may have occurred. On the other hand, if preoperative instability problems turn to complaints of pain postoperatively a possible explanation is inappropriate transfer of articular load onto an articular lesion.

4.5 Past Medical History

It is important to determine if there is a personal or family history of any problems that commonly cause musculoskeletal pain (gout, inflammatory arteries, sickle cell disease, etc.).

Patellofemoral disorders show a strong familial pattern. A family history of patellar instability was noted in 15% of the patients [7]. Reider et al. [34] find a family history of knee disorders in half of their patients compared with 9% of Atkin et al. [2].

4.6 Differential Diagnosis

Peripatellar disorders such as prepatellar bursitis, plica syndrome, retinacular pain, Osgood–Schlatter or Sinding–Johansson–Larsen syndrome, patellar or quadriceps tendonitis, and iliotibial band syndrome are all possible diagnoses.

Neuroma in the lateral retinaculum, sometimes associated with previous surgical scars may be the source of focal pain symptoms.

4.7 Summary Statement

Evaluating a clinical history of anterior knee pain we must look for an overuse pattern. Daily living activities associated with high patellar loads became symptomatic (going up and down stairs, kneeling, squatting, or sitting for prolonged periods of time).

Pain commonly begins insidiously, but can be acute after a traumatic episode

Patellar instability is defined as an abnormal movement of the patella with respect to the trochlear groove of the femur. The patient complains of "goes out" or "giving way" episodes.

Patellar dislocation is the most severe form of patellar instability, described as the kneecap "going out," and the most commonly affected are young athletes of either gender.

Isolated patellofemoral arthritis is a rare condition, and the most important anatomical factor is trochlear dysplasia.

Most of the patients displayed crepitation by movement or grinding associated with pain on the front of the knee that typically worsens with exercise, kneeling, squatting, and stairs. ADL scores do not correlate with the severity of arthritis on x-ray.

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5 Clinical Examination of the Patellofemoral Patient

Jacques Vallotton and Santiago Echeverri

5.1 Introduction

A careful history should point towards the presence of anterior knee pain (jumper's knee/patellofemoral pain syndrome [PFPS]) or patellofemoral instability, described as episodes of giving way, subluxation or dislocation of the patella. Often, pain and instability co exist and the clinical examination is there to help us define the cause of the pain and/or the degree of instability. The origin of patellofemoral symptoms is generally multi factorial and the clinical examination cannot be limited to the knee but must take account of the patient as a whole: evaluate his morphology and understand the way he moves and walks. Each patient, whether he is young or elderly, male or female, active or sedentary, thin or obese, has a specific way of functioning [6, 10, 15], and must therefore be examined on a case per case basis. Certain combinations of causal factors are more relevant than others; however only a systematic clinical examination guided by the history will allow us to identify the right factors for a specific case [20]. Being able to identify them is a must for treatment to be successful.

A systematic clinical examination should include an orderly evaluation of the patient: (1) standing (bipodal/monopodal), (2) Gait analysis, (3) sitting position, (4) lower extremity examination while lying down, and (5) examination of the patellofemoral joint using specific tests to identify painful trigger points and stability.

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5.1.1 Standing Examination

5.1.1.1 Bipodal Stance

One should ask the patient to stand barefoot in front of the examiner.

From the front: one can appreciate the varus/valgus alignment of the knee, the orientation of the patellae (convergent, divergent, or neutral), the morphology of the forefeet (pronatus, hallux valgus, or rigidus).

From the side: one should see the inclination of the pelvis that is related to the postural muscular tone, the spinal curvatures, particularly a lumbar hyperlordosis, the position of the upper body with respect to the pelvis (forward, neutral, or rear displacement), a recurvatum or flexum of the knees.

From the back: one can appreciate the existence of a scoliotic curve, a tilted pelvis due to malrotation or a leg length discrepancy, a varus or valgus alignment of the talus, an abduction or adduction of the forefeet.

5.1.1.2 One Leg Stance

The patient is asked to bend the hip bringing the knee close to the thorax without any external support (Fig. 5.1). This position makes it possible to appreciate his or her equilibrium; a lack of balance is frequently associated with femoropatellar symptoms such as pain with or without instability and secondary diffuse muscular weakness. In case of lack of balance, one could observe deficient hip abductors (contro lateral pelvic tilt), a tendency to kneel-in, (medial collapse in valgus) hyperpronation at the foot and a compensatory inclination of the upper body. When the patient is asked to bend the knee on which he is standing, the deficiencies tend to worsen.

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Fig. 5.1 *One leg standing*. The hip has to be flexed more than 90°. The static equilibrium is evaluated analyzing the position of the shoulders, the pelvis, and the stabilizing motions at the foot

5.1.2 Gait Analysis

While having the patient walk, we can observe him from the front and from the back, look at the symmetry of his gait, the way he balances his arms, the length of the stride, the orientation of the patellae, the varus/valgus alignment of the extremity, the intensity of the heel strike, the step angle, the pelvic tilt.

A pelvic tilt during stance phase, a tendency to kneel-in (medial collapse in valgus) and a hyperpronation are frequently seen together and point to a global lack of dynamic and static stability.

5.1.3 Seated Position

With the patient sitting on the examination table with the legs hanging, we proceed to the knee inspection. It can reveal a swelling of the bony attachments of the patellar tendon suggesting the presence of an osteochondrosis, an insertion tendonitis or a partial rupture of the patellar tendon. It can also reveal the presence of a joint effusion, a patellar bursitis, tissue edema, or a hematoma as result of a capsular sprain or a contusion. The muscular torphicity is evaluated, particularly that of the vastus medialis. An atrophy of the vastus medialis obliquus (VMO) is a common finding in femoropatellar conditions, it can be a causal factor or simply an expression of patellofemoral pain or instability.

The *tubercle-sulcus angle* can be assessed by measuring the Q angle at 90° of flexion (Fig. 5.1). It is defined according to Kolowich [19], by referencing a point at the center of the patella to a point at the center of the tibial tubercle (Fig. 5.2). The normal value has been defined as 0°. When above 10°, it means there is an excessive lateralization of the anterior tibial tubercle. This measurement is more accurate than the Q angle in extension given that the patella is centered in the trochlea and rotational abnormalities are accounted for. The patellar tracking is evaluated by asking the patient to flex and extend the knee while sitting. In the presence of instability one can see the patella centered on the trochlea in flexion and a lateral subluxation near full extension, this lateral shift constitutes the so-called

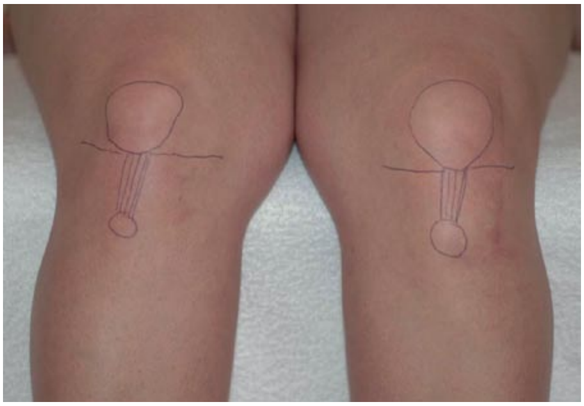

Fig. 5.2 *Tubercle-sulcus angle at 90° of knee flexion*. The angle is measured between a line perpendicular to the transepicondylar axis and a second line passing through the center of the patella and the center of the tibial tubercle. In this case, a normal value between 0° and 10° is noted for the right knee, a negative value is noted on the left knee due to an excessive medialisation after a tibial tubercle tranfer

J-sign [32]. In the presence of patellae alta, they may look like "grasshopper eyes" in full extension particularly if the patellae are lateralized [15].

5.1.4 Supine Position

Upon inspection we will look at the spontaneous position. An external rotation of the extremities with diverging patellae might suggest a femoral retro torsion, a retraction of the piriformis, an external tibial torsion or all of them in a variable degree. One could observe the opposite, an internal rotation of the extremities with converging patellae suggesting an excessive femoral antetorsion that could be more or less compensated by an increased external tibial torsion, with all the combinations being possible [21].

The knee varus or valgus can vary depending on the degree of knee flexion and can therefore be affected by the presence of a knee flexion contracture or recurvatum. Recurvatum when the knee is in hyperextension, allows a more proximal placement of the patella with respect to the trochlea and therefore decreases the control and the joint congruence. It is often associated with a varus and a lateralization of the anterior tibial tuberosity due to the screw home mechanism [9]. Inversely the flexion contracture induces increased forces on the femoropatellar joint.

5.1.4.1 Measurement of the Q Angle

The Q angle is a reflection of the valgus vector of the quadriceps pull acting on the patella and indicates the medial or lateral insertion of the quadriceps mechanism [3]. It is measured by drawing a line between the center of the patella and the anterior-superior iliac spine and a second line between the center of the patella and the center of the tibial tubercle. This is not a reliable indicator of patellar malalignment and there is a lot of controversy about what should be accepted as normal and how to measure it [2]. The Q angle can be found increased in patients with excessive femoral antetorsion, external tibial torsion, or genu valgum.

5.1.5 Prone Position

Femoral antetorsion is evaluated by measuring the internal and external rotation of the hip with the knee flexed at 90°. A greater internal rotation than external rotation points towards an increased femoral anteversion. One can also evaluate the anteversion by rotating the hip in extension while palpating the greater trochanter: when the latter reaches the maximal prominence, the femoral neck is parallel to the examination table and the angle between a vertical plane and the leg corresponds to the anteversion.

The external tibial torsion is obtained by measuring the angle between the bi malleolar plane and the longitudinal axis of the femur (Fig. 5.3).

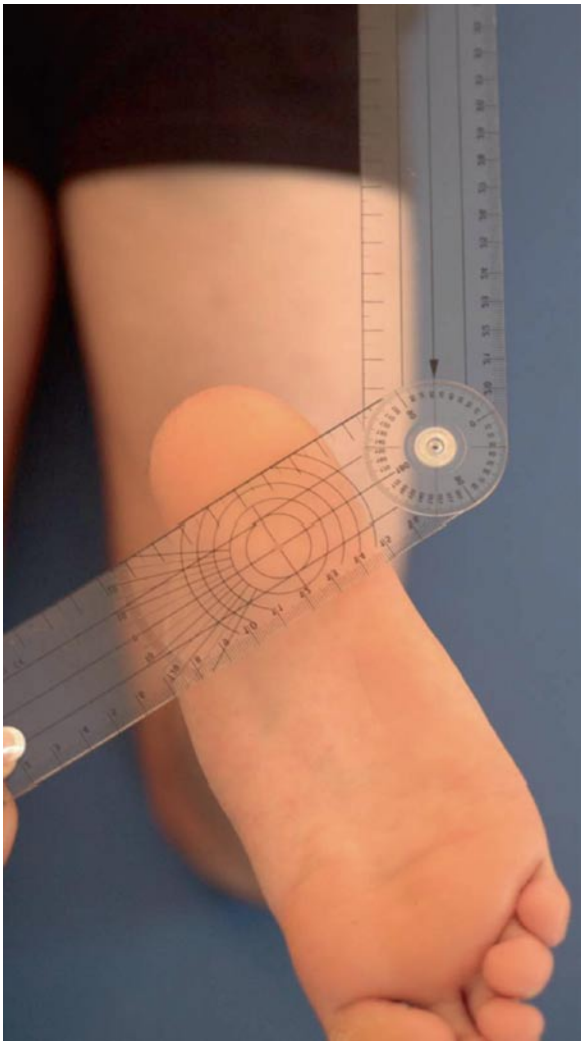

Fig. 5.3 *The external tibial torsion* is estimated by measuring the angle between the bimalleolar plane and the longitudinal axis of the femur. The ankle is placed in neutral position of flexion-extension. In this case the value is somewhere between 30° and 35°

5.1.6 Evaluation Tests for Static and Dynamic Forces Acting on the Patella

The knee examination must be complete in order to diagnose or rule out any other conditions not related to the patellofemoral joint.

5.1.6.1 Effusion

Joint effusion can be detected by the "ice cube test" (Fig. 5.4): compression is applied around the patella with both hands reducing the volume of the joint space. In the presence of a joint effusion, the patella will be elevated and when pushed with the index finger, it will feel like an ice cube in a drink.

5.1.6.2 Palpation

All the anatomic structures of the knee are palpated to detect painful trigger points, inflammation, or structural defects; the patella, the tendinous insertions of the quadriceps or the patellar tendon (Fig. 5.5), the medial and lateral retinaculum, the medial and lateral patellar facets, the fat pad, the adductor tubercle (frequent site of medial patellofemoral ligament MPFL lesions), the pes anserinus, the iliotibial band.

Fig. 5.4 *Joint effusion* is diagnosed by the "ice cube test": a compression is applied around the patella with both hands forcing the liquid under the patella. In the presence of a joint effusion, the patella will be elevated and when pushed with the index finger, it will feel like an ice cube in a drink

In case of pain over the medial retinaculum, it is necessary to look for a medial patellar or supra patellar plica by palpating the medial shelf. Slight flexion-extension movements while palpating the plica triggers pain.

Pain on the lateral aspect of the patellofemoral joint should raise the question of an external hyperpressure syndrome of the patella or a patellofemoral arthritis with retraction of the external retinaculum. The differential diagnosis is a patella bipartite or an iliotibial band friction syndrome.

5.1.6.3 Passive Patellar Tilt Test

The retraction of the lateral retinaculum is objectively evaluated by the "passive patellar tilt test" when it is impossible to lift the lateral edge of the patella while the knee is in full extension with the quadriceps relaxed. The normal tilt is considered to be around 0° tilt with the patellar plane being parallel to the examination table [10, 11]. In case of an excessive surgical release of the lateral retinaculum, the tilt is increased and the patellar plane may be rotated internally [1, 19].

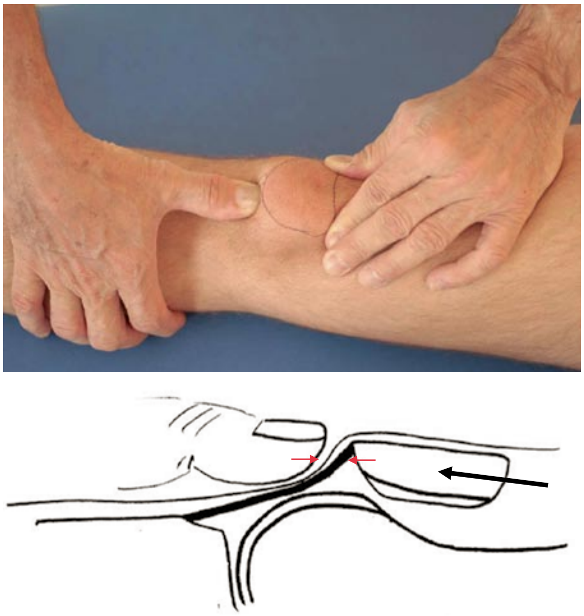

Fig. 5.5 *Palpation of the patellar tendon.* The patella is stabilized laterally and pushed distally against the thumb. In case of patellar tendonitis (jumper's knee) the pain is recognized by the patient

5.1.6.4 Passive Patellar Glide Test

This test allows us to estimate the degree of lateral and medial translation of the patella while holding the knee at 20–30° and the quadriceps relaxed. The measurement is taken by estimating visually the distance between the center of the patella and the lateral and medial epicondyles, which should be equal with the knee in 20° of flexion [19]. In the presence of a tear of the medial or lateral restraints, the translation is increased. In case of arthrofibrosis, the translation is reduced including that in the cranial direction. Powers has shown a weak correlation for this test when the measurements were compared with those obtained by MRI [25].

5.2 Muscle Flexibility

PFPS has been frequently associated with deficits of lower limb flexibility and several retrospective studies have shown this relationship in athletes [18, 27]. There have been consistent results showing this association with a tight quadriceps. The same studies did not find an association between PFPS and hamstring tightness [30].Tightness of the quadriceps muscle is measured by placing the patient in ventral decubitus, stabilizing the pelvis and flexing the knee bringing the heels as close as possible to the buttocks. The distance from the heels to the buttocks is measured in finger breadths [8].

The Thomas test is used to asess a flexion contracture of the iliopsoas muscle. The patient lies in supine position, brings one thigh towards the chest with both hands while allowing the other leg to overhang at the edge of the table. The sacrum has to rest flat on the table. Iliopsoas tightness is present if the opposite thigh raises off the horizontal plane. Iliopsoas and piriformis tightness induce a hip contracture in external rotation. An easy way to evaluate a piriformis tightness is to sit with the hips flexed at 90° and to cross one leg over the other forming a number 4 figure. Leaning forward in straight inclination of the trunk will cause discomfort and pain in the buttock.

ITB tightness has also been implicated in a number of studies as a contributing factor to PFPS [26, 31]. The Ober's test [23] reviewed by Gose and Schweitzer [11] is a simple method to assess the ITB tightness with reference to the horizontal or sagittal body planes: the patient lies on his side, with the thigh in contact to the table and flexed enough to eliminate any lumbar lordosis. The examiner stabilizes the pelvis perpendicularly to the horizontal plane with one hand. With the other hand he positions the upper leg in full extension. Inability to adduct and have the knee touch the table constitutes a mild tightness. Passive adduction to the horizontal plane at best constitutes a moderate tightness. Fixed abducted position constitutes a severe tightness.

5.2.1 Patellofemoral Grinding Test

This test is performed in supine position with the knees extended. The examiner moves the patella superiorly and inferiorly while compressing against the femoral groove. The presence of pain makes the test positive and supposedly associated to the presence of PFPS. However the test has also been found positive in contralateral asymptomatic knees which means the specificity and hence usefulness of this test is certainly limited [14].

5.3 Flexion-Extension Crepitus

By using a stethoscope or simply by placing the hand stretched out over the patella, one asks the patient to flex and extend the knee. Occasionally we can hear or feel a patellar clunk at about 20°–30° of flexion (its cause is often uncertain) and sometimes there is a crepitation that can be caused by cartilaginous lesions or even an arthrosis of the patellofemoral joint. No correlation has been found between the severity of the crepitus and the cartilaginous lesions [2, 17].

5.3.1 Engagement Sign

On occasion there may be a conflict as the patella engages into the proximal trochlea. A short trochlea, a Patella Alta, a knee recurvatum are all factors that predispose to a problematic patellar engagement and hence a source of pain. A step is sometimes present at the cartilage/bone junction at superior pole of the trochlea. One can objectivize this finding by placing the knee in full extension or hyperextension and placing the patella at the superior

Fig. 5.6 *Engagement sign*. Patient in supine position, knees in full extension, the thumb is applied firmly on the tip of the patella and then the knee is flexed to 20°. The test is positive if the contact between the patella and the trochlea is painful. By this test, one can feel if the upper border of the trochlea makes a bump and if the patella need to jump this bump like a step to engage in the trochlea

edge of the trochlea and keeping it in contact by pushing against it with the thumb (Fig. 5.6). When one bends the knee, the patient recognizes the pain (located at the inferior articular pole of the patella) at the moment when the patella engages on the trochlea. This sign reproduces the pain but also testifies the existence of predisposing factors to a patellofemoral instability.

5.4 Apprehension Test

The apprehension test (Fairbanks sign) is a pathognomonic sign of patellofemoral instability [7]. The patient is instructed to extend the knee starting at 20°–30° of flexion while the examiner pushes the patella laterally. The test is positive when the patient resists and recognizes instability symptoms (Fig. 5.7). A positive apprehension test is often related with abnormal lateral glide, a positive engagement test, and sometimes with patellar maltracking.

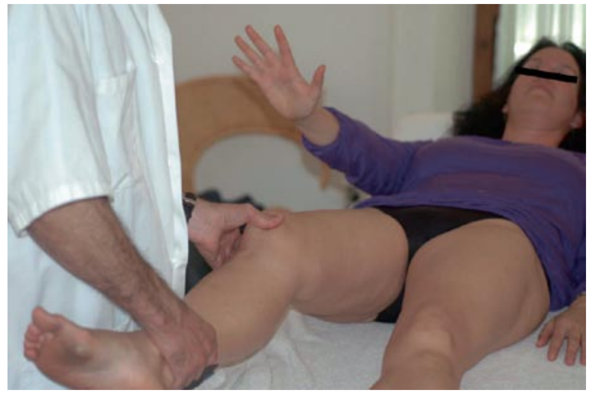

Fig. 5.7 *Apprehension test.* The test starts with the knee at 20° or 30° of flexion. Applying firmly the thumb on the medial border of the patella, the patient is asked to extend the knee. The test is positive when the patient feels fear of lateral subluxation of the patella and resists. This test can be also performed starting in knee extension. The knee is then bended passively and the patient reacts immediately in case of instability

5.4.1 Lateral Pull Sign

The resultant vector of the extensor mechanism is estimated by the direction followed by the patella when the quadriceps is contracted with the knee in full extension. In case of superolateral or lateral displacement of the patella, the test is positive and means that an excessive lateral pull of the quadriceps is taking place [19]. An abnormal lateral pull test could be due to an atrophic, deficient VMO or a hypertonic external vastus. There are certain factors that predispose to a lateral pull sign such as trochlear dysplasia, distension of the medial retinaculum or retraction of the lateral retinaculum or Patella Alta.

Repeated lateral pull tests and patellar tilt tests had fair intraobserver and poor interobserver reliability. These results suggest that care must be taken in placing too much emphasis on these tests when making clinical decisions [8, 29].

5.4.2 Special Recommendation

In our clinic, we consider lack of adequate mobility of the subtalar joint and normal mobility of the Flexor Hallucis Longus tendon as important factors contributing to patellofemoral pain (Fig. 5.8).

Functional hallux limitus (FHL) is a loss of MTP joint extension during terminal stance when the weight bearing foot is in maximal dorsal flexion and it constitutes a sagittal plane blockade [5]. As a consequence the mechanical support and stability mechanisms of the foot are disrupted with important consequences not only in the foot but also in the knee, hip and lower back. The compensatory mechanisms required to overcome this sagittal plane blockade include increased flexion of the ankle, the knee, the hip, and the spine [24]. In our opinion, Patellofemoral pain is strongly related to FHL.

Fig. 5.8 *Subtalar joint mobility.* To assess the mobility of the subtalar joint place the hands as shown on the picture and carry out soft varus/valgus swaying. If the joint is locked, by swaying movements and traction on the joint you can recover the mobility feeling sometimes a "pop" or a "crac." This maneuver leads to a normal glide of the flexor hallucis longus tendon [28]

The diagnosis is clinical but requires a high degree of suspicion. FHL may cause local symptoms such as callous formation under the IP, pain over the sesamoids, and retromalleolar pain. It also reduces the mobility of the subtalar joint leading to poor equilibrium and a higher risk of ankle sprains.

Hamilton [13] described a clinical test to diagnose the tenodesis effect that causes a "Functional Hallux Limitus." This test demonstrates a restricted MTP1 dorsal flexion when the ankle is placed in full dorsal flexion. This qualitative and diagnostic test has also been called by Michelson the "Flexor Hallucis Longus Stretch Test" (Fig. 5.9) [22].

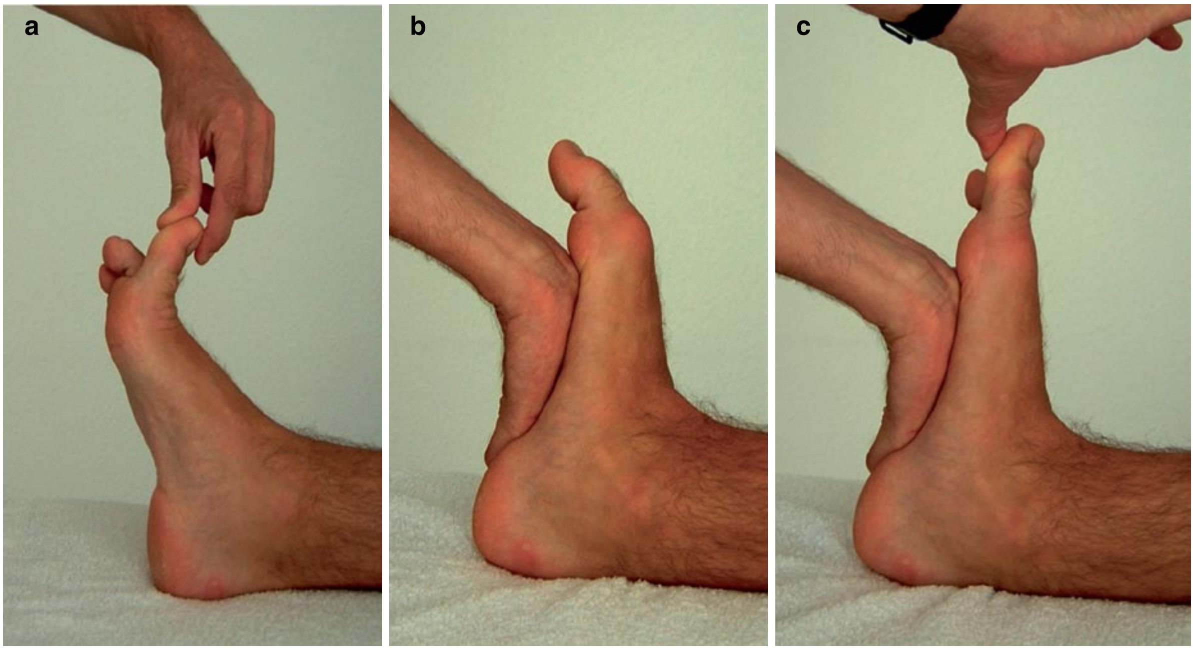

Fig. 5.9 *Flexor hallucis longus stretch test.* (**a**) Evaluate the range of motion (ROM) of the MTP1 joint in plantar flexion of the ankle. A dorsiflexion of about 50°–80° is normally present [13]. When reduced, a degenerative hallux rigidus must be ruled out. (**b**) Place the ankle in full dorsiflexion by pushing the foot backwards as much as possible with the palm of your hand placed beneath the MTP 1 head, while supporting your bent elbow against your iliac crest. This manoeuver will put under tension the flexor hallucis longus tendon. (**c**) Test the passive extension of the MTP1 joint by pushing the 1st toe backwards. The test is *negative* if the extension of the MTP1 is possible and not restricted, *positive* (c) if the extension of the MTP1 joint is restricted or not possible

5.5 Conclusions

The origin of patellofemoral pain is multifactorial and needs a global approach, a thorough examination of the patient including his morphology, his static equilibrium, and the way he moves.

Palpation localizes the source of pain. Patellofemoral instability can be objectivized by specific tests such as the apprehension test, the engagement sign, excessive patellar glide, or maltracking of the patella. Some other tests such as the lateral pull test and the Q angle are not very reliable and could lead to inaccurate interpretations. In the near future we could expect more functional clinical tests based on dynamic analysis such as a 3D Q angle in gait helping us define the casual relationship between these parameters and patellofemoral pain.

5.6 Summary

- The clinical exam must be systematic. It must take into consideration the patient as a whole, his individual corporal architecture, his static and dynamic equilibrium, and function during gait.
- Guided by a thorough history, it should lead in most cases to a clear diagnosis that can then be confirmed or complemented with additional para clinical tests.
- It should allow us to identify the painful areas, confirm or exclude the presence of patellofemoral instability.
- Some clinical tests have a strong diagnostic value (the engagement sign or the apprehension test) while others are of less use (Q angle value and patellar tilt).
- One must be extremely careful, inadequate interpretation of some of these tests can lead to inadequate and unnecessary surgical treatments.
- The adequate estimation of the lower limb alignment is essential.
- Particular attention must be paid to femoral and tibial torsions and the joint mobility in rotation.
- The patellofemoral joint is placed between two “ball-in-a-socket joints”: the coxofemoral and the subtalar joint, key joints for the rotational balance of the lower limb.
- Their range of motion (ROM) should be carefully examined given their functional effect on the patellofemoral joint during gait and balance control.
- The clinical exam is certainly the best tool to determine additional para clinical and radiological studies in order to confirm the diagnosis and choose the best treatment option.

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Standard X-Ray Examination: Patellofemoral Disorders

6

David Dejour, P. R. Saggin, X. Meyer, and T. Tavernier

6.1 Introduction

X-rays analysis [21] is the first step before any other investigation for all knee pathology. Coming from this exam and combined with the clinical exam, the physician will be able to request other specific radiological exams (MRI, Arthro MRI, CT scan, arthro CT, bone scan, ultrasonography).

The basic incidences do not change much depending on the pathology, chronic or acute. The only factor necessary to obtain these radiographs is the ability of the patient to stand up. Sometimes the physician can ask for ¾ obliques to detect some postero-medial or postero-lateral fractures.

6.2 Basic Standard X-Rays

6.2.1 *Antero-Posterior View*

The AP has to be done in monopodal stance every time the patient is able to. Until 50 years old this incidence is performed in 15°–20° of flexion. After 50 years old, or in cases of orthopedic surgical antecedents, like previous meniscectomy, anterior cruciate ligament (ACL) surgery or trauma surgery, a semi-flexed position x-ray at 30 or 45° of flexion (Schuss or Rosenberg view [19]) is better to detect joint line narrowing (Fig 6.1a, b).

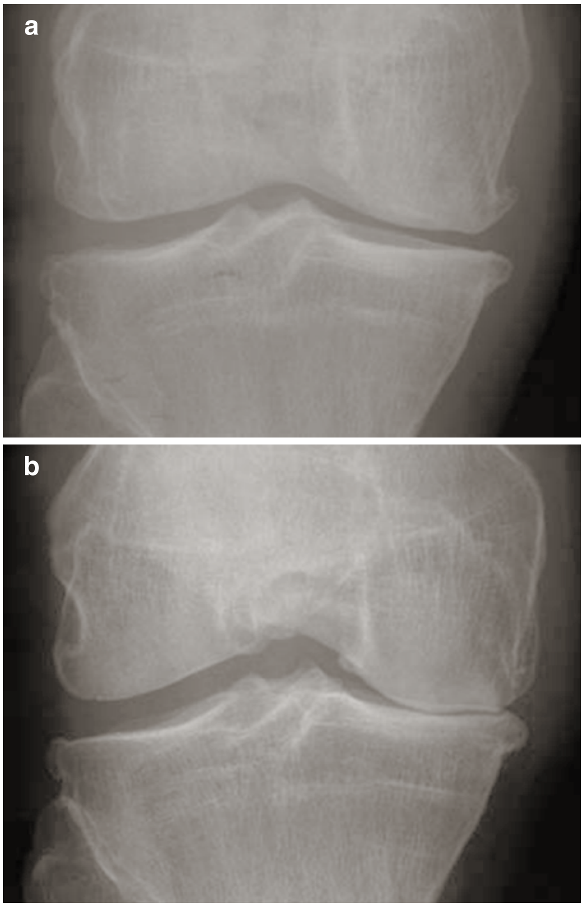

Fig. 6.1 (**a**) AP weight-bearing view at 20° flexion: remodeling of the medial compartment with no joint line narrowing. (**b**) Same patient AP at 45° flexion showing the medial arthritis bone on bone

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The reason for this is that humans walk in knee flexion and the stance phase is close to 30° flexion, so the wear pattern starts in flexion.

The first analysis has to check:

- The bone quality and the bone density (calcific changes, osteopenia, osteoporosis)
- Tibial plateau densification, medial or lateral

The second analysis will search specific features depending on the patient's history and clinical examination:

1. Femorotibial arthritis

The most used classification is the Ahlback classification

Stage I - remodeling
Stage II - joint line narrowing less than 50%
Stage III - joint line narrowing more than 50%
Stage IV - bone on bone.

This classification is less precise than the chondrometry but it is closer to the anatomic definition of arthritis, which is bone on bone. The presence of osteophytes, remodeling, or subchondral cysts are usually anatomical phenomena which are common. Some etiologic factors like a hooked spine or a postero-medial cupula combined with an anterior tibial translation are characteristic of arthritis in chronic ACL deficiency.

2. Traumatic history

Fractures on the femur, tibia, or patella should be searched for, and if there is a suspicion of fracture ¾ oblique x-rays are helpful to develop the anatomy. Search also for sequelae like axis deviation or degenerative changes. A classical differential diagnosis for patella fracture is the patella bipartite; the axial view will help in making the final diagnosis.

3. Patellar instability

A loose body in the lateral gutter means a lateral condyle fracture occurred during the patellar dislocation.

4. Ligamentous injuries

A segond fracture is pathognomonic of an ACL tear.

A tear of the medial collateral ligament at the femoral insertion could lead in the chronic phase to the pellegrini-stieda sign.

6.3 Sagittal View

This is the most interesting view of the knee; the reliability of its interpretation depends on the technical quality of the radiologist. It is absolutely essential to have a perfect superimposition of the two posterior condyles [4, 7]. The x-ray is done in monopodal weight bearing with an angle of flexion between 15°–20°. The sagittal view can also be taken in full extension, but its accuracy is controversial because the quadriceps contraction can modify the patellar height. Sometimes a patient can go into hyperextension with recurvatum and give a false positive Patella Alta and false information about the patellar engagement.

6.3.1 Joint Line Thickness

The analysis of the joint line thickness is possible and accurate, that is the reason why it is better to do it in monopodal stance. The location of the wear is interesting: if it is posterior it could indicate that there is a chronic ACL tear, and if the clear posterior triangle has disappeared, it could be an indication of an old medial meniscectomy.

6.3.1.1 Anterior or Posterior Tibial Translation

It is the distance between the posterior edge of the medial tibial plateau and the posterior edge of the medial condyle [21] (Fig. 6.2). (The medial condyle has the most anterior trochleo-condylar line). The value of this measurement is the differential value between the involved knee and the control knee. Anterior tibial translation increases in the case of anterior chronic laxity and posterior tibial translation increases in cases of chronic posterior laxity. The AP translation is statistically correlated to the tibial slope in normal and pathological knees. There are six methods for measuring the tibial slope [2]. The two most reliable are the use of the anatomical proximal tibial axis or the posterior tibial cortex. The mean value is 9° ± 3° for the anatomical axis and 7° ± 3° for the posterior cortex.

Fig. 6.2 Sagittal view weight bearing at 20° flexion. Both condyles are on the same line, the analysis look at: joint line thickness; patellar height; trochlear shape – patellar tilt; anterior tibial translation; tibial slope; thickness of the meniscus place

6.3.2 The Trochlea

The sulcus line follows the Blumenstat line. In a normal knee this line stays posterior to the condylar line, meaning that the trochlea is deep and congruent. Henri Dejour [6–8] described in 1987 the "crossing sign" which characterize the trochlear dysplasia on the sagittal view (Fig. 6.3). In case of a trochlear dysplasia there will be a crossing sign between the sulcus line and the lateral condyle meaning that the trochlea is flat. The crossing sign is found in 96% of the population with a history of true dislocation and only in 3% of the healthy controls population [6, 7]. The first classification published graded the dysplasia in three types depending on the level of the crossing sign. Lower crossing signs meant higher grades of dysplasia. The other signs were the deepness of the trochlea measured at different angles and the "bump", which was defined by the distance between a line drawn parallel to the anterior femoral cortex and the highest point of the trochlea. It was considered pathological if superior to 5 mm and represented the prominence of the entire trochlea.

The classification in three types had some limitations and this was corroborated by the work of François Gougeon, Frank Remy [17] and Henri Migaud from Lille (France). In fact, they have showed that interobserver reproducibility of trochlear analysis was low, especially for type II dysplasia. This led to a new study performed in 1996 by D. Dejour and B. Le Coultre, comparing 177 patellar instabilities with radiography as well as pre and postoperative CT scans [5]. They defined a new and more precise classification with four grades of trochlear dysplasia. They added to the crossing sign two new signs. The first is the "supratrochlear

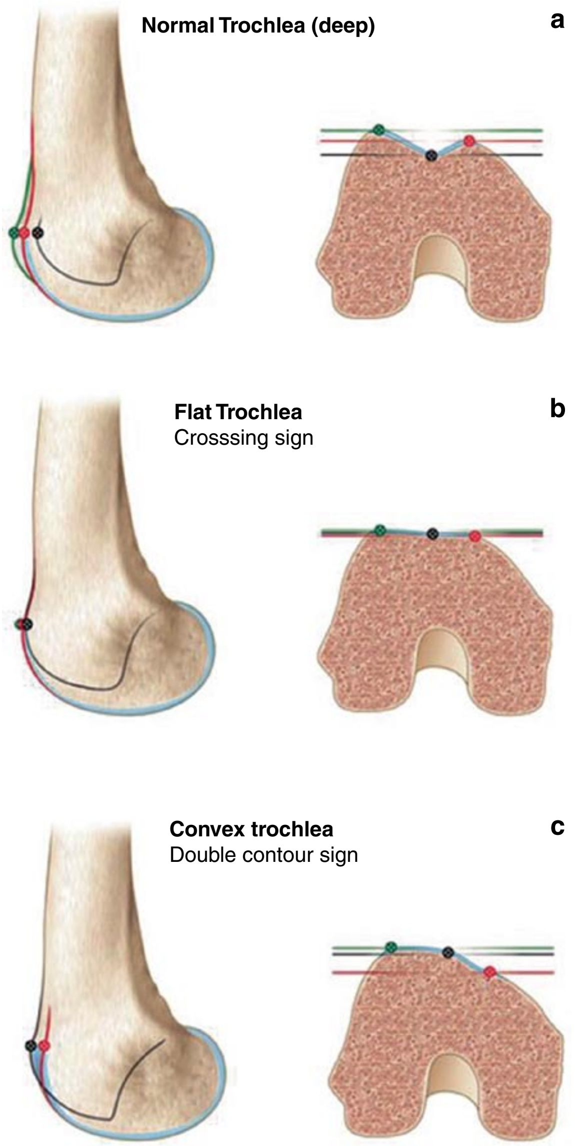


Fig. 6.3 The crossing sign defines the trochlear dysplasia: the groove line links the condyles' anterior part; at that point the trochlea is flat or convex

spur" which represents the global prominence of the trochlea and plays the role of a "ski jump" when the patella engages the trochlea. The second sign is the "double contour" which is the radiographic line ending below the crossing sign; it represents the subchondral condensation of the hypoplastic medial facet on the lateral view (Fig. 6.4). A classification with four types of trochlear dysplasia was then described [4] (Fig. 6.5).

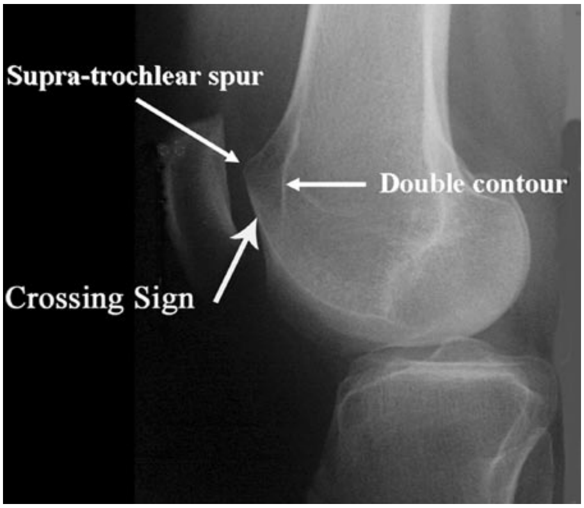


Fig. 6.4 The three patterns of trochlear dysplasia: Crossing sign; Supratrochlear spur: defines the prominence of the trochlea; Double contour: projection on the lateral view of the hypoplasic medial facet (subchondral bone); it should be below the crossing to be pathological

A new inter-observer study [18] was conducted and concluded that "this new classification system was more reproducible than the former three-type system proposed by Henri Dejour. The crossing sign and the supratrochlear spur are the most reproducible signs".

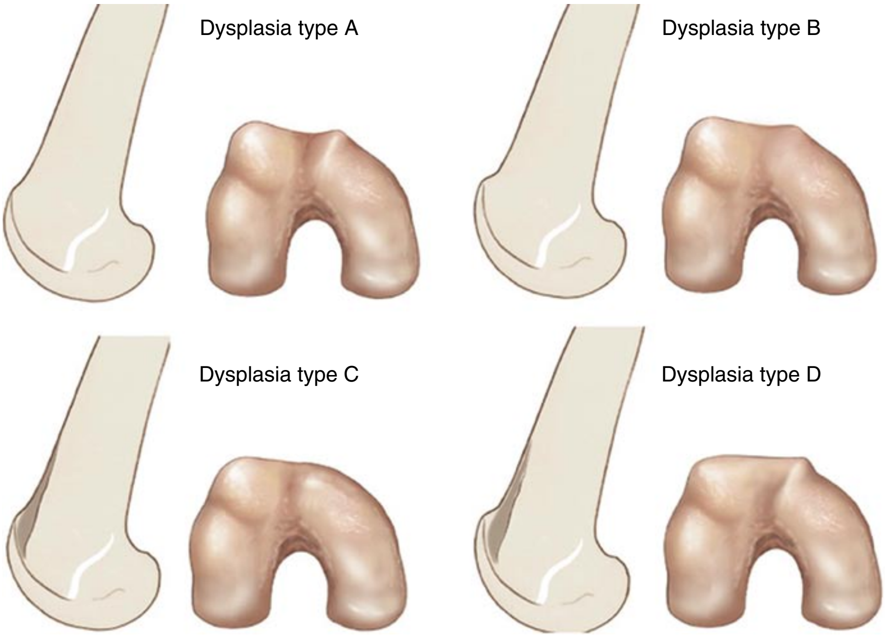
The trochlear dysplasia classification has four types combining all the three dysplastic signs. Starting from the Type A in 54% of the Objective Patellar Dislocation population, type B in 17%, type C in 9% and type D in 11% [4].

6.3.2.1 The Patella

The shape of the patella on the lateral view is correlated to the tilt, and to the global morphology of the patella.

Grelsamer [20] performed a study describing three types of patella depending on the ratio between the length of the patella and the length of the articular surface (Fig. 6.6a–c). Most of the patellae exhibit a ratio between 1.2 and 1.5 (type I). Those with a ratio greater than 1.5 give the appearance of having a long nose: type II (in fact a relatively long, not articulating inferior pole). Those with a ratio less inferior to 1.2 (short nose) are the type III.

Fig. 6.5 Dejour's Trochlear dysplasia classification. Type A: Crossing sign, Trochlear morphology preserved (fairly shallow trochlea > 145°); Type B: Crossing sign, Supratrochlear spur, Flat or convex trochlea; Type C: Crossing sign, Double contour (projection on the lateral view of the hypoplatsic medial facet); Type D: Crossing sign; Supratrochlear spur, Double contour, Asymmetry of trochlear facets, vertical link between medial and lateral facets (cliff pattern)



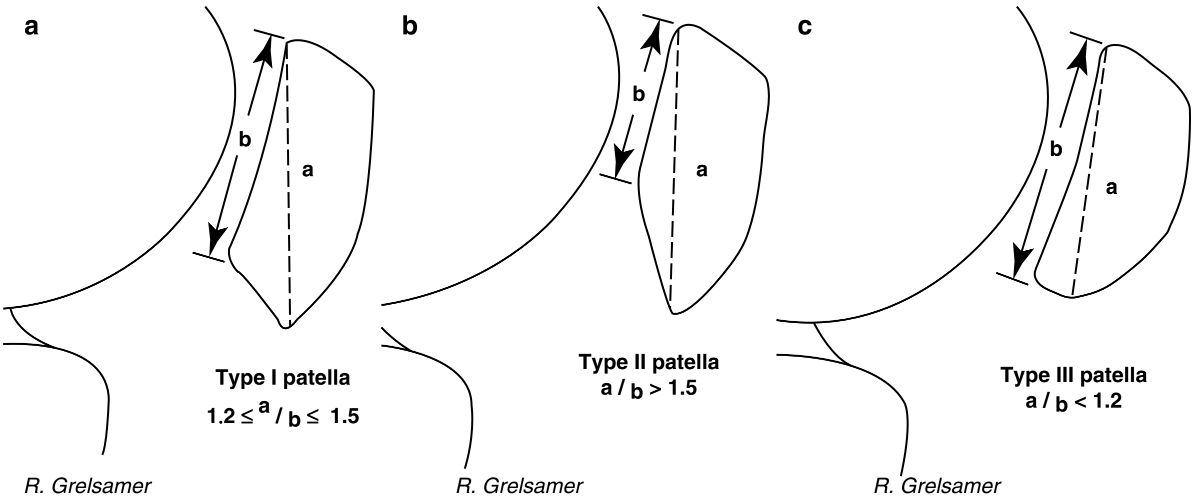


Fig. 6.6 Different type of patellar shape upon the Grelsamer classification

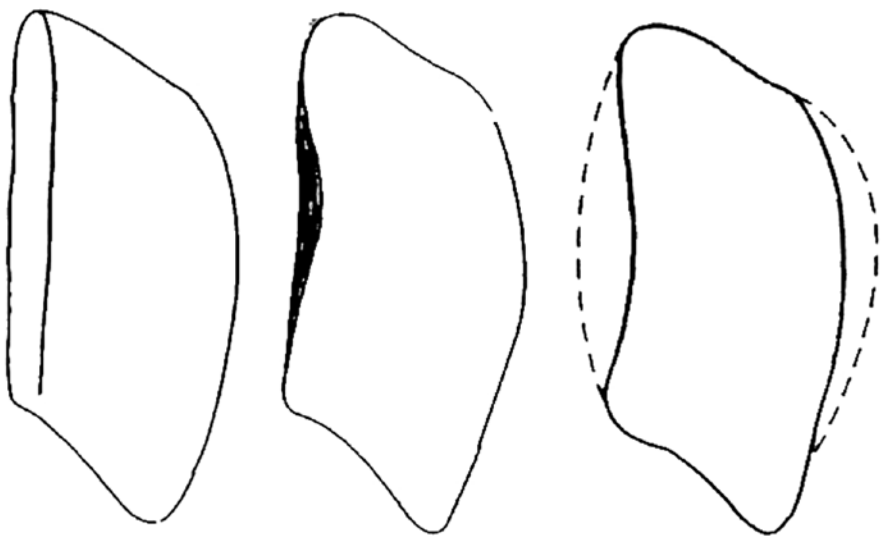


Fig. 6.7 Identification of the patellar tilt on the lateral view according to Maldague & Malghem

The tilt evaluation has been described by Maldague and Malghem [13, 15]. Three positions are described: position 1 is normal position (the lateral facet is in front of the crest): position 2 is mild tilt, the two lines (lateral facet and crest) are on the same level; position 3 is major tilt, the lateral facet is behind the crest (Fig. 6.7).

6.3.2.2 The Patellar Height

The patellar height has to be measured each time using an identified index. The main indexes used in the literature are:

- The Caton-Deschamps [3] index which is the ratio between the distance from the lower edge of the articular surface of the patella to the antero-superior angle of the tibia outline (AT) and the length of the articular surface of the patella (AP). A ratio (AT/AP) of 0.6 and smaller indicates a Patella Infera and a ratio of 1.2 and greater indicates a Patella Alta.
- The Insall-Salvati [9] index is the ratio between the length of the patellar tendon (LT) and the longest sagittal diameter of the patella (LP). Insall determined that this ratio (LT/LP) is normally 1. A ratio smaller than 0.8 indicates Patella Infera and a ratio greater than 1.2 indicates Patella Alta

- The Blackburne and Peel [1] index is the ratio between the distance measured from a line projected tangential to the tibial plateau to the inferior part of the patellar articular surface and the length of the patellar articular surface. The ratio A/B provides a measure of patellar level. The normal ratio was defined as 0.8. In Patella Infera it is smaller than 0.5, in Patella Alta greater than 1.0.

More details on patellar height and accuracy of the patellar index are given in the next chapter.

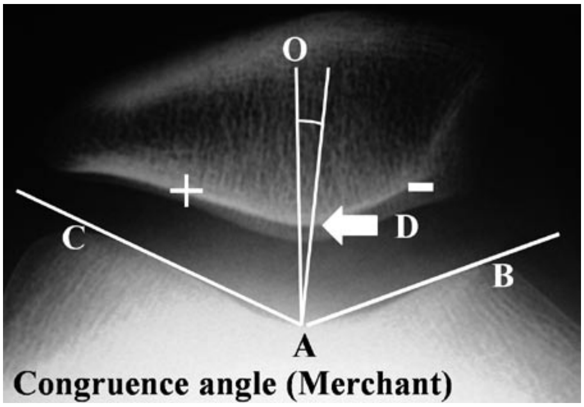


Fig. 6.8 The congruence angle is measured by bisecting the sulcus angle to construct a reference line and then projecting a second line from the apex of the sulcus angle to the lower point of the subchondral articular surface of the patella (apex)

6.4 Axial View

The axial view has been described at different angles of flexion and different positions of the x-ray cassette. Two basic types of axial views can be done with different types of measurements.

1. The Merchant [16] view is obtained with the patient in the supine position, the knees flexed at 45°, and the lower legs resting on an angle platform. The x-ray beam is angled toward the feet 30° from the horizontal and the film cassette is positioned 30 cm below the knees. The x-ray beam strikes the cassette at a 90° angle, imaging both knees simultaneously. Two angles are measured on this view the sulcus angle and the congruence angle.
   - The sulcus angle is the angle formed by two lines connecting the deepest point of the trochlear groove to the highest points on the medial and lateral femoral condyles. This measurement evaluates the shape of the groove; the greater the sulcus angle the flatter is the trochlea. The average sulcus angle on the merchant view is 138°, equal in males and females.
   - The congruence angle (Fig. 6.8) is measured by bisecting the sulcus angle to construct a reference line and then projecting a second line from the apex of the sulcus angle to the lower point of the subchondral articular surface of the patella (apex). If the line drawn from the patellar apex is lateral to the reference line the angle is assigned positive; if it is medial to this line a negative value is assigned; the normal congruence angle averages −6° (SD of 11°). These values are subjective and cannot define any category of patient unless a statistical study finds a pathological threshold.

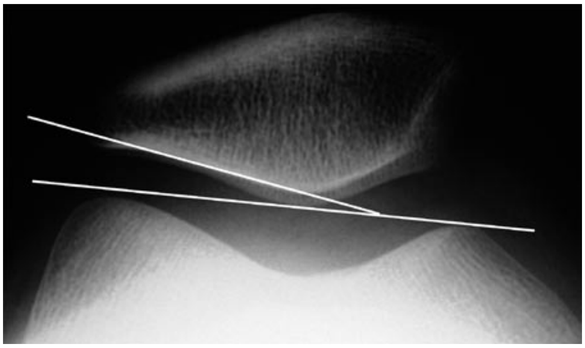


Fig. 6.9 The lateral patellofemoral angle is formed by the intersection of one line drawn from the superior point of medial and lateral trochlear facets and a second line drawn tangent to the lateral facet of the patella

2. The Laurin [11, 12] view is obtained with the patient sitting and the knee flexed 20°. The x-ray cassette is held approximately 12 cm proximal to the patellae and pushed against the anterior thighs; the x-ray beam is directed cephalic and superior 20° from the horizontal point. Two measurements are made on this view: the lateral patellofemoral angle and the patellofemoral index.
   - The lateral patellofemoral angle (Fig. 6.9) is formed by one line drawn from the superior points of the medial and lateral trochlear facets and a second line tangent to the lateral facet of the patella.

- The patellofemoral index is the ratio of the thickness of the medial joint space and the lateral joint space.

Both values were described by authors to quantify the amount of patellar tilt.

- Maldague and Malghem [14] added to the merchant view another view in external rotation to search for pathological subluxation.

No matter which technique is chosen, the angle of flexion is essential for an adequate analysis of the x-ray. If the angle is between 0 and 30 degrees the medial facet should represent one third of the trochlea and the lateral facet two thirds. If one facet represent 50% it means that the x-rays have been done close to 90° flexion becoming less informative.

6.4.1 Patellar Shape

The patella has three facets, the medial, the lateral and the "odd facet" (located medially and smaller than the medial facet). There is a great variability in the patellar shape and Wiberg [22] classified them into three types (Fig. 6.10 a–c).

- Type I: the medial and the lateral facets are both concave and closely equivalent in size
- Type II: the medial facet is smaller than the lateral facet and has a flat or concave surface. The lateral facet has a concave contour.
- Type III: the medial facet is very small, nearly inexistent, describing a right angle in relation to the lateral facet.

The most frequent type of patella in objective patellar dislocation is the Wiberg type II, and in cases of high grade patellofemoral dysplasia it will be the type III.

Bipartite or multipartite patella can also be observed. They are the result of an incomplete fusion of the ossification center. They are described to have a frequency between 0.005% and 1.66%, mostly located close to the supero-lateral part, and the edges of the fragment are smooth, which makes the differentiation from patella fracture. The bi or multi partite patellae are often bilateral. They are different from the classical medial bone fragment due to patellar dislocation, which is characteristic of a true dislocation (Fig. 6.11).

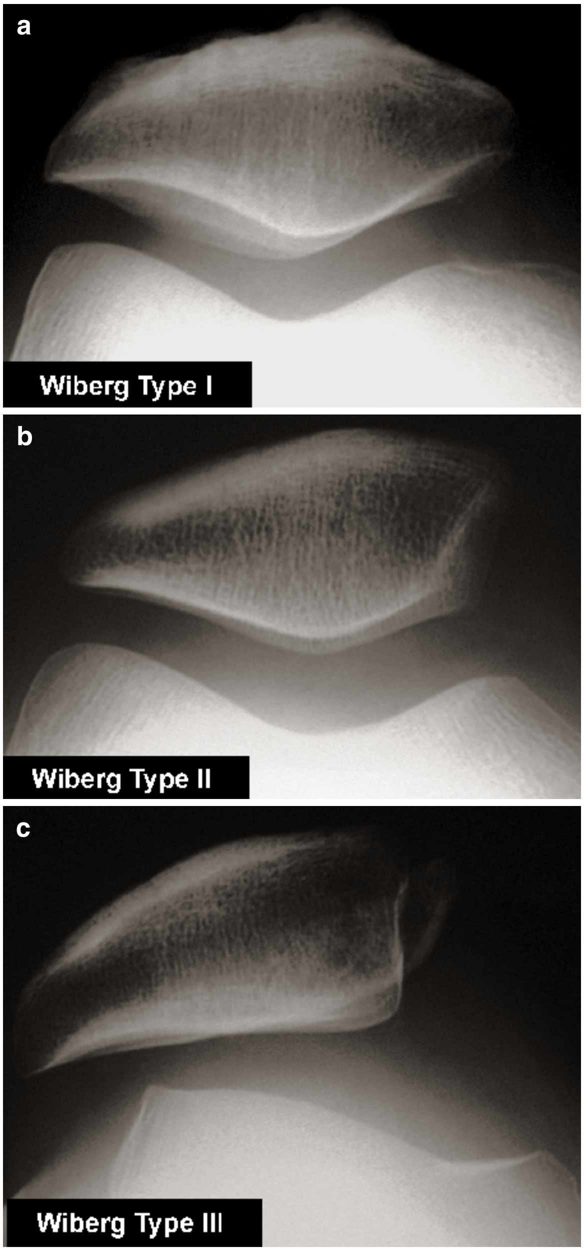


Fig. 6.10 Wiberg classification for patellar shape. Type 1 (**a**), Type 2 (**b**) and Type 3 (**c**)

6.4.2 Arthritis

The patellofemoral joint space is studied on the 30° axial view, which, in OA, will show narrowing of the joint space and, in severe cases, bone-to-bone contact between the trochlea and the patella. The axial view also shows which side of the compartment is affected (usually the lateral side is involved).

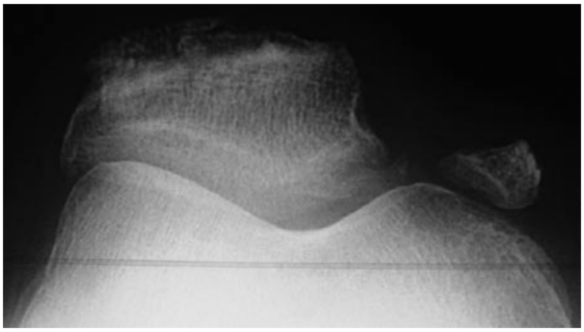


Fig. 6.11 Medial bone tear after a patellar dislocation. The proof of a true dislocation

Information is also provided on the size of osteophytes, and on whether the patella is well centered or subluxated.

Iwano [10] et al. have produced a simple staging system of lateral patellofemoral OA (Fig. 6.12):

- Stage I: Mild OA joint space at least 3 mm
- Stage II: Moderate OA; Joint space less than 3 mm, but no bony contact
- Stage III: Severe OA; Bony contact less than one-quarter of the joint surface
- Stage IV: Very severe OA; Joint surfaces entirely touch each other

6.5 Conclusion

Standard x-rays are the first step in the diagnosis of any knee pathology and can detect any anatomical abnormalities in cases of patellofemoral disorders.

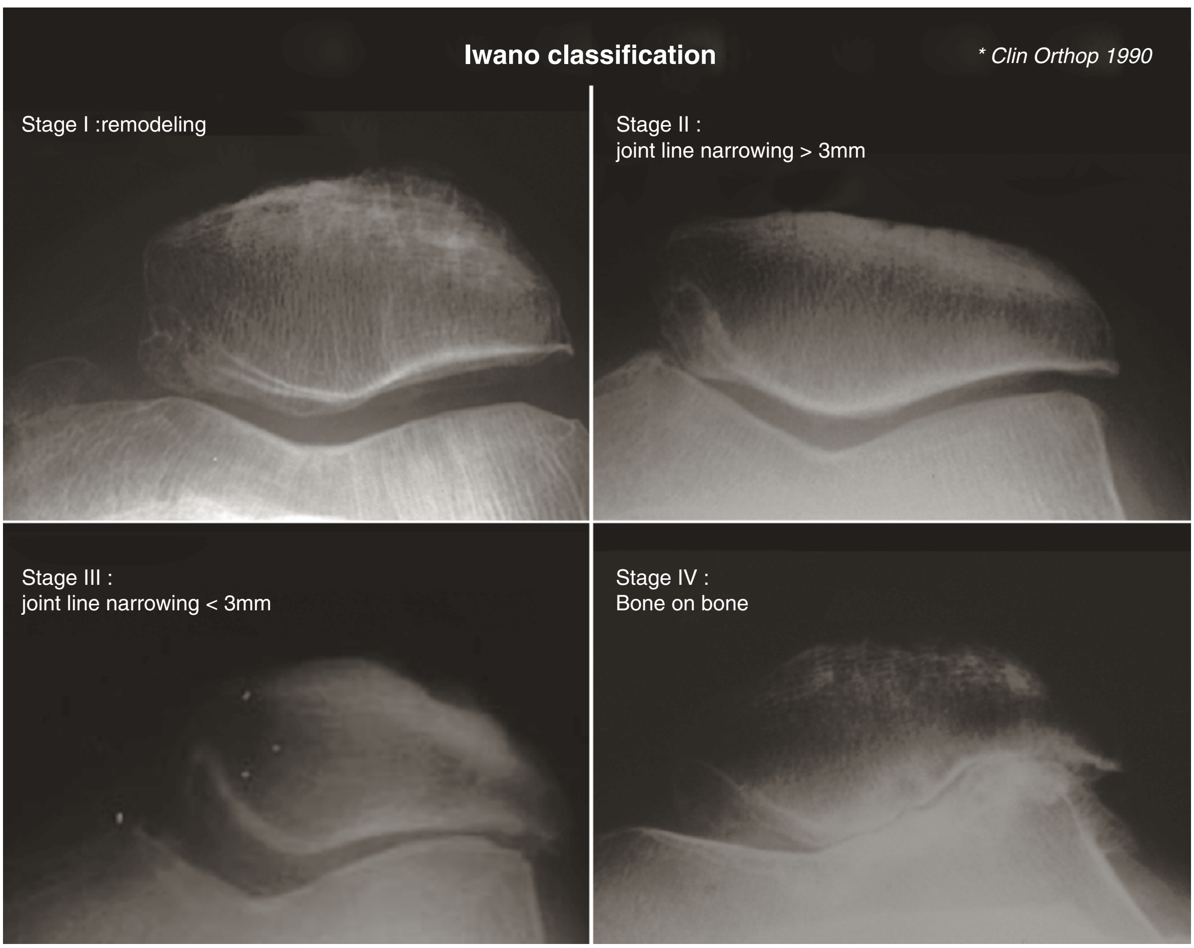


Fig. 6.12 Iwano classification for isolated patellofemoral arthritis [10]

6.6 Summary

1. Ask for AP weight-bearing x-rays and check:
   – Joint line narrowing in schuss position if over 50 years old or previous knee surgery.
2. Ask for true sagittal weight-bearing views (both condyles on the same line) and check:
   – Joint line narrowing
   – Antero-posterior translation
   – Tibial slope
   – Measure patellar height (using an identified patellar index)
   – Shape of trochlea (Dejour classification: crossing sign, supratrochlear spur, double contour)
   – Patellar tilt
3. Ask axial views at 30° of flexion and check
   – Shape of the patella (Wiberg's classification)
   – Measure sulcus angle
   – Joint line narrowing (Iwano classification)

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7 Patellar Height: Which Index?

J. Bruderer, E. Servien, and P. Neyret

7.1 Introduction

The definition of the patellar height has been the topic of numerous articles [1–4, 8, 15–19, 21] and still no consensus has been found when to use which index. The patellar height remains to be a widely discussed topic. The importance of a broadly accepted definition is evident, as the patellar height is part of defining anatomical and physiological factors of the extensor mechanism which again demands a standard evaluation.

Over the years regional preferences for a patella index have evolved; for example the Caton-Deschamps index [16] is most commonly used in France while the Insall-Salvati [8, 9, 15] index is widespread in the United-States. We propose to use the indices adapted to the clinical disorders and to the surgical procedures. The goal is to achieve a consensus in the application of the various indices. By creating an international standard we might simplify scientific discussions and the comparability of clinical and research results.

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7.2 Definition [1–5]

7.2.1 Patella Alta

A Patella Alta lies proximal to its normal position in the trochlea and is often accompanied by anatomical abnormalities such as trochlear dysplasia and an overlong patellar tendon. These abnormalities are often associated with pain and/or instability.

7.2.2 Patella Baja (Infera)

A Patella Baja lies distal to its normal position in the trochlea and is usually a post surgical condition.

7.2.3 Method of Evaluation

Over the years numerous indices have been described to measure and define the patellar height. According to the method of evaluation these indices can be classified into two groups [6, 23]:

1. Patella tibia indices
2. Patella femur or trochlea indices

Femur referencing indices are dependent on the angle of knee flexion [6, 22] because the patella moves compared to the femur whilst compared to the tibia the patella stays statically. The patellar tendon keeps the patella at the same distance to the tibia over the range of flexion from 20° onwards. Under 20° of flexion the tendon is slackened [17, 22] and so the measurement reliability is not very satisfying. We therefore do not recommend femur referencing indices except when the femoral groove is

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very dysplastic. In this case a trochlea referencing index may be useful to help understand the distance the patella needs to descend before it engages into the groove [22].

7.3 Indices

There are three major indices referencing to the tibia. These are the Insall-Salvati [8, 9], the Caton-Deschamps [16], and Blackburne and Peel [17] indices. They are all calculated on lateral radiographs obtained in a lying position in at least 20° of flexion, which ensures that the patellar tendon is under tension and so it develops its full length [17].

7.3.1 Patella Tibia Indices

7.3.1.1 Insall-Salvati [8, 9] (Fig. 7.1)

The index is the ratio of the length of the patellar tendon (LT) to the longest sagittal diameter of the patella (LP). Insall determined that this ratio (LT/LP) is normally 1. A ratio smaller than 0.8 was determined to indicate a Patella Baja. A ratio greater than 1.2 was determined to indicate a Patella Alta.

Advantage: This index is easily applied and independent of knee flexion as long as the patellar tendon is under tension. Normally the radiograph is taken between 20° and 70° of flexion [15, 17].

Disadvantage: A variable morphology of the patella, especially a long-nosed patella, can leave a Patella Alta undetected. The nose, the distal, nonarticulating facet, of the patella is not a good landmark for patellar height because anatomically and physiologically it is the position of the articular surface which determines the patellar height [10–13, 15, 17, 19]. Further this ratio depends on the tibial tubercle being at a standard distance below the tibial plateau [17]. There may be also difficulties defining the length of the patellar tendon: distally if the tibial tubercle is not prominent or after Osgood–Schlatter's disease or proximally after Larsen-Johansson's disease [17]. After surgical procedure like tibial tubercle transfer (TTT) to a more distal or proximal position the index will remain the same because the landmarks we use for this index will be retained unchanged.

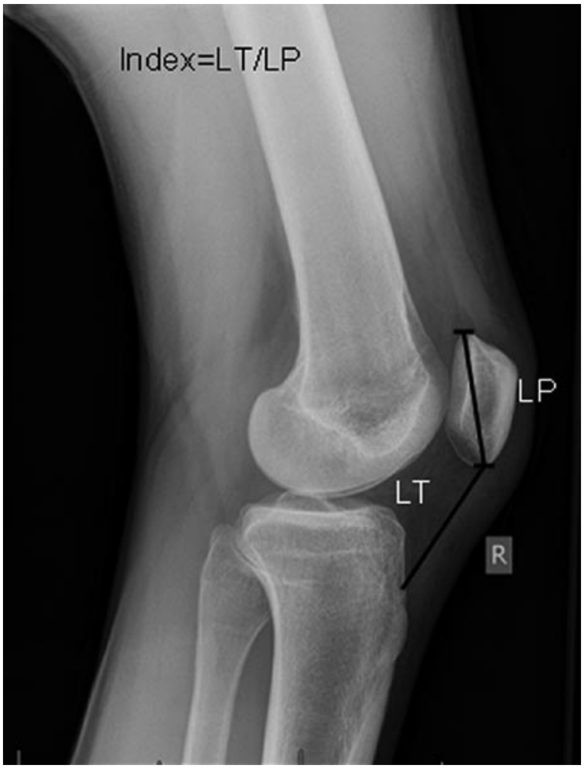

Fig. 7.1 Insall-Salvati index

7.3.1.2 Insall-Salvati Modified by Grelsamer [15] (Fig. 7.2)

The index is the ratio of the length of the patellar tendon (A) to the length of the articular surface of the patella (B). The ratio is calculated A/B. By choosing 2 as the cutoff point between a normal patella and Patella Alta Grelsamer sacrificed some sensitivity for the sake of clinical practicality. Taking the 95th percentile as the cutoff of normal values would have yielded 1.93 as the cutoff value which Grelsamer thought of as a very impractical number. A Patella Baja was not defined by the authors.

Advantage: This index is also easily applied and independent of knee flexion as long as the patellar tendon is under tension. Normally the radiograph is taken between 20° and 70° of flexion [15, 17]. It is recommended to use this index together with the Insall-Salvati index to detect a Patella Alta missed by the Insall-Salvati index [15].

Disadvantage: Because the patellar surface is used this index can be inaccurate in certain patellar

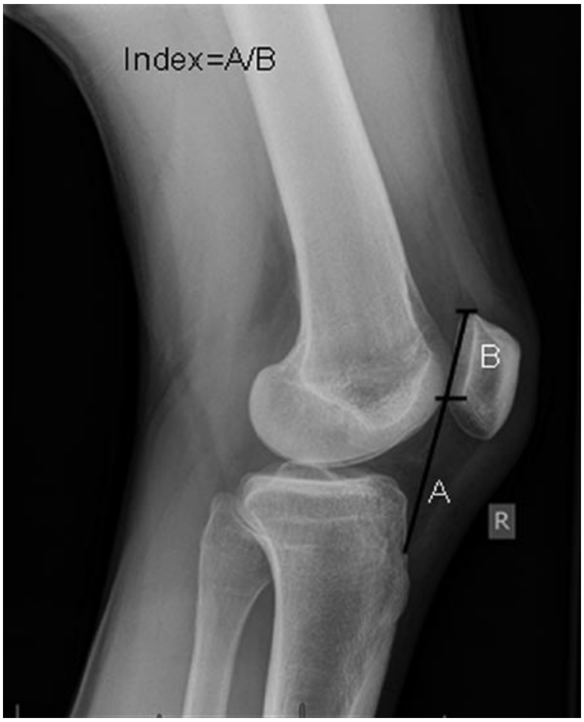

Fig. 7.2 Insall-Salvati modified by Gresalmer

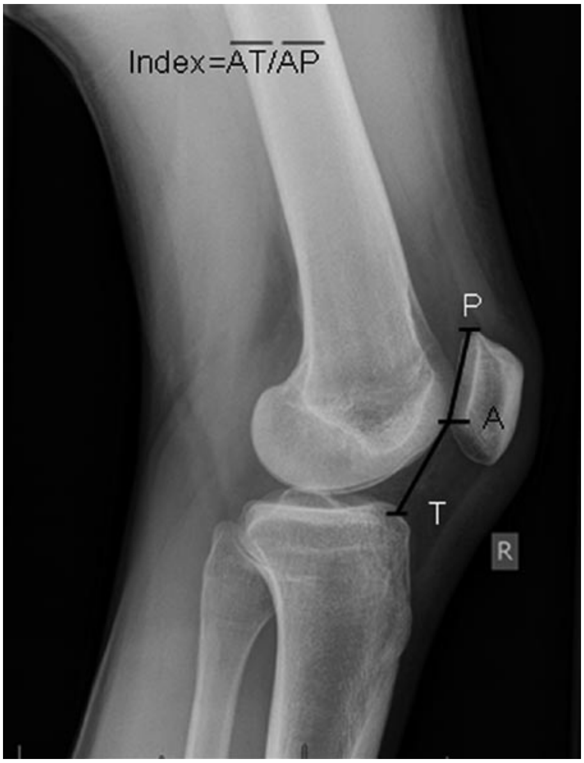

Fig. 7.3 Caton-Deschamps index

morphotypes with a short patellar surface [22]. Further this ratio has the same disadvantages referring to the tibial tubercle and the distal part of the patella as the Insall-Salvati index; namely the distance of the tibial tubercle to the tibial plateau [17] and defining the length of the patellar tendon [17]. Another drawback in common with the Insall-Salvati index is that after surgical intervention like TTT to a more distal or proximal position the index will not be affected.

7.3.1.3 Caton-Deschamps [16] (Fig. 7.3)

The index is the ratio of the distance from the lower edge of the articular surface of the patella to the antero-superior angle of the tibia outline (AT) to the length of the articular surface of the patella (AP). A ratio (AT/AP) of 0.6 and smaller was determined to indicate a Patella Baja. A ratio of 1.2 and greater was determined to indicate a Patella Alta.

Advantage: This index is independent of knee flexion as long as the patellar tendon is under tension. This is normally achieved at 30° of flexion [15–17]. A great advantage of this index is that it can be used quite simply for planning the amount of correction needed for a TTT. If AT = 45 mm and AP = 30 mm the ratio will be 45/30 = 1.5 which indicates a Patella Alta. Now if you want to position the tibial tubercle more distally you simply calculate 45 − 30 = 15. This is the amount of mm you will have to distalise the tubercle. For example if you want a ratio of 1 you will have to calculate 30/30 = 1, as AP (articular surface of the patella) cannot be changed only AT can be shortened and so always the difference between AT and AP will be the amount of correction required. The index can also be used to measure changes after high tibial osteotomy (HTO) because while the landmarks remain unchanged the distance between them changes and so does the ratio.

Disadvantage: According to the authors the antero-superior angle of the tibia is often difficult to identify in 10% of the cases [15, 22]. Then the Caton-Deschamps index converts into the de Carvalho index [21] which itself uses the most proximal aspect of the tibia. This aspect is also not quite straight forward as it shows a considerable patient variability [15]. Because the patellar surface is used this index can be inaccurate in certain patellar morphotypes with a short patellar surface [15, 22]. After tenodesis of the patellar tendon the ratio remains the same [23]. Besides patellofemoral disorders, this index cannot be used to measure the patella height after TKA.

7.3.1.4 Blackburne and Peel [17] (Fig. 7.4)

The index is the ratio of the length of the perpendicular line drawn from the inferior pole of the articular surface of the patella to the tangent of the tibial plateau (A) and the length of the articular surface of the patella (B). The ratio A/B provides a measure of patellar level. The normal ratio was defined as 0.8. In Patella Baja it is smaller than 0.5, in Patella Alta greater than 1.0.

Advantage: Again this index is independent of knee flexion as long as the patellar tendon is under tension. [15, 17] The authors measured in 30° of flexion. This index can be used to measure changes after TTT and HTO (if tibial slope is not changed) because while the landmarks remain unchanged the distance between them changes and so does the ratio.

Disadvantage: Because the patellar surface is used this index can be inaccurate in certain patellar morphotypes with a short patellar surface [22]. The tibial slope varies from patient to patient and also to draw a line along the tibial plateau can be quiet fiddly in some cases [22]. The bigger the slope the shorter the perpendicular line to the tangent of the tibial slope will be [15], in this case a Patella Alta can stay undetected.

7.3.2 Patella Femur or Trochlea Indices

7.3.2.1 Bernageau [18] (Fig. 7.5)

The index is represented by a radiograph with the knee in 0° extension with contraction of the quadriceps muscle. The distance (d) between the superior line of the trochlea (T) and the inferior edge of the articular surface of the patella(R) is measured. Bernageau determined

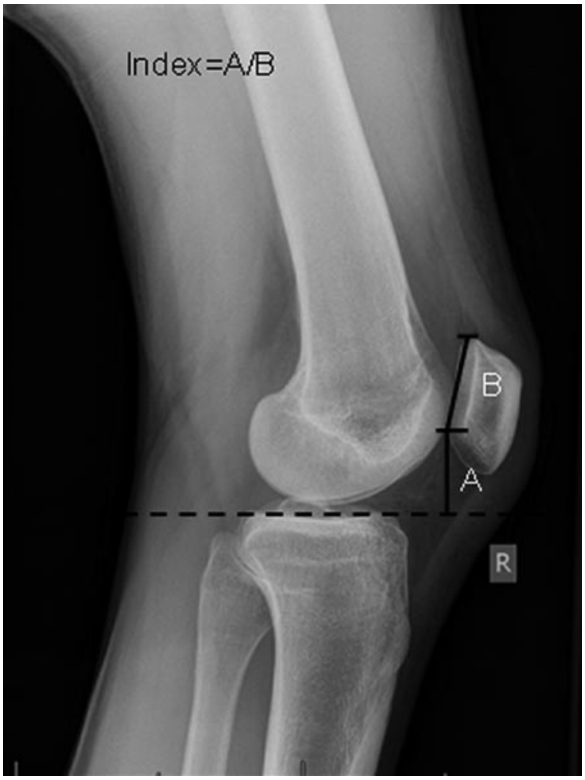

Fig. 7.4 Blackburne-Peel index

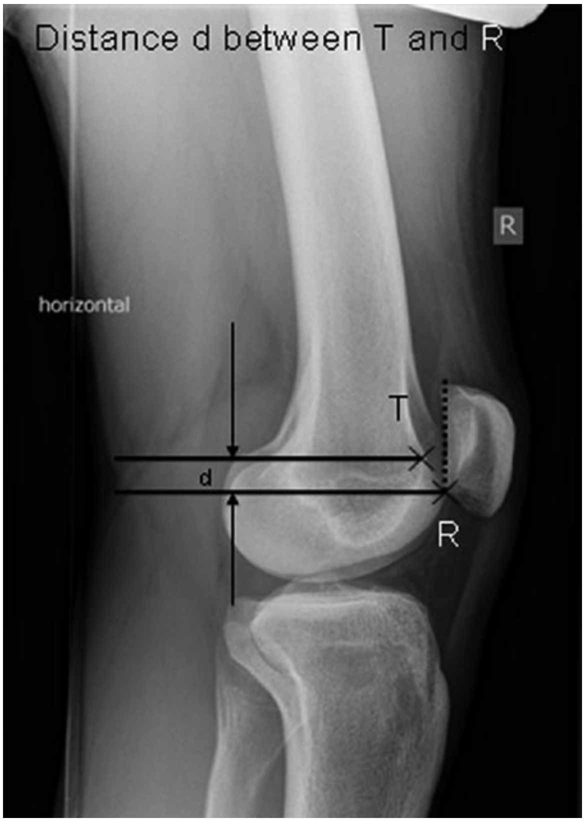

Fig. 7.5 Bernageau index

that T is approximately at the same height as R. Further he determined that if R is more than 6 mm above T we have a Patella Alta and if R is more than 6 mm beneath T we have a Patella Baja. Advantage: This index respects physiology as only the ratio between the articular surfaces is significant in determining the exact patellar height. For the same reasons as mentioned above this index can be used to measure changes after TTT.

Disadvantage: This index is difficult to measure because the landmarks are not always identified easily on the radiograph. Also it is difficult to objectify the contraction of the quadriceps and so the reliability of this measurement is uncertain [23]. After tenodesis of the patellar tendon the ratio remains the same [23].

7.3.2.2 Patellotrochlear Index by Biedert and Albrecht [19] (Fig. 7.6)

Using MRI this method documents the true articular cartilage relationship in the patellofemoral joint. The index is measured on sagital MR images with the knee in 0° extension, the foot in 15° external rotation and the quadriceps muscle consciously relaxed. The patellotrochlear index is the ratio baseline trochlea (BLt)/ baseline patella (BLp) calculated in percentages. Biedert and Albrecht determined that values more than 50% determine Patella Baja and values less than 12.5% determine Patella Alta.

Advantage: Exact measurement of the patellotrochlear articular correlation. Osseous morphotypes of the patella do not affect the ratio [14]. Length and shape of the trochlea are considered. Variations of the patellar tendon attachment areas are insignificant. No dependence on the position of the tibial tuberosity (Osgood–Schlatter's disease or following surgical interventions). Imaging in full 0° of extension is easier to obtain than in 30° of flexion. The inter- and intraobserver variability is low which was confirmed by low mean standard errors and high correlation coefficients [19].

Disadvantage: The difference between contracted and relaxed quadriceps muscle is not seen. The conscious muscle relaxation is difficult to control. Imaging in flexion has not yet been performed. No repeat MRIs have been performed on the same patient, the reliability of this measurement is still to be proven.

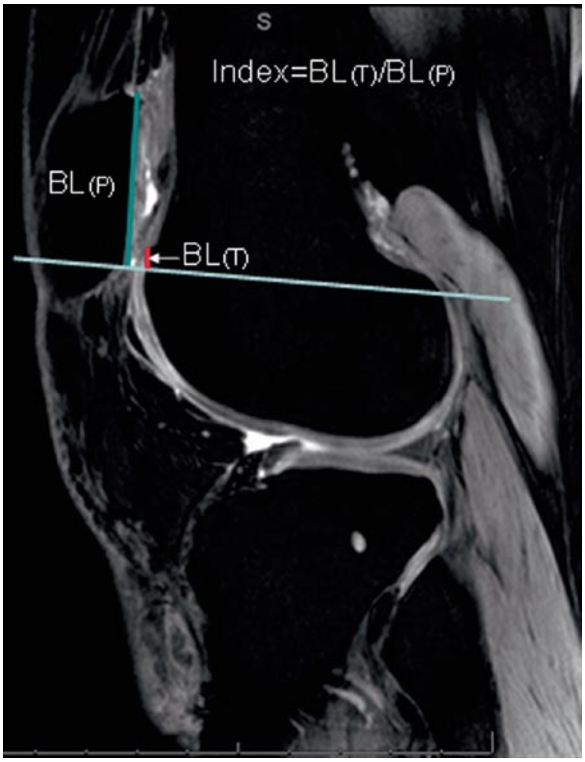

Fig. 7.6 Biedert and Albrecht index

Summarization of the above discussed indices in a table:

Indices	Patella Baja	Patella Alta
Insall-Salvati	<0.8	>1.2
Insall-Salvati modified by Grelsamer	No definition	>2
Caton-Deschamps	<0.6	>1.2
Blackburne and Peel	<0.5	>1.0
Bernageau	R more than 6 mm beneath T	R more than 6 mm above T
Biedert and Albrecht	>50%	<12.5%

7.4 Conclusion

There are still more indices which could be discussed. Nevertheless there is still no perfect index found. Each has its advantages and disadvantages. In case of patellofemoral disorders the orthopedic surgeon is interested in the position of the articular surface of the patella in relation to the trochlear cartilage [7, 14, 19, 20]. It appears that indices referencing to the trochlea respect this demand and furthermore they seem to be more anatomical and physiological [6, 22]. Also only MRIs can assess the true articulating surface. In some cases of dysplastic and distal trochleas MRIs will show a functional Patella Alta [22]; although a normal high patella was measured with a tibial referenced index.

One must also mention a slight drawback of indices using standard radiographs. Here we only document the osseous contours of the patellofemoral joint. Considering Bosshard et al. we do not measure the articular surface as there is no exact contour congruence of articular cartilage and subchondral bone of the patellofemoral joint both in the sagittal and axial plane [14, 19, 20].

Using a ratio which contains patellar size, patellar tendon length, or size of the articulation surface of the patella, we assume that these factors are always in the same proportions to body height which they are not [10–12, 24]. This may be a drawback comparing one patient with another; on the contrary it will have no influence comparing the patellar height pre- and postoperatively on the same patient if respecting the mentioned disadvantages.

Under consideration of the discussed indices we may propose the following approach. In a first step conventional radiographs in two planes are performed. To measure the patella height routinely we suggest using the Caton-Deschamps index because in our opinion it is the most convenient for clinical investigations as already proposed in Grelsamer's study [15]. In a second step if MRI is available we recommend to complete the analysis of the patellar height by applying the Biedert and Albrecht index [19] or by measuring the length of the patellar tendon because the primary abnormality in Patella Alta is one of a long patellar tendon [24]. Before the patient undergoes surgical intervention we have to contemplate which indices can be applied best pre- and postoperatively because the surgery may influence the accuracy of the index used. In this manner we can measure the true change in patellar height postoperatively.

In our opinion there are indices more suitable for diagnosis such as Insall-Salvati combined with Insall-Salvati modified by Grelsamer, Bernageau and Biedert, and Albrecht; others such as Caton-Deschamps and Blackburne and Peel are more suitable for planning and controlling surgical intervention. The task of the orthopedic surgeon is to combine the different indices in a relevant way. This will help him to analyze the patellofemoral disorders and to plan the surgical procedure.

7.5 Summary

- Numerous indices have been described to measure and define the patellar height.
- These indices can be classified into two groups: patella tibia indices and patella femur indices. There are three major indices referencing to the tibia, the Insall-Salvati, the Caton-Deschamps, and Blackburne and Peel indices.
  - They are all calculated on lateral radiographs obtained in a lying position in at least 20° of flexion.
- The Bernageau trochlea index is represented by a radiograph with the knee in 0° extension with contraction of the quadriceps muscle.
- In our opinion there are indices more suitable for diagnosis such as Insall-Salvati combined with Insall-Salvati modified by Grelsamer, Bernageau and Biedert, and Albrecht; others such as Caton-Deschamps and Blackburne and Peel are more suitable for planning and controlling surgical intervention.

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8 Stress Radiographs in the Diagnosis of Patellofemoral Instability

Robert Teitge

Importance: Stress radiographs provide the only available objective measurement of PF joint instability.

The diagnosis of joint instability is only confirmed by demonstrating the pathological separation of joint surfaces. This is normally accomplished by applying stress to the joint and demonstrating an abnormal displacement of the two surfaces. Measuring this displacement is needed to document the test result. Nonspecific criteria such as pain or apprehension are frequently used as circumstantial evidence for making the diagnosis of joint instability. Pain and apprehension may be the result of conditions not related to joint instability such as arthrosis. A demonstration of excess displacement is evidence of instability but the amount of displacement should be documented by a valid measurement tool.

Instability is a pathological separation of the bones (the patella from the trochlea) which causes a loss of joint function. This loss of function may be due to pain or due to mechanical collapse because the muscle force lever arm is lost or most often both. The majority of imaging descriptions of unstable patellofemoral joints rely on demonstrating bone or cartilage features which have been associated with instability. These images however seldom actually demonstrate the pathological displacement needed to verify instability. Both the normal relationships of the patella to the trochlear groove of the femur and the abnormal displacement must be defined. A system to measure the difference between normal position and displaced position must be developed. Radiographic methods of stress and unstressed joints have classically been used as a measure of displacement and thus of instability [2–5, 8, 9] (Fig. 8.1).

The position in which the joint is placed while stress is applied is variable and determined by the examiner based on what is desired to be demonstrated. For example, anterior stress of the knee to demonstrate anterior cruciate ligament insufficiency may be made with the knee at 90° of flexion (the anterior drawer test) or 30° of flexion (the Lachman Test) [5]. Knowledge of any

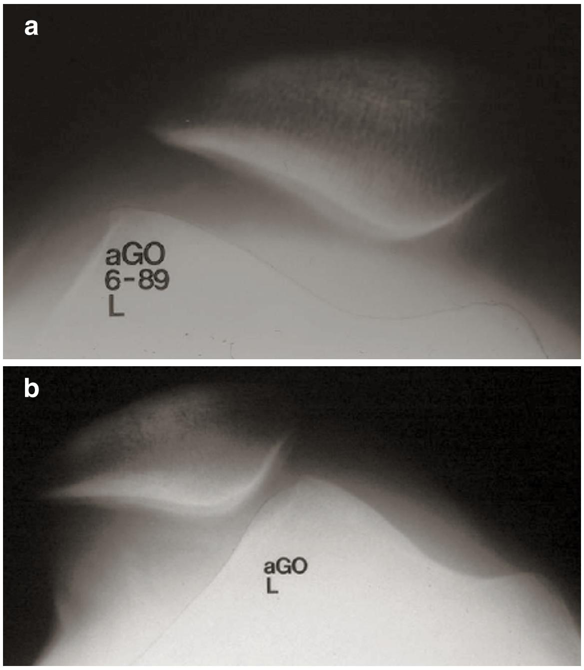

Fig. 8.1 (**a**) Axial view of patient with anterior knee pain and apprehension and increased lateral excursion with lateral patellar stress. (**b**) Lateral stress radiograph of the patient with anterior knee pain, apprehension and increased lateral patellar excursion on stress examination. The radiograph clearly demonstrates complete lateral dislocation not recognized in (**a**)

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clinical significance in the differences of obtaining patellar stress views in different flexion position is unknown.

Patellar instability most often occurs in the first 30° of knee flexion. An axial (skyline or sunrise) view of the PF joint cannot usually be obtained without flexing the knee to at least 30° as the x-ray tube and the x-ray plate cannot be pressed sufficiently into the thigh or tibia.

8.1 Technique of Obtaining Patellofemoral Stress Radiographs

Technique: Flex the knee to 30°, stabilize the femur, usually with a hand. Apply a force to the medial side of the patella to push it laterally, obtain the radiograph. To measure medial excursion, place the stabilizing hand on the medial side of the distal femur apply the force to push the patella in the medial direction (Fig. 8.2). Take axial radiographs both with and without stress to measure the displacement (Fig. 8.3). Take axial radiographs of the normal knee (if the complaint is unilateral) to obtain a comparison. Apply stress to both the medial side of the patella to test for lateral instability and to the lateral side of the patella to test for medial instability.

To measure displacement I use the method described by Laurin [6] of drawing a tangent line across the anterior surface of the femoral condyles and a second line perpendicular to the tangent line and located at the point of contact of the tangent line (Fig. 8.4).

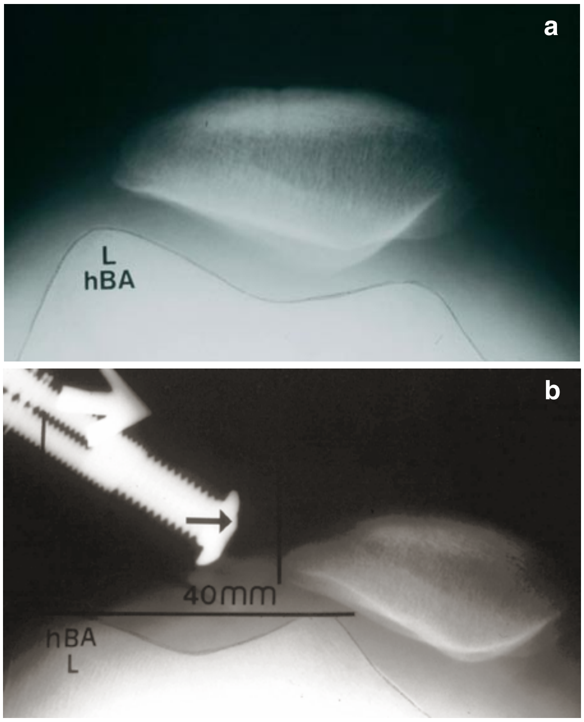

Fig. 8.2 (**a**) Axial view of patella in patient with “dashboard injury” much worse after lateral retinacular release. (**b**) Stress radiograph of the PF joint shows complete medial dislocation of the patella and when compared with the opposite normal knee a 24 mm increase in medial excursion

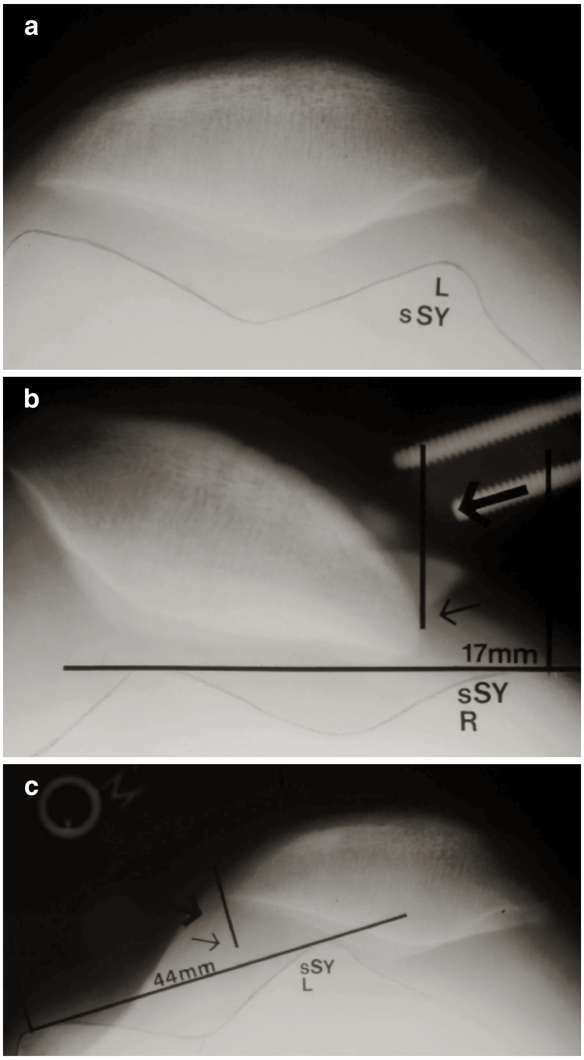

Fig. 8.3 (**a**) Axial view of PF joint in a patient who had undergone nine surgeries for patellar instability. (**b**) Medial stress radiograph of the asymtomatic PF joint, showing an excursion of 17 mm with the median ridge of the patella just ready to cross the anterior surface of the medial trochlear condyle. (**c**) Medial stress radiograph of the symptomatic knee demonstrates 44 mm of excursion with a medial dislocation of the patella. The increase from the asymptomatic (normal) side is 27 mm

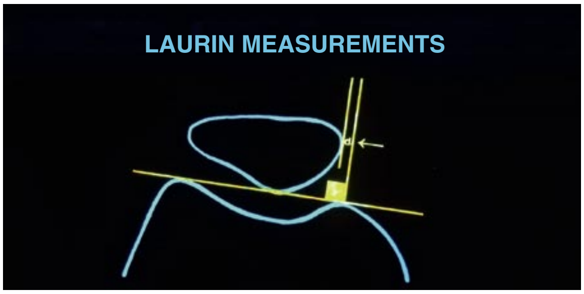

Fig. 8.4 Laurin Measurement. A tangent is drawn across the anterior surface of the trochlear condyles. A perpendicular is drawn from the tangent line at the point of contact with the condyle. The distance between this perpendicular line and the edge of the patella may be compared both with stress applied and without stress applied

The author uses this technique is every case of suspected instability. Suspected instability is when there is apprehension on stress examination, excess patellar mobility on stress examination or a history of dislocation or slipping out of the patella. There are cases in the clinic where the apprehension is too great or pain or anxiety is too great to obtain meaningful displacement before the patient tenses the quadriceps in a protective maneuver. In these instances only an examination under anesthesia will yield a proper evaluation. Currently, I obtain radiographs under anesthesia in every surgical case in which patellar instability is suspected (Fig. 8.5).

In the operating theater under anesthesia, the image intensifier is placed horizontal and the knee joint is flexed 30° so that an axial view is obtained. Both right and left knee stress radiographs are always taken.

It is convenient to have a pushing device such as a padded curved block of wood to more easily grip the side of the patella. A device which measures the applied force has been manufactured by Medmetric®, although it may no longer be available. This device measures the force produced and thus allows an equal force to be applied to both knees.

A study to measure different displacement differences with different degrees of trochlear flattening (dysplasia) or different degrees of patellar height (Alta or Baja), or different degrees of knee flexion has not been performed. A study of different degrees of displacement in patients with different degrees of soft tissue laxity has not been made. Therefore, the absolute displacement measures are not meaningful. A device to measure patellar displacement without radiographs has been developed [5,7], but has not been validated.

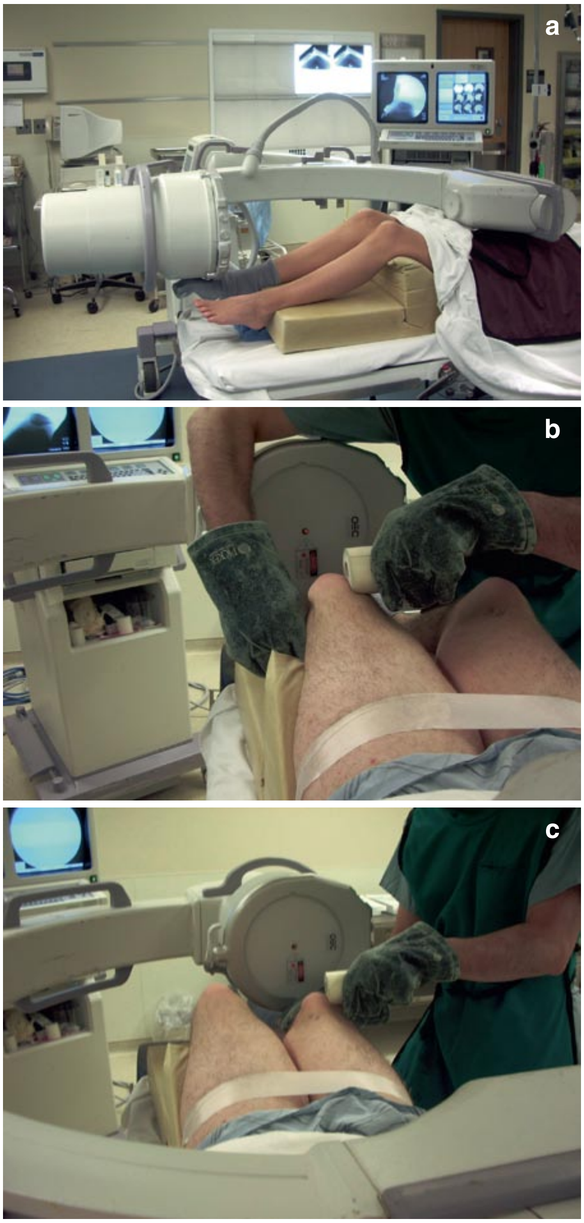

Fig. 8.5 (**a**) The image intensifier is placed in the horizontal position and the knees are flexed about 30°–40° for an intraoperative stress radiograph. (**b**) For a lateral stress radiograph, the knee is stabilized with one hand to prevent external limb rotation and a force is applied to the medial side of the patella, while the radiograph is taken. (**c**) For a medial stress radiograph, the knee is stabilized medially to prevent rotation while stress is applied to the lateral side of the patella

8.2 Measurements of Patellar Displacement

A study was obtained to compare the difference in displacement in the right and left knees in patients with unilateral symptoms consistent with instability [10]. Four groups of subjects were studied.

1. Normal controls
2. Lateral dislocation
3. Medial dislocation
4. Multidirectional instability

These patient groups were compromised of (1) normal asymptomatic individuals, (2) patients with a history of lateral dislocation, the lateral instability group, (3) patients with a history of pain which developed after a lateral retinacular release had been performed for anterior knee pain and in whom apprehension and or pain was provoked when a medial displacement maneuver was performed and in whom medial patellar displacement was deemed greater than what was present in the contralateral asymptomatic knee. These patients with medial dislocation make up the medial dislocation group (4), patients who were worse after a lateral retinacular release performed for a diagnosis of lateral patellar instability and in whom a patellar stress examination demonstrating apprehension and or pain and increased patellar displacement both in the medial and lateral direction when compared with the normal (asymptomatic) side. These patients made up the multidirectional group.

Comparison of the patellar displacement in the two knees in these four patient groups demonstrated definite differences in groups. The mean measurement of right to left displacement differences were:

	Lateral stress Right/left (mm)	Medial stress Right/left (mm)
Normal group	1.5	1.2
Lateral instability	7.5*	0.1
Medial instability	0.5	10.3*
Multidirectional instability	9.5*	10.8*

*$p < .0001$

It is seen that the right and left knees of normal subjects have similar degrees of patellar excursion. Those with lateral dislocation have a significant increase in lateral excursion (7.5 vs 1.5 mm). Those with medial dislocation have a significant increase in medial excursion (10.3 vs 1.2 mm) Those in the multidirectional group have a significant increase in both the lateral direction (9.5 vs 1.5 mm) and in the medial direction (10.8 vs 1.2 mm). It is noted that after a lateral release lateral excursion exceeds that seen in the lateral dislocation group without lateral release.

In conclusion: If two standard deviations from the measurements obtained are added, it is concluded that a 4 mm difference between the displacement of the patella on the asymptomatic side and the symptomatic was significant for instability ($p < .0001$).

A radiograph taken with the patella in a position of maximum side displacement compared with the radiograph if the stressed asymptomatic patella was more significant in the diagnosis of patellar instability than measurements of Merchant congruence angle, sulcus angle [1], lateral patellofemoral angle, lateral to medial condylar height ratio [1], or patella height.

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9 Computed Tomography and Arthro-CT Scan in Patellofemoral Disorders

P. R. Saggin, David Dejour, X. Meyer, and T. Tavernier

9.1 Introduction

The computed tomography (CT) scan has great importance in the analysis of the patellofemoral joint [17]. It shows perfectly the bone morphology of the knee and allows the measurement of many knee parameters [1, 6, 7, 13, 14]. Some criticism exists about it not being able to evaluate the cartilage, but this can be solved if a contrast protocol (intra-articular) is used with the CT (arthro-CT).

The CT scan was the first exam to establish some of the pathological threshold levels for the objective patellar dislocation population [6, 8], giving some guidelines for surgical correction in terms of trochlear morphology, malalignment, patellar tilt and rotational abnormalities.

Many parameters observed in CT images are similar to those observed in X-ray axial views. One of CT's contribution is the ability to produce such images in full knee extension. This is particularly helpful when considering patellofemoral tilt or subluxation, because the flexion of the knee leads the patella to engage the trochlear sulcus, thus correcting (or at least reducing) these abnormalities. It also provides a constant reference for measures: the posterior femoral condyles, otherwise not visualized in axial views.

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9.2 The Protocol (Lyon's Protocol)

The protocol is used to obtain information regarding patellofemoral instability.

9.2.1 *Image Acquisition: Volumic Acquisition*

The patient is installed in supine position, lying on a rigid table, with the knee in full extension and the patella strictly anterior, "looking to the roof." This usually places the feet in 15° of external rotation. The feet are then fixed with straps to the table (Fig. 9.1).

Image acquisition is performed for hip, ankle and knee, the last with and without quadriceps contraction Fig. 9.2. The following protocol is applied:
Hip:

- High resolution filter
- Sequential acquisition
- Eight to 12 slices
- Slices thickness 2.5 mm
- 120 kV, 200 mA

Knee (quadriceps contracted):

- High resolution filter
- Sequential acquisition
- Eight to 12 slices
- Slices thickness 2.5 mm
- 120 kV, 200 mA

Ankle:

- High resolution filter
- Sequential acquisition
- Four to eight slices

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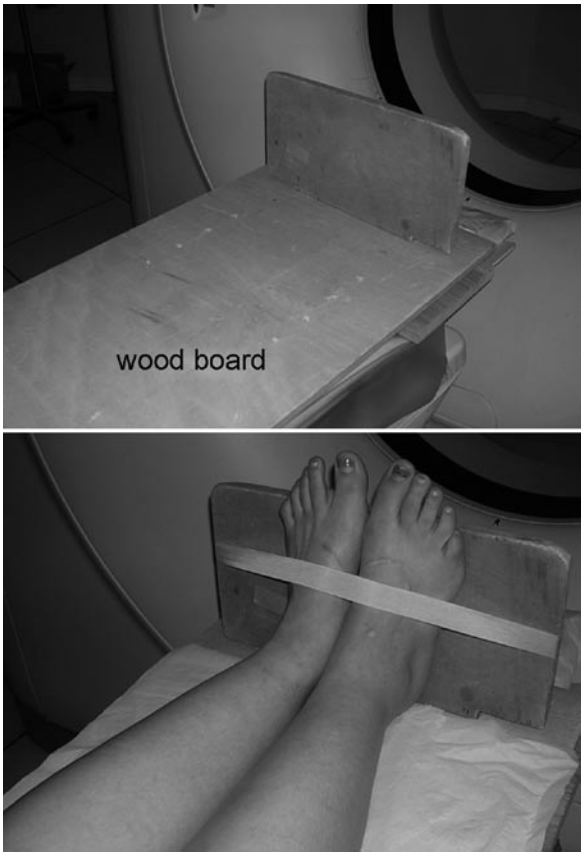

Fig. 9.1 The patient is installed on a wood board with the feet fixed at 15° external rotation

- Slices thickness 2.5 mm
- 120 kV, 200 mA

Knee-specific volumic acquisition:

- High resolution filter
- Slices thickness 1.4/0.7 mm
- 140 kV, 300 mA

For measurements, some specific axial sections should be acquired:

- A section through both the femoral necks at the top of the trochanteric fossa.
- A section through the center of the patella, through its larger transverse axis.
- A section through the proximal trochlea (where the intercondylar notch looks like a roman arch, and there is a slight condensation of the trochlear lateral facet subchondral bone).
- A section through the proximal tibial epiphysis, just beneath the articular surface.

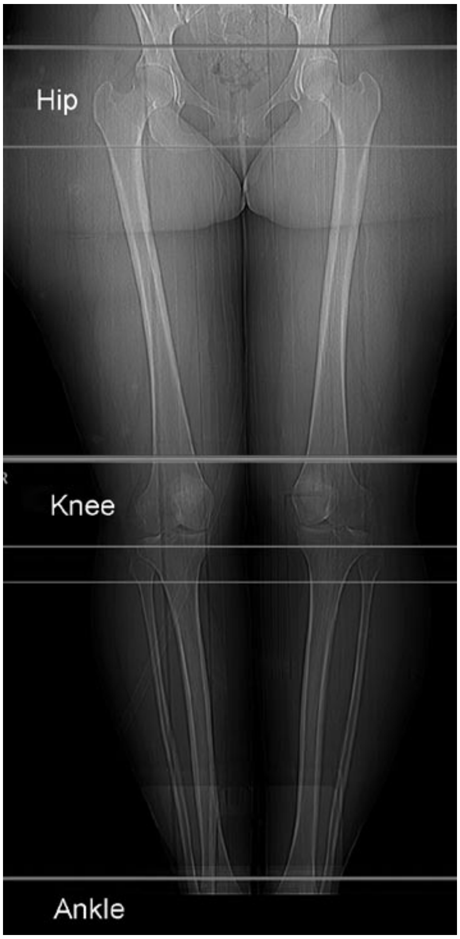

Fig. 9.2 A topogram is done to determine the different acquisition on the hip, knee and ankle

- A section through the proximal part of the tibial tuberosity.
- A section near the ankle joint, at the base of the malleoli.

9.2.2 CT Scan Measurement and Analysis

Once the images are acquired, the measures are performed. Henri Dejour et al. [5, 6], analyzing images of 143 knees operated on for symptomatic patellar instability and 27 control knee scans, described the methods of measurement, normal and pathological values, and determined some pathological thresholds for the patellar dislocation population. The CT scan also has the advantage to show both knees and allow a bilateral analysis of this congenital disease. A comparison between the involved knee and the control knee is interesting.

9.3 Tibial Tubercle-Trochlear Groove Distance

The tibial tubercle-trochlear groove distance (TT-TG) has been described first by Goutallier [9] and Bernageau in 1978 on X-ray axial views at 30° of knee flexion. This distance was able to quantify the coronal alignment of the extensor mechanism, or what is called in clinical evaluation the "Q angle." In 1987, Henri Dejour and his team adapted this measurement to the CT scan. At the beginning, the CT scan was done with 15° of knee flexion and in full extension. It appeared to the authors that the measurements in full extension were more reliable, did not depend on the technician ability, and were not really different from slight flexion. Thus the protocol was defined with extension measures.

Two specific cuts are necessary (Fig. 9.3). The first is the one through the proximal trochlea. It is call the "reference cut". It is the first cut with cartilage, identified by a slight condensation of the lateral facet or by the shape of the notch which is well rounded like a roman arch. The second cut is the one which goes through the proximal part of the tibial tubercle. These two cuts are then superimposed. The deepest point of the trochlear groove and the central point of the tibial tubercle are projected on a line tangential to the posterior condyles. The distance between both points is measured. The normal value in the control population is 12 mm; in the objective patellar dislocation population (at least one true patellar dislocation) this value is greater than to 20 mm in 56% of the cases. This constitutes the pathological threshold where an indication of tibial tubercle medialization could be proposed.

Another method of measurement has been proposed by Wymega [13]. In this technique the trochlear groove image is not projected upon the tibial tuberosity image, but the lines of the trochlear groove are copied onto the tibial tubercle image using the readily available Impax software. No specific adjustments to the software are necessary (Impax for Radiology, Agfa-Gevaert, Agfa HealthCare, Mortsel, Belgium). These lines are then used to measure the tibial tuberosity-trochlear groove distance with increased reliability.

9.4 Patellar Tilt

The tilt is measured using two cuts [5, 6]. The first is the reference trochlear cut (the same used for TT-TG). The second cut goes through the larger axis of the patella. A line is drawn going through the transverse axis of the patella. Another line is tangential to the posterior femoral condyles. The angle formed between these two lines is the patellar tilt angle (Fig. 9.4).

The tilt is measured with and without quadriceps contraction, giving dynamic information about the

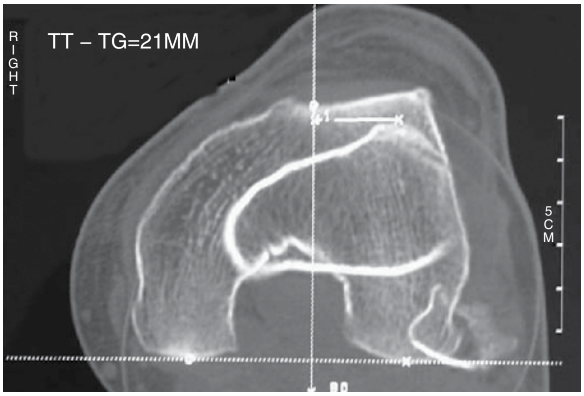

Fig. 9.3 The distance between tibial tubercle and trochlear groove (TT-TG) in a superimposition of two cuts, one going through the reference trochlear cut (roman arch) and other going through the tibial tubercle

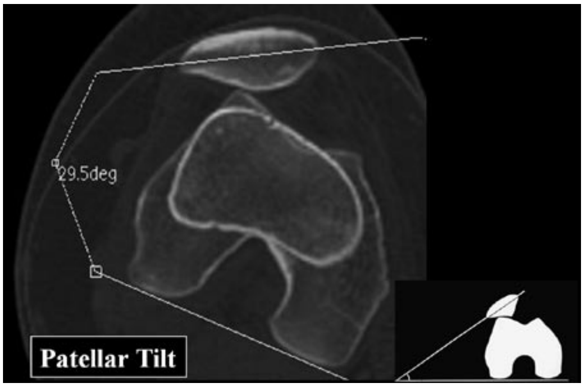

Fig. 9.4 The patellar tilt is the angle between the transverse axis of the patella and the posterior femoral condyles. It is done with and without quadriceps contraction

stability of the patella. Eighty three percent of the objective patellar dislocation group have a patellar tilt greater than to 20° compared to 3% in the reference normal group [5, 6]. If instead of using only the relaxed quadriceps measure a mean is calculated between the measures performed relaxed and in contraction, and the threshold value remain the same, sensitivity and specificity are improved. Ninety percent of the objective patellar dislocation population have presented values over 20°, while only the same is true for only 3% of controls.

Patellar tilt was previously considered a direct consequence of vastus medialis dysplasia, as in dysplasia the insertion of this muscle is higher and more vertical, with no oblique fibers. More recently [3, 4], it has been shown that there is a high statistical correlation between the type of trochlear dysplasia and the patellar tilt: the greater the trochlear dysplasia the higher the patellar tilt.

9.5 Femoral Anteversion

Two cuts are superimposed. The trochlear reference cut and the posterior condyles tangent line are again used. In the femoral neck section, a line is drawn joining the center of the femoral head and the center of the femoral neck (Fig. 9.5). This line and the posterior condyles line form the femoral anteversion angle [15, 18].

Femoral anteversion mean value is 10.8 ± 8.7° in controls, while 15.6±9° in objective patellar instability patients. There is some overhanging of values in both groups, and no statistical threshold could be set.

9.6 External Tibial Torsion

The proximal (beneath the articular surface) and distal (ankle) tibial cuts are superimposed. One line is drawn tangent to the posterior aspect of the plateau, and other through the bimalleolar axis. The angle between them is measured [11, 12, 19] (Fig. 9.6).

Mean tibial external rotation was 33° in the objective patellar instability group and 35° in the control group. Too much variation was present, and no particular significance could be demonstrated.

9.7 Other Features of CT Imaging

9.7.1 Trochlear Analysis

CT adds information to the trochlear shape analysis performed with x-rays. CT scan allows one to make a precise analysis of the trochlear morphology. The slices have to be done every 1.4 mm to have higher precision. The analysis shows the bony shape and the relation between the lateral and the medial facets. This analysis helps to grade the trochlear dysplasia and to analyze the supra trochlear area. Carillon [2] did a study about the lateral trochlear inclination of the lateral facet on magnetic resonance images. He showed statistical difference between the control population

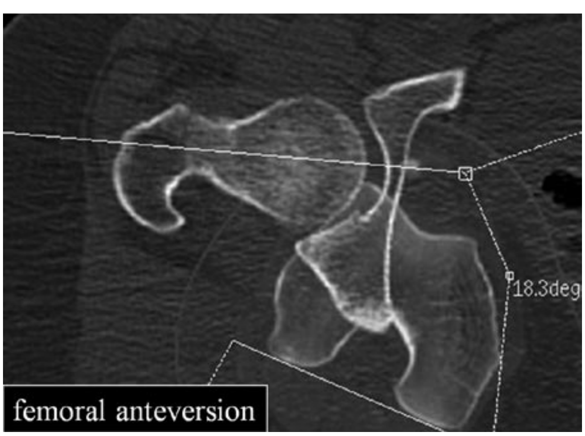

Fig. 9.5 Femoral anteversion

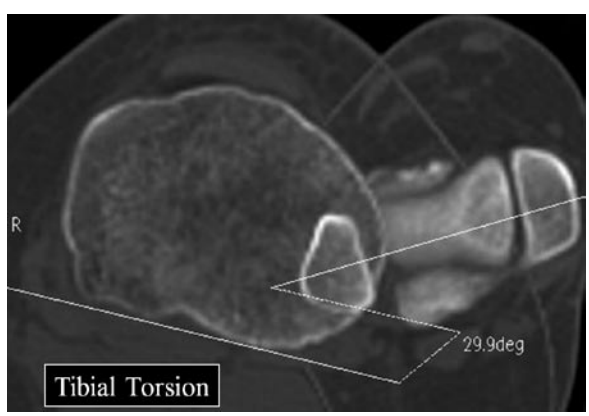

Fig. 9.6 External tibial torsion

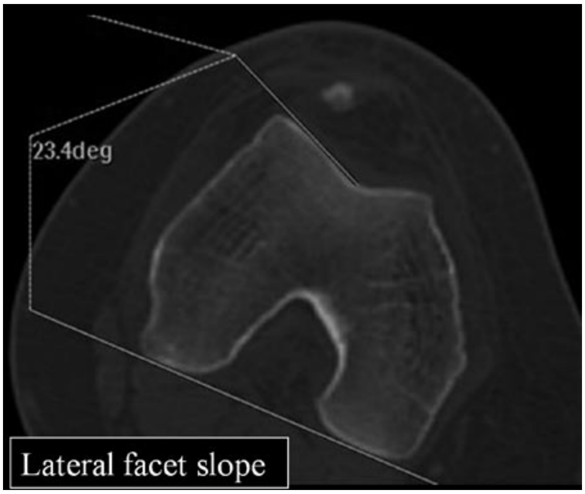

Fig. 9.7 The threshold for the lateral facet slope is 11° it determines the trochlear dysplasia on the reference cut

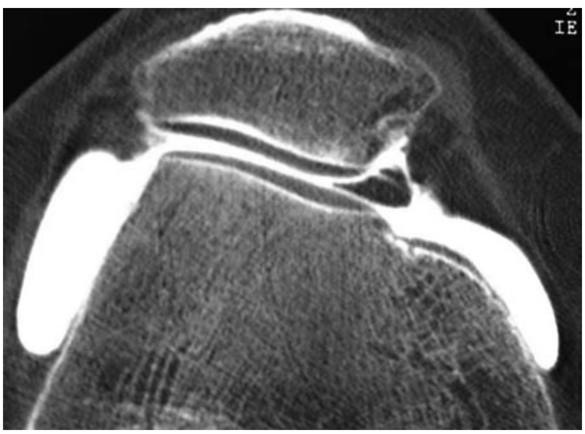

Fig. 9.8 In case of trochlear dysplasia (flat or convex) the cartilage matches perfectly the bony contour

and the dysplastic population. The threshold value was fixed at 11°. This measurement can also be done on the CT scan with the same value (Fig. 9.7).

Staubli [16] showed that there was a mismatch between bony and cartilaginous shapes using the MR arthrotomography. This analysis remains true when the trochlea is not dysplastic but when the trochlea is flat or convex the matching between bone and cartilage is perfect (Fig. 9.8).

Three-dimensional (3D) images are now possible. They show the global aspect of the bony structures but they give only a subjective approach and are not useful for determining the amount of correction the surgeon should do (Fig. 9.9).

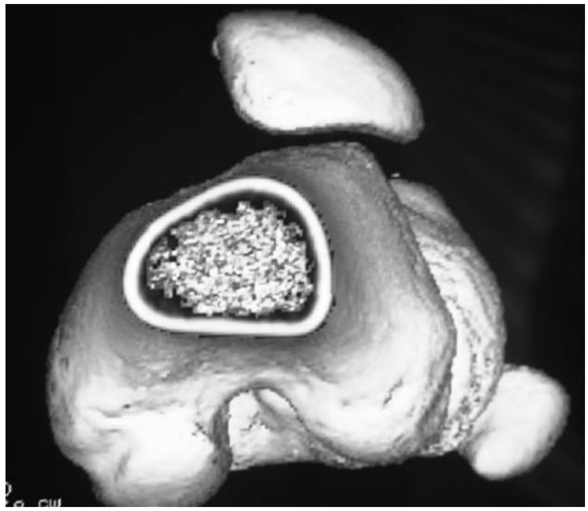

Fig. 9.9 Three-dimensional (3D) images visualize the abnormalities but are not able to quantify them

9.7.2 Cartilage Analysis and Arthro-CT

Ordinary CT scans do not provide much information about cartilage status, unless advanced osteoarthritis is established. However, cartilage can be well analysed if intra-articular contrast is injected. Double-contrast methods utilize room air and positive contrast material. Two principles should be followed during double-contrast arthro-CT examination: first, an adequate amount of air is essential to separate the articular cartilage from the surrounding soft tissues. Second an adequate volume of positive contrast material is essential. The joint is injected with 10 cc of iodinated contrast with a concentration of 320 mmol/L, the volumetric acquisition needs thinner slices (0.5mm).

The use of the arthro-CT allows the identification of several types of chondral lesions from stage I to IV: fissures, fibrillation, ulcers and erosion are noted (Fig. 9.10). Excessive amounts of positive contrast material have a tendency to make the edge of the cartilage obscure, thus making fibrillation diagnosis very difficult. Conversely, if too little contrast is used, fibrillation and ulcers cannot be observed. Imbibition of contrast material is a sign of cartilage fibrillation. Decreased CT value of the cartilage, increased thickness at a noncontact area, and decreased thickness at a contact area may indicate the possibility of cartilage softening. Overall cartilage thickness can also be

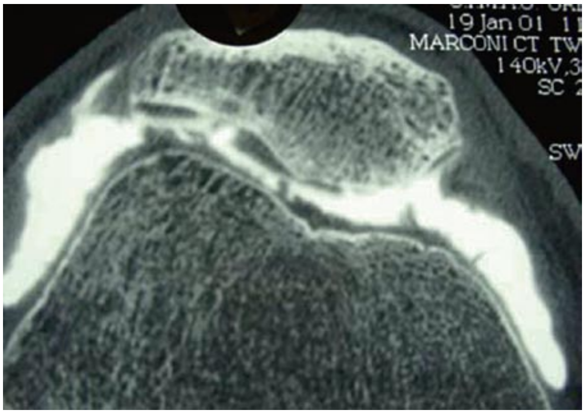

Fig. 9.10 Arthro-CT is perfect exam to grade the cartilage damage; it could be coupled to all the CT scan measurement

assessed. Ihara [10] has shown that for patellofemoral cartilage, when CT findings were compared with arthroscopy or arthrotomy, CT diagnosis was accurate in 68 of 70 knees (97.1%).

It is also useful for the diagnosis of plicae syndromes and for detection of loose bodies.

9.7.3 CT and X-Ray Irradiation

Lower limb CT scan has a 600 mGy/cm DLP, 100 are for the pelvis and 500 for the knee. The knee is not a radio-sensible area and the irradiation remains low. It is less than a long standing X-ray in which there is 800 DLP irradiation and it is equal to a 4 days stay in a ski area. Thus, this argument should not be used to ban this useful exam.

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MRI Analysis of Patellla Instability Factors

10

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10.1 Static Analysis of Instability Factors

10.1.1 Introduction

Different methods of evaluation by x-rays [1, 3, 8, 10, 15, 20, 21, 24] and CT scan [9, 11, 13, 14, 22, 27, 29, 40] were proposed in the literature in order to define the various factors responsible for patellar instability or pain.

Objective and potential patellar instabilities, according to classification of Lyonnaises school, are determined by four principal factors of instability:

(a) Trochlear dysplasia
(b) Pathological TT-TG value
(c) Patella tilt
(d) Patella Alta

Each of these factors are defined by parameters measured on lateral or axial view x-rays and/or on CT scan.

Classification of trochlear dysplasia was first proposed by Henry Dejour [10] on lateral view x-rays and later integrated by information from CT scan examination in axial projection.

TT-TG length was developed by Goutallier et al. [11] on CT scan of the extended knee joint in an axial view and its normal value was defined between the range of 1 ± 0.2 mm.

Different radiographic indices were proposed to study the height of the patella on lateral x-rays [3, 8, 15]. Its normal value is conventionally defined as 1 ± 0.2 mm.

Patellar tilt has been studied radiographically [20] in the past and more recently by CT without and with quadriceps contraction [29].

MRI has been considered more useful in defining cartilage status of the patellofemoral joint or to evaluate dynamically patellofemoral tracking abnormalities [4, 19, 34] than to measure parameters which could determine patellar instability.

The proper advantages of MRI are:

- Knee evaluation in full extension (like CT)
- Absence of ionizing radiation
- Information concerning the other osseous, cartilaginous and soft tissues structures of the knee to detect associated lesions or damages

MRI is like a CT scan, but with thinner slices and without ionizing radiation, it can show with a higher resolution the cartilage surface of the PF joint and can allow measurements at this level (Fig. 10.1) and not only at subchondral bone (Fig. 10.2) cuts as in radiographic examination.

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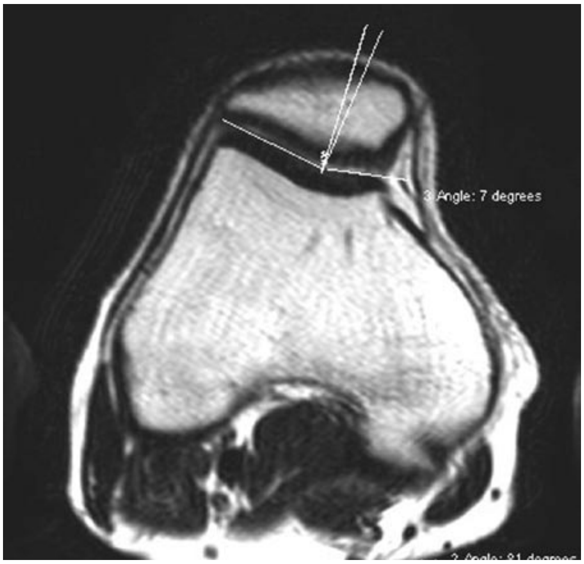

Fig. 10.1 TSE-T2 angles measurements at cartilaginous level

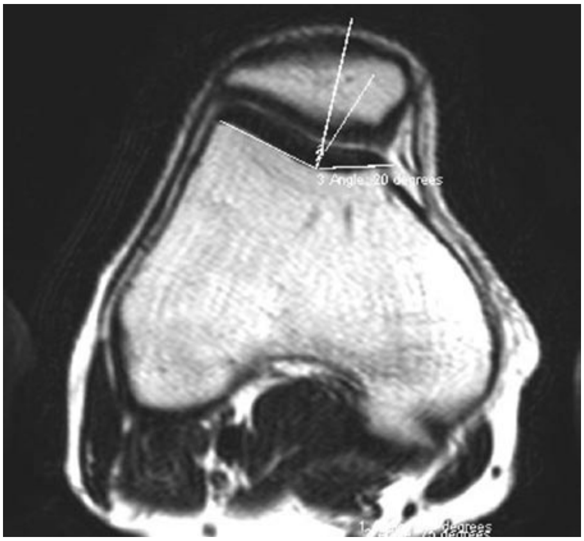

Fig. 10.2 TSE-T2 angles measurements at bony level

Muellner et al. [26] have compared outcomes of sulcus angle, congruence angle and lateral patellofemoral angle measured by MRI in 20 volunteers at 20° and 45° of knee flexion at the subchondral bone and cartilage level. At both flexion angles outcomes were different between the two levels of measurement and differences were more significant at 45°. Sulcus angle and lateral patellofemoral angle were both significantly smaller when measured at the bony level (132° and 10.3° respectively) if compared to those recorded at the cartilage level (145° and 13.4°).

Koskinen et al. [18] analyzing by MRI the patellofemoral relationship of 11 patients with patellar dislocation compared with 15 asymptomatic subjects, modified the measurement of lateral patellofemoral angle at the cartilage level and demonstrated an increasing mean of 7° at 0° and 20° of knee flexion if compared to standard measurements at the subchondral bone level.

Staubli et al. [41, 42] studied the articular joint morphology and osseous anatomy of the patellofemoral joint in the axial and sagittal planes on cryosection and on MR arthrotomography. Findings demonstrated a low percentage of correspondence between cartilage and bone anatomy. In the axial view, for only 4 of 30 patients examined was the position of the ridge of the articular cartilage of the patella coincident with the corresponding subchondral bone prominence. Distances between bone and cartilage level and the medial tangent were a mean of 18.9 and 20.3 mm, respectively on the patellar side and 44.9 and 43.6 on the trochlea side.

In the sagittal plane the articular cartilage surface of the patella and the corresponding osseous contour did not match. The subchondral osseous contour showed an anteriorly oriented concave indentation of the subchondral plate, while the articular cartilage surface revealed a posterior-oriented convex joint surface. The concave subchondral bony indentation was located an average of 44.7% from the base of the patella, while the most prominent posterior convexity of the retropatellar articular cartilage thickness was located at 49.2%. Also on the trochlear side there was a significant contour incongruence between the subchondral part and the anterior cartilage surface of the superior and anterior most part of the intercondylar sulcus.

All those studies support the consideration that MR could help in developing and collecting more reliable parameters of patellofemoral joint abnormalities.

At this time no studies define and validate indices which could be commonly adopted in the measurement of normal and abnormal patellofemoral joint.

10.2 MRI Operative Protocol to Analyze Instability Factors

The study of the PF articulation implies the possibility to perform measurements with the knee in extension and in flexion at 20° and 40°, with a relaxed and contracted quadriceps, using measurements carried out on the osseous and cartilaginous level.

For the flexion examination, we use a stiff slant (footing) conveniently graduated at 20° and 40°. The flexible coil is usually used for shoulder MRI studies. With a MRI machine of 1.5 T the sequences in which the cartilage is well represented are: 3D-T2, DP-Fat Sat, and TSE-T2.

The sequence to be used should give a good image of the cartilage, and should be comfortable for the patient. The overall time of the exam should not exceed the time for a standard exam.

The DP-FS sequence allows one to easily make the measurements and is highly sensitive for the evaluation of potential alterations of the cartilage and subcortical bone signal with duration of the sequence a little longer than 1 min. Artifacts from movement of the patient often invalidate the contraction sequences. For this reason it is better to use a fast sequence like TSE-T2 with duration of approximately 30–40 s.

The 3D-T2 sequence is the most sensitive for chondral alterations and allows one to carry out multiplanar reconstructions (MPR). However this requires a longer exam so we should use them if necessary as an adjunctive sequence for a diagnostic deepening.

The protocol schedules:

Resting extension study with:

1. Axial DP-FS with a thickness of 3–4 mm, from the superior limit of the patella to the anterior tibial tubercle.
2. Sagittal TSE-T2 with a thickness of 3–4 mm, pointed to the patellar tendon, or DP-FS extended to the condyles if we want to examine the menis-cuses and the cruciate ligaments. Contraction study with:
   (a) Axial TSE-T2 with a thickness of 4–5 mm, pointed to the P-F articulation

Flexion study at 20° and 40° resting and in contraction:

1. Axial TSE-T2 with a thickness of 4–5 mm pointed to the P-F.

The postprocessing of the images could be performed on PACS or Workstation.

Regarding the four principal factors of instability discussed above, we can examine what is the contribution of the MR.

10.2.1 Trochlear Dysplasia

Carrillon et al. [7] have studied by MR 30 consecutive patients with patellar instability compared with a control group of 30 healthy people, to establish the reliability of the lateral trochlear inclination index (LTI). This index was previously introduced by Bernageau et al. [2] for radiographic definition of trochlear dysplasia.

MR was performed on the knee in full extension with a transverse fat-suppressed T2-weighted turbo spin-echo sequence. The measurement was done on the first craniocaudal image that demonstrates cartilaginous trochlea. LTI was calculated by means of a line tangential to subchondral bone of the posterior aspect of the two femoral condyles, crossed with a line tangential to the subchondral bone of the lateral trochlea facet (Fig. 10.3). A significant difference between groups was recorded. The mean value in patients was 6.17° while in the control group was 16.9°.

Choosing 11° as the threshold value for LTI, results were excellent in discrimination between the two groups with a sensitivity of 93% a specificity of 87% and an accuracy of 90%.

Using 11° of LTI value as a reference to distinguish trochlear dysplasia, Kerr et al. [16] have examined 104 patients with anterior knee pain and a control group of

Fig. 10.3 Lateral trochlear inclination index (LTI) to measure trochlear dysplasia. LTI was calculated by means of a line tangential to subchondral bone of the posterior aspect of the two femoral condyles, crossed with a line tangential to the subchondral bone of the lateral trochlea facet

74 healthy knees. The measurement of LTI was done at the cartilage level. No significant differences were recorded between male and female outcomes in both groups. The mean LTI value was 21.5° in the anterior knee pain group and 17.5° in the control group. 16.5% of patients with anterior knee pain had LTI higher than 11°, while this percentage was 2.7% in the control group. 77.7% of patients with trochlear dysplasia had an associated patellar tilt.

Pathological LTI value measured by two studies ranged from 6.7° to 21.5° considering two different pathologies: instability and pain.

Future studies could help to validate the value of 11° of LTI as MR parameter of measuring trochlear dysplasia.

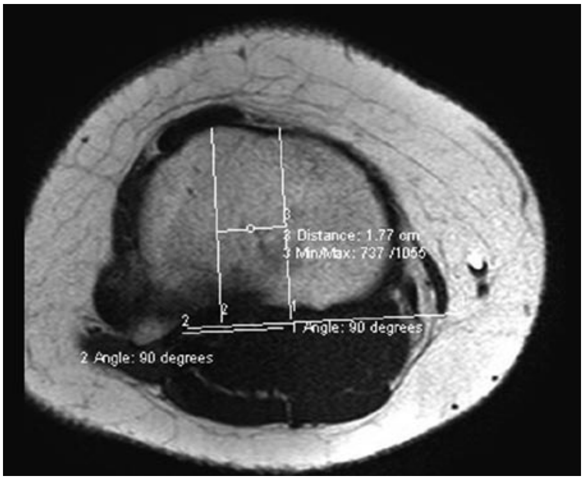

Fig. 10.4 TSE-T1 study of the TT-TG in extension

10.2.2 TT-TG

In 2006 Schottle et al. [32] have compared the outcomes of TT-TG value measured on 12 patients, most of patients with patellar instability, by CT scan and MRI. Measurements were taken at the bony and cartilaginous-tendon level (Figs. 10.4 and 10.5).

The mean bony TT-TG value was 14.4 mm as determined on CT and 13.9 mm as determined on MRI. At the cartilaginous-tendon level, the mean TT-TG values were 15.3 on CT and 13.5 mm on MRI. The difference at this level was statistically significant. The study demonstrated a high intermethods reliability of 86%. The significant differences recorded at the cartilaginous-tendon level between the two methods confirm that the use of tissue landmarks with MRI examination seems more reasonable because they represent the points where forces really act on the patellofemoral joint. The major problem with MRI is to define exactly the correct slice on the femur to take the measurement from that corresponds to the deepest cartilaginous point of the most proximal position where the trochlea is completely covered by cartilage. Choosing a more distal slice decreased the TT-TG value because the trochlea groove deviates medially at its distal part.

A second study was conducted for measuring TT-TG with MRI [44], but the method of acquiring images and measuring parameters was different. Fourteen patients, most with anterior knee pain and 14 healthy people were examined with MRI and with a 30° sunrise view of the patellofemoral joint. Four slices were taken by MRI. The first corresponded to the axial view of the distal femur at the greatest anterior to posterior diameter of the femoral condyles. At this level, three lines were designed. The second is along the anterior and posterior aspects of the femoral condyles, and the third perpendicular to the line across the posterior aspect of the condyles through the apex of the femoral trochlea.

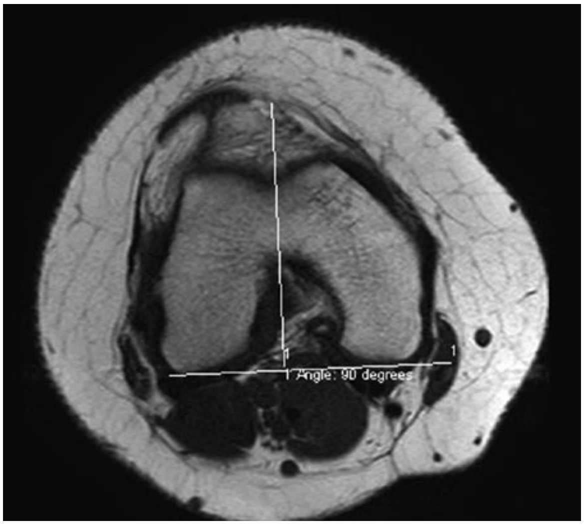

Fig. 10.5 TSE-T1 study of the TT-TG in extension

The second axial slice at the distal femur was taken at the greatest transverse diameter of the patella. At this level, a line between the apex of the patella and the lateral border of the lateral facet cortex was designed. This line with the one created at the first slice across the anterior aspect of femoral condyles to determine the lateral patellofemoral angle.

The third axial slice was taken at the level of insertion of the patellar tendon at the proximal tibial tubercle. The distance between the line designed at this level passing through the midpoint of the insertion of the patellar tendon and the one drawn on the first slice passing through the trochlea represents the TT-TG value measured with MRI.

The height of the patella was measured on the fourth slice taken sagittally using the Insall-Salvati method [15]. Critical values of 10 mm of TT-TG and 8° of lateral patellofemoral angle were chosen to evaluate the sensitivity and specificity of the MRI findings. In symptomatic patients, TT-TG value was greater (12.6 mm) compared to a control group (9.4 mm) and the lateral patellofemoral angle was smaller (2.56°). The Insall-Salvati index was greater in symptomatic patients (1.17 vs 1.02) and Patella Alta (value > 1.2) occurred more frequently in symptomatic patients. Choosing 10 mm as critical TT-TG lateral tubercle deviation was 70% specific and 64% sensitive for knee pain. Nine of 14 patients had TT-TG values greater than 10 mm and lateral patellofemoral angle <8° while four had normal TT-TG and pathological lateral patellofemoral angle.

The study confirms the possibility of reproducible measurement of TT-TG by MRI. The weakness of the paper was represented by the study design (single blinded case controlled and disomogenous gender distribution between groups) and MRI method of measurement which did not consider the shape of trochlear groove.

Based on these studies a pathological value of TT-TG measured with MRI ranged between 12.6 and 13.5 mm considering two different type of pathologies: pain and instability

10.2.3 Patellar Tilt

Different studies and different methods were proposed to determine patellar tilt [12, 17, 18, 31, 44] Values obtained were different and were considered predictive, according to different authors, of vastus medialis insertion level [18], anterior knee pain [44] and patellar dislocation [17]. None of the studies were randomized, double-blinded and prospective; evaluation methods were different, patient population were too small, quadriceps contraction was not considered in all papers, and the angle values obtained were different.

Grelsamer et al. [12] measured the tilt angle according to Powers et al. [31] and Nove'-Josserand [29] method with MRI in 81 patients, 30 with anterior knee pain and clinically positive patellar tilt and 51 with anterior knee pain without clinical evidence of patellar tilt. MRI was taken with the knee at 10° of flexion without quadriceps contraction and the angle was calculated using bony and not cartilaginous references. One-hundred percent of patients with clinical tilt had a >10° lateral patellofemoral angle on MRI (22% in control group). The mean value of the angle was 18 ± 7° in pathological group and 6 ± 5° in control group. There was an overall agreement between the radiographic and clinical examination in 88%.

The limitation of the study was the absence of quadriceps contraction and by choosing bony and not cartilaginous references for angle determination.

Too many different factors affect MRI outcomes of patellar tilt. More homogeneous studies and methods of evaluation are necessary to validate MRI as a reliable tool for defining the patellar tilt.

10.2.4 Patella Alta

Several studies have been conducted on measuring the height of the patella on MRI [12, 18, 25, 29, 33, 44] (Fig.10.6). Miller et al. [25] found a good correlation between findings on x-rays and MRI, using the Insall-Salvati index [15] in both. A 1.3 ratio as the higher limit for Patella Alta was stated by the authors. They did not find significant differences in values between male and female, and the ratio was not affected by a sagging or wrinkled patellar tendon.

The ratio limits defined by Shabshin et al. [33] examining 245 patients in a retrospective evaluation were 0.74 for Patella Baja and 1.5 for Patella Alta.

The possible relevance of patellar tendon length as a principal cause of Patella Alta was demonstrated by Neyret et al. [28]. An examination was conducted comparing two groups of patients (instability and control) with x-ray and MRI using the Caton-Deschamps index [8] for Patella Alta, and measuring the length of patellar tendon and the tibial tuberosity height. The later parameter was similar between groups (28 and 29 mm). Otherwise the mean length of the patellar tendon

Fig. 10.6 TSE-T2 study of the height of the patella in extension

was 53 mm in the instability group and 46 mm in the control. The correlation between x-ray and MR indices measurement was excellent in both groups and MR demonstrated in the instability group more sensitivity in revealing a pathological value of Caton-Deschamps index (60% vs 48% with x-ray findings). The study supports the hypothesis that Patella Alta can be determined by a long patellar tendon and not by its distal insertion into the tibia and consequently in these cases a patellar tendon tenodesis needs to be performed.

More studies need to be conducted possibly using the cartilaginous level for defining a repeatable MR index for Patella Alta and for detecting the role of patellar tendon length in etiology of this pathological factor.

10.3 Dynamic Evaluation of Patellofemoral Joint

The stability of the patella in the femoral trochlea groove appears to be most critical in the first 20°–30° of knee flexion. The difficulty in determination of the patellar position at this range of motion with conventional axial radiographic examination is well known [20–24].

Consequently CT has been introduced to evaluate patellar position in the critical range. The results reported in literature are still controversial

Delgado-Martins [9] found that in studies performed without muscle contraction, 13% of the patellae were centered in the fully extended knee while the others were displaced and tilted laterally. Similar results with CT were reported by Schutzer et al. [40] who found a mild degree of lateral shifting and tilting from 5° to 0° and a central or medialized patella at 10° of knee flexion in healthy subjects. Findings by Martinez et al. [22] were the opposite: 95% of healthy subjects investigated had the patella centered during complete extension; this percentage decreased with quadriceps contraction.

In 1988 Shellock et al. [34] described a method of dynamic evaluation of patellofemoral motion using MRI.

Since Kinematic MR imaging studies of patellofemoral joint motion and abnormalities were introduced, two different methods of evaluation were developed: qualitative and quantitative. Until now both have demonstrated limits in describing and correctly defining patellofemoral joint physiology and pathology.

10.3.1 *Kinematic MR Evaluation: Qualitative Method*

In 1989 Shellock et al. [35] studied by Kinematic MR 130 patients (260 knees) who had a clinical diagnosis of abnormal patellar tracking. In addition 14 healthy subjects were examined to define normal patellofemoral joint kinematics.

A special nonferromagnetic position device to allow simultaneous axial imaging of both patellofemoral joints was developed. Patients were examined in the prone position at 0°, 10°, 15°, 20°, 25° and 30°.The device had a patient activated mechanism for knee flexion, a gauge that indicated the degree of knee flexion and a cut-out area that allowed uninhibited movement of the patellofemoral joint.

A 1.5 T, 64 Mhz MR imager with a transient body coil was used. T1 weighted, spin-echo, axial plane imaging was performed. Section thickness was 5 mm. No active muscle contraction occurred during examination.

10.3.2 Using a Qualitative Method of Patellofemoral Joint Tracking Evaluation the Following Classification was Introduced

- *Normal*: the apex of the patella is aligned with the femoral trochlea groove so that the lateral and medial patella facets articulate with the medial and lateral aspect of the trochlea.
- *Lateral subluxation*: the apex of the patella is laterally displaced relative to the femoral trochlea and the lateral facet of the patella overlaps the lateral aspect of the femoral trochlea.
- *Excessive lateral pressure syndrome (ELPS)*: the lateral facet of the patella is tilted toward the lateral aspect of the femoral trochlea with little or no lateral subluxation. The relative degree of tilting typically increases with increased knee flexion.
- *Medial subluxation*: the apex of the patella is medially displaced relative to the femoral trochlea.
- *Lateral to medial subluxation*: the patella starts in a laterally displaced position and moves to a medially displaced position with increasing knee flexion.
- *Dislocation*: the patella is completely displaced from its normal position relative to the femoral throclear groove.

Based on these criteria Shellock's study [35] demonstrated normal patellar tracking in 17% of the patient population, 7% of which were symptomatic, 26% of lateral subluxation, 8% of ELPS, 41% of medial subluxation and 7% of lateral to medial subluxation. Of the 235 symptomatic patellofemoral joints, 93% had evidence of patellar malalignment on Kinematic MR investigation. The paper is observational and did not show any relationship between MR and clinical findings.

Another study was conducted with the same protocol on 40 patients (43 knees) with persistent symptoms after an arthroscopically performed lateral retinacular release [36]. Ninety-eight percent demonstrated MR signs of patellar tracking abnormalities; the majority (63%) had medial subluxation of the patella, although in 43% this condition was found in the nonoperated contralateral knee too. The study confirms the lack of correction of patellar instability predisposing conditions by lateral release, but is still observational, without a control group and preoperatively collected data.

The development of an ultrafast spoiled GRASS MR imaging system allowed to increase to 45° the knee flexion angle studied,to define patellofemoral tracking under active movement [37] and to compare patellofemoral joint motion in unloaded versus loaded condition [38].

Although active knee movement seems to not modify patellar alignment and tracking patterns [37], the results collected under unloaded or loaded examination are different [38]. Nineteen patients with a clinical diagnosis of abnormal patellar alignment and tracking were bilaterally studied (39 knees, 23 with symptoms). Six had previous surgery. Five healthy volunteers were also examined. Abnormal kinematic MR outcomes increased from 16 of 23 symptomatic knees under the unloaded condition, to 22 of 23 under loaded examination. Also the severity of abnormal patellar maltracking was greater under the loaded condition. The study indicates that active movement loaded kinematic MR imaging enhances identification of abnormal alignment and tracking of the patella.

This methodology was applied to study the effect of a patellar realignment brace on 21 patellofemoral joints with patellar subluxation [39]. Seventy-six percent demonstrated a qualitative correction of patellar tracking after application of the brace. No correlation with symptoms evolution was defined.

10.3.3 Kinematic MR Evaluation: Quantitative Methods

In 1989 the first quantitative evaluation of patellar motion by MR was performed by Kujala et al. [19]. Ten males and ten females without knee symptoms were examined by MR imaging. Patients were supine with the knee at 0°, 10°, 20°, and 30° of flexion, without and with quadriceps contraction.

Axial and sagittal views were taken. Parameters similar to those collected on axial x-rays were considered: sulcus angle, lateral patellofemoral angle, lateral patellar tilt angle and congruence angle. Lateral patellar displacement (LPD) and lateral patellar tilt decreased during knee flexion. At 20° of flexion all the indices measured from axial images, showed that in females the patella lay more laterally in the femoral sulcus. All the knees seemed to be congruent at 30° of flexion but not at the smaller flexion angle. During isometric quadriceps contraction with the knee in extension, there was no difference in the mean values of LPD if compared with data collected without muscle contraction, but lateral patellar tilt decreased a mean of 5°. The study is observational, does not compare normal and pathologic condition and does not develop or validate any specific MR index for defining patellofemoral tracking normalities and abnormalities

A more specific development of MR indices were proposed by Brossman et al. [4] evaluating patellar tracking patterns with motion-triggered cine MR imaging. Two groups were compared: 15 patients (seven males and eight females) were healthy, 15 (all females) had diagnosis of recurrent patellar subluxation. All knees were positioned in a non ferromagnetic device and patients were tested in the supine position. To perceive the beginning of knee extension a pneumatic pressure transducer was used. The sensor was placed onto the patella with tape. The motion of the patella caused pressure changes in the compressible foam rubber cushion which was connected to a respiratory monitor. The pressure changes were transformed into electrical signals which were displayed on a monitor as a pressure curve. The pressure curve was converted to an electrocardiographic like signal and indicated the beginning of extension. This signal was fed to the MR system through the electrocardiographic monitor. Gradient echoes acquisition were used in a multiple section phase technique. The interval between two successive time frames within one cycle of motion was 83 ms. Section thickness was 10 mm. A static MRI exam was added for each patient.

Brossman's indices were previously used in CT scan [22–40] and x-ray [20] measurements:

- *Patellar tilt angle (PTA):* measure of tilting of the patella. Formed by a tangent to the lateral facet of the articular cartilage of the patella and a second line parallel to a tangent to the posterior part of the condyles. The angle is positive if it is open laterally, and negative, in case of stronger tilting, when medially opened.
- *Bisect offset (BO):* measure the relative patellar lateralization. From a line tangent to the posterior part of the condyles a perpendicular line is projected anteriorly through the deepest point of the trochlear groove and intersects with a patellar width line. A bisect offset is the percentage of the patella lateral to the projected perpendicular line.
- *Lateral patellar displacement (LPD):* measure of absolute patellar lateralization. From a line tangent to the posterior part of the condyles a perpendicular line is projected anteriorly through the most anterior point of the medial condyle. The distance from this line to the medial edge of the patella is expressed either positively or negatively in millimeters depending on lateral or medial position, respectively, of the medial patellar edge to a perpendicular line.

Outcomes revealed that all three indices had statistically significant differences in the final 10° of knee extension compared with their value at 30°. Significant differences between static and dynamic condition were found in the PTA from 20° to 0°, in the BSO from 25°to 0° and in the LPD from 15° to 0°. These findings indicate a marked lateral shifting and tilting of the patella in extension. The outcomes were also different between the two groups of patients in PTA in all positions and in the BSO and LPD from 10° to 0° in dynamic conditions. In patients with patellar subluxation the difference between patellar tracking parameters measured during passive and dynamic extension were highly significant. Significant changes in the tracking parameters were found at dynamic extension from 25° to full extension indicating a severe early lateral shifting and tilting of the patella.

The study by Brossman demonstrated the crucial role of quadriceps contraction for detecting patellar maltracking. The groups compared were not homogeneous in terms of sex distribution, which is a determinant in patellofemoral joint abnormalities.

Motion-triggered cine MR imaging showed significant correlation with arthroscopic findings in 20 patients with patellofemoral pathology evaluated with the two different diagnostic methods [5]. Doubts remain about the reliability of arthroscopy in detecting and classifying patellofemoral instability.

Patients were also analyzed with the same method before and after realignment surgery and outcomes were compared with those recorded with axial radiographs [6]. Fifteen patients were studied. Results demonstrated significant differences between findings before and after surgery recorded by MRI when compared to those measured on plain x-rays. These differences must be attributed to extensor mechanism activation during MR examination. The number of patients examined in this study was very small.

Different findings were recorded using ultrafast spoiled GRASS MR imaging system and measuring patellar tracking with bisect offset and lateral patellar tilt indices [43]. The study showed in normal conditions, movement of the patella medially from 45° to 18° of flexion followed by lateral displacement from 18° to full extension. In contrast with the largest number of author's observations, in this study, lateral patellar tilt revealed a tendency of decreasing as the knee extended.

Other authors have analyzed patellar tracking by kinematic MRI. Their methods of study, parameters used and outcomes are nonhomogenous and difficult to compare [23, 30, 45].

Qualitative and quantitative outcomes of Kinematic MR analysis of patellofemoral motion in normal and pathological conditions, are different, nonhomogenous and non comparable at this time.

10.4 Summary Statements

- MRI has been considered more useful in defining the cartilage status of the patellofemoral joint or to evaluate dynamically patellofemoral tracking abnormalities than to measure parameters which could determine patellar instability.
- MRI, like CT scan, but with thinner slices and without ionizing radiation, can show with a higher resolution the cartilage surface of the PF joint and can allow measurements at this level and not only at the subchondral bone cut as in radiographic examination.
- Angle values measured by MRI at the cartilaginous level are higher than those recorded at the bony level because of a low percentage of correspondence between cartilage and bone anatomy demonstrated by cadaver cross section studies on MRI.
- Trochlear dysplasia by MRI should be determined by the LTI previously introduced for radiographic measurement. MR was performed on the knee in full extension with a transverse fat-suppressed T2-weighted turbo spin-echo sequence. The measurement was done on the first craniocaudal image that demonstrates cartilaginous trochlea. LTI was calculated by means of a line tangential to subchondral bone of the posterior aspect of the two femoral condyles, crossed with a line tangential to the subchondral bone of the lateral trochlea facet. Pathological LTI value deducted by studies published ranged from 6.7° to 21.5°, with a threshold value of 11°, considering respectively two different pathologies: instability and pain.
- MRI measurement of TT-TG values seems to be more reliable at the cartilaginous-tendon level. Use of tissue landmarks with MRI examination seem more reasonable because they represent the points where forces really act on the patellofemoral joint. Pathological values of TT-TG measured with MRI ranged between 12.6 and 13.5 mm considering two different type of pathologies: pain and instability and are statistically significantly different from values measured on CT. The major problem with MRI for obtaining a correct measurement is to define exactly the correct slice on the femur where the measurement is taken, that corresponds to the deepest cartilaginous point of the most proximal position where the trochlea is completely covered by cartilage. Choosing a more distal slice decreased the TT-TG value because the trochlea groove deviates medially at its distal part.
- Too many different factors affect MRI outcomes of patellar tilt. More homogeneous studies and methods of evaluation are necessary to validate MRI as a reliable tool for defining the patellar tilt.
- Good correlations were demonstrated in measuring Patella Alta on x-rays and MRI, using Insall-Salvati and Caton indices. A 1.3 ratio is considered the higher limit for Patella Alta by MR measurement. By MR is also possible to determine the mean length of the patellar tendon whose value is 46 mm in normal patient and 53 mm in patients with patellar instability.
- Patellofemoral joint tracking should be studied dynamically by MR using a qualitative or a quantitative method. The possibility of evaluating the patellofemoral joint from extension to the first 30° of flexion, without using ionizing radiation, with thin slices, associating images of other knee structures represents an indisputable advantage.
- Although Kinematic MR imaging seems to be theoretically useful for analyzing the patellofemoral joint in normal and pathological conditions, non uniform data were produced by studies published.
- The lack of consensus between authors did not allow the establishment of a validated protocol for the study by Kinematic MR of patellofemoral joint

tracking with defined parameters in normal and pathological conditions.

- No correlations were defined between preoperative findings and different factors determining patellofemoral joint instability or pain in order to assess the different surgical options. No quantitative or qualitative evaluation has been evaluated postoperatively to surgical treatment in order to understand when surgery has reached its goals and when and why it failed.
- Despite all the studies published, kinematic MR evaluation of patellofemoral joint still remains at this time a promising procedure, useful to support biomechanics findings of patellofemoral joints but without a well defined clinical application.

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MRI of the Patellofemoral Articular Cartilage

11

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11.1 Introduction

Patellofemoral pain is common and can be disabling [19, 49]. In the absence of severe trauma or anatomical abnormality, the cause is frequently unclear. Mechanical factors that increase forces across the joint resulting in cartilage degeneration with concomitant greater stress to the subchondral bone are considered to be important etiological factors.

The patellofemoral joint cartilage consists of the articular surface of the patella with its seven facets, and the trochlear groove of the distal femur. The articular cartilage to the patella is the thickest in the knee and can be more than twice as thick as the cartilage to the medial and lateral femoral condyles [12, 17]. Lesions to patellofemoral joint cartilage are common and can result from both acute and repetitive trauma as well as chronic mechanical overload [19]. Patellofemoral kinematics is complex. Tracking of the patella within the trochlear groove depends on diverse dynamic and anatomical factors to include neuromuscular competence, femoral offset and version, geometry of the patella and the trochlea, tibiofemoral relationships, and patellar position. These factors impact on mechanical loading of the articular cartilage.

Early changes to both the articular cartilage and the subchondral bone that are not apparent to radiographic exam can be identified by magnetic resonance imaging (MRI). Improved methods to diagnose and stage articular cartilage damage prior to onset of radiographic changes may provide key information concerning areas of joint overload. As a noninvasive imaging technology well suited to imaging soft tissues and with multiplanar capabilities, MRI has strong potential to be useful for these purposes in the clinical care and evaluation of patients with anterior knee pain.

11.1.1 Cartilage Lesions of the Patellofemoral Joint

Articular cartilage abnormalities due to injury or degeneration are common. The damaged articular surfaces can be unipolar affecting either the patella or the trochlea, or bipolar affecting both the patella and the trochlea. Cartilage lesions are typically referred to as chondral defects, chondrosis or chondromalacia.

The clinical entity of fissuring and degeneration of the patellar cartilage of unknown etiology was described by Budinger in 1906 and referred to as chondromalacia patellae by Koenig [6]. Anterior knee pain was attributed to chondromalacia patellae (CP) for several decades until several studies showed a high percentage of patients with anterior knee pain did not have cartilage damage appreciable by arthroscopic exam [22, 40]. An arthroscopic grading system for CP introduced by Outerbridge et al. [35] describing softening as Grade 1; fibrillation or fissuring in an area of less than 0.5 inches as Grade 2; fibrillation or fissuring

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in an area of greater than 0.5 inches as Grade 3; and fibrillation or fissuring with exposed bone as Grade 4, has since been adapted for general use for arthroscopic grading of articular cartilage lesions.

While the term chondromalacia refers to softening of the cartilage and reflects structural weakness that can be traumatic, degenerative, developmental or genetic, current orthopedic treatment focuses on addressing mechanical issues. Several anatomical factors contributing to altered patellofemoral contact stresses include trochlear and patellar dysplasia, excessive femoral anteversion, Patella Alta, and abnormal tibiofemoral relationships. Neuromuscular and soft tissue factors also play a large role in abnormal patellofemoral kinematics.

While significant anatomical injuries and abnormalities such as fracture, trochlear dysplasia, Patella Alta and tibiofemoral relationships can be evaluated radiographically, mechanical overload due to neuromuscular and soft tissue abnormalities cannot be easily appreciated radiographically. Traumatic cartilage injuries, chondromalacia patella and lateral facet syndrome are examples of patellofemoral problems for which radiographic exams are frequently normal. MRI is capable of multiplanar imaging of soft tissues and can identify changes to subchondral bone and articular cartilage not apparent by radiographic exam.

11.2 Magnetic Resonance Imaging of the Patellofemoral Joint

11.2.1 General Cartilage Imaging Techniques

For imaging of articular cartilage, common MRI techniques include fat-suppressed 3D spoiled or T1-weighted gradient-echo and fast spin-echo (FSE) techniques [5]. When using FSE techniques, articular cartilage will show low to intermediate signal intensity. Water, either in the joint or in the degenerating cartilage, will be of high signal intensity. In contrast, spoiled gradient-echo sequences will depict the cartilage with high signal intensity and water with low signal intensity. The use of fat-suppressed 3D SPGR (spoiled gradient-echo) MR imaging for the detection of cartilage lesions has been shown to result in a sensitivity of 75%–85% and a specificity of 97% [11]. When applied to the patellofemoral joint, Recht et al reported that with fat-suppressed 3D fast low-angle shot MR imaging, the sensitivity was 81%, the specificity was 97%, and the accuracy was 97% for detection of abnormal cartilage at 1.0 T [37].

11.2.2 Imaging Techniques of the Patellofemoral joint

Chondral defects of the patellofemoral joint can occur in the patella, the trochlear groove, or both [4, 21]. Due to the relative thickness of the patellar cartilage, it can be visualized on both axial and sagittal cuts. The articular cartilage of the patella is particularly well seen on axial MRI cuts (Figs. 11.1 and 11.2). Both full and partial thickness cartilage defects of the patella can be diagnosed by MRI (Fig. 11.2).

On the other hand, the geometry of the trochlea and the thinner cartilage make it harder to assess by MRI. Muhle et al. [33] showed that imaging of the trochlear cartilage is more difficult than imaging the patellar cartilage in part due to the trochlear cartilage being about two to three times thinner than the patellar cartilage. In addition, obtaining only transverse MR images may lead to limitations with regard to delineation of the trochlear groove due to variation between the convex shape of the femoral condyle and the concave configuration of the trochlear groove. Therefore, trochlear pathology may be better visualized on sagittal cuts than axial cuts (Fig. 11.3). Partial thickness chondral defects of the trochlea are also difficult to see by MRI. In some instances, full-thickness defects of the trochlea can be identified prior to radiographic changes due to MRI evidence of subchondral bone pathology (Fig. 11.3).

T1-weighted axial and sagittal images are useful for imaging of the patellar cartilage when effusion is not present. When effusion is present the use of 3D FISP (fast imaging with steady procession) sequences have been recommended because of maximally enhancing arthrographic effect of the synovia. T1-weighted 3D FLASH sequences permit both excellent detection and grading of articular cartilage lesions of the patellofemoral joint. In newer studies T2-weighted FSE, spectral presaturation with inversion recovery (SPIR) sequences showed improved detection of earlier stage lesions. This greater sensitivity can show at an early stage if

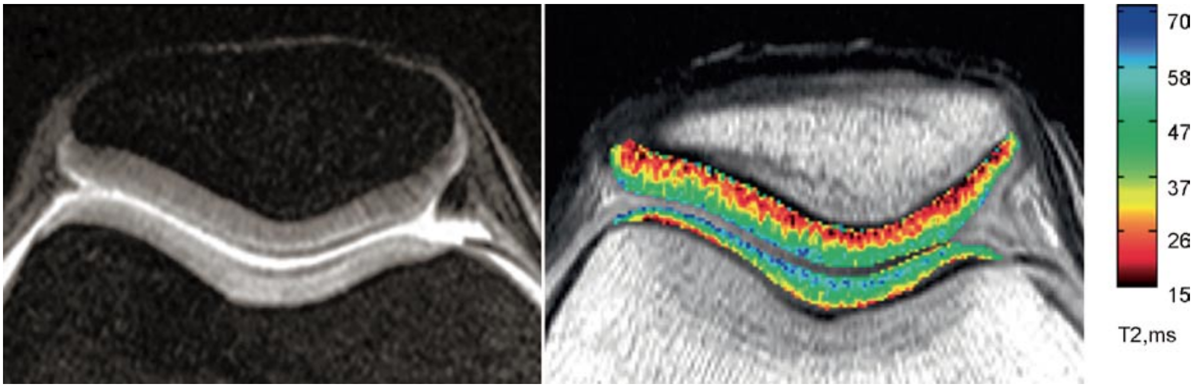

Fig. 11.1 Axial MRI of Patellofemoral Joint Cartilage. (**a**) Example morphologic 3 T DESS image. Striations indicative of collagen fibril arrangement in the thick patellar cartilage are clearly evident in this axial DESS image of a 20-year-old female with healthy cartilage. (**b**) MRI T2 map of the same subject shows a distinct lamellar pattern

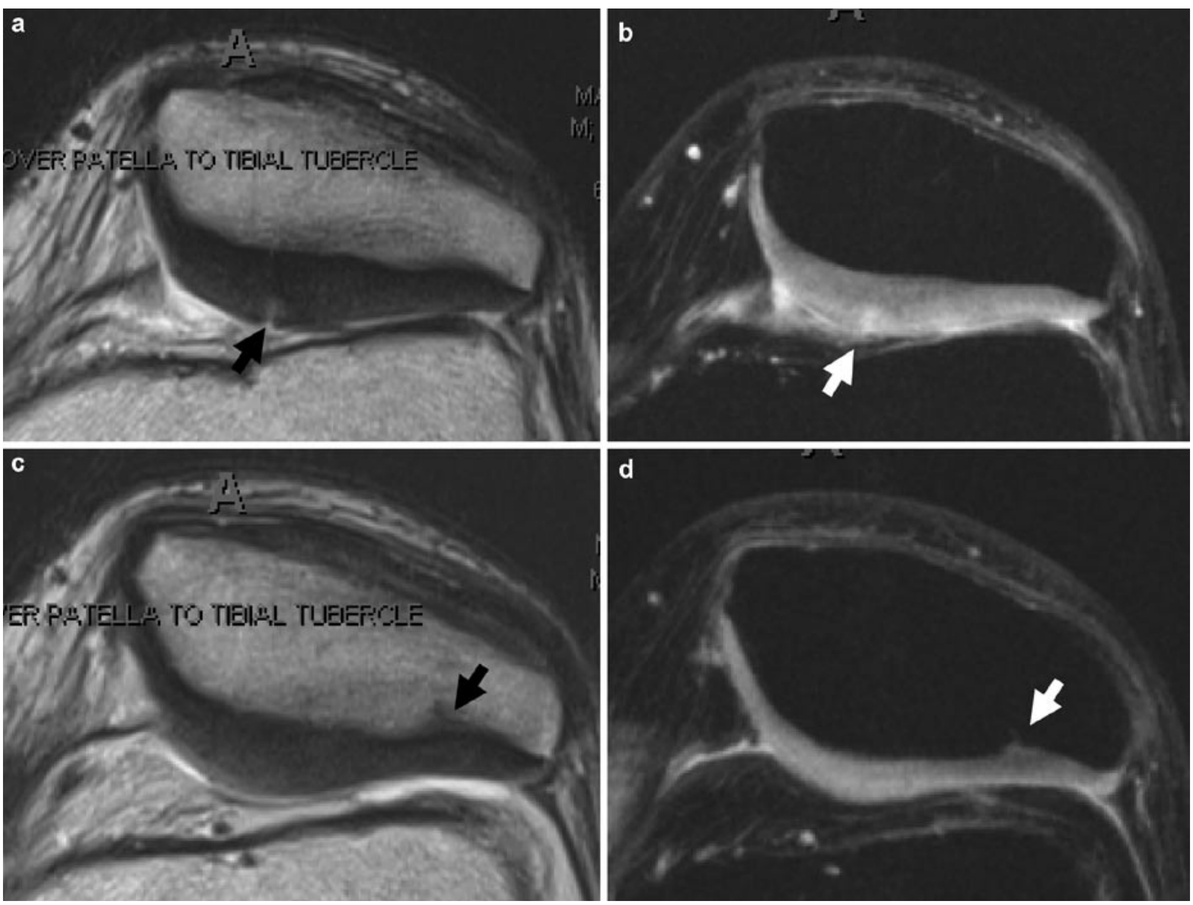

Fig. 11.2 Axial MRI of patient with lateral facet pain and no radiographic joint space narrowing. (**a**)T2-weighted MRI shows partial thickness chondral defect (*arrow*). (**b**) This defect is less well seen on the fat sat image. (**c**, **d**) Both techniques show intact articular surfaces with subchondral bone irregularity to the lateral facet indicative of excess stress to the lateral facet. The fat sat image (d) shows abnormal signal to the cartilage adjacent to the subchondral bone

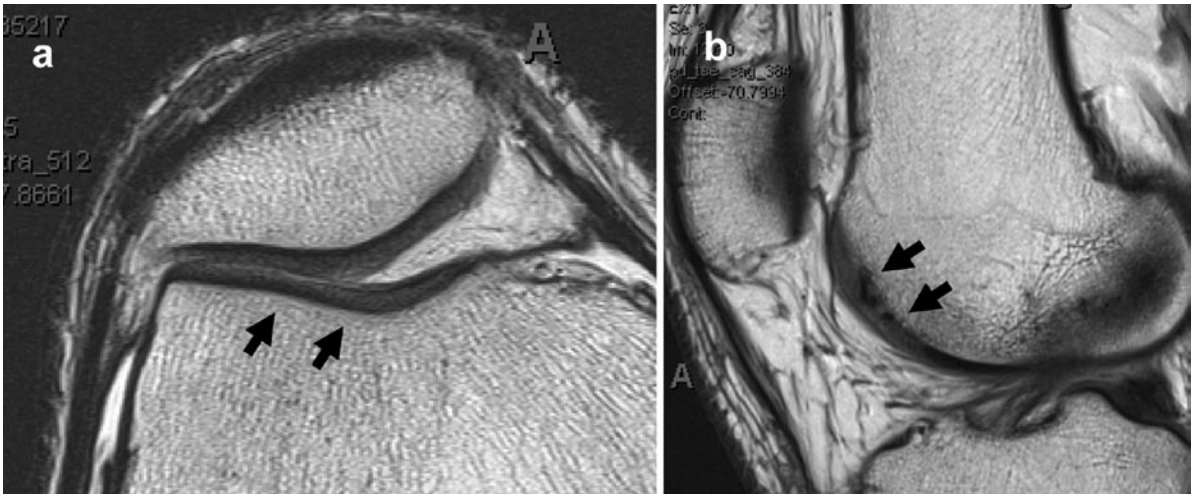

Fig. 11.3 Structural MRI showing cartilage of the lateral trochlea (*arrows*). (**a**) Axial imaging shows slight disruption of the patellar cartilage surface with intact appearing trochlea. (**b**) Sagittal image shows changes to the subchondral bone-cartilage junction. The articular surface appears intact. At arthroscopy, a large full-thickness chondral defect of the trochlea was seen

knee pain can be attributed to pathologic changes of the articular cartilage or to other articular structures [9, 24, 37].

11.2.3 Novel and Emerging MRI Evaluation of the Patellofemoral Joint

MRI of articular cartilage is a technically challenging area for which new techniques are emerging at a rapid pace. New and emerging technologies include high-field and ultra high-field imaging, quantitative MRI, and improved techniques to evaluate the morphological and physiological properties of articular cartilage. Morphologic techniques are used to detect surface irregularities (e.g., fissures) and to quantify volume changes. Physiologic techniques are used to detect biochemical abnormalities before development of a morphologic abnormality. Dynamic techniques may also play a role in improved assessment of patellofemoral tracking abnormalities.

The patellofemoral joint is typically imaged with the knee fully extended. However, patellofemoral range of motion can be examined from full extension up to 45° of knee flexion, depending on the MR scanner used and the patient position selected [43]. In order to analyze patellofemoral tracking, axial sections through the femur are timed to cover the range of motion of the patella during knee flexion and extension. The patellar position in regards of tilting and lateralization is evaluated in relation to the femoral condyles and to the intercondylar groove [34].

Improved morphologic/morphometric imaging of cartilage has been evaluated in high-resolution images with high cartilage/bone and cartilage/synovium contrast and fat suppression [16, 20]. Use of high-field (3 T) three dimensional (3D) sequences result in improved signal to noise ratio (SNR) and more isotropic voxels than typically afforded by lower field two dimensional (2D) imaging. High-field (3D) techniques being used to study cartilage surface irregularities and cartilage thinning also permit longitudinal volumetric analysis [8]. Emerging sequences include 3–T 3-D DESS (double echo steady state) [15] (Fig. 11.1a) and 3 T 3D SPGR (spoiled gradient-echo) [44].

MRI techniques permitting quantitative analysis of cartilage matrix properties are under evaluation to determine the potential or noninvasive clinical assessment of the functional integrity of articular cartilage [7, 25, 26]. These techniques include dGEMRIC, T1rho, Na-MRI, diffusion-weighted imaging (DWI), and T2 mapping. Because the primary components of articular cartilage are water, type II collagen, and proteoglycans, these techniques have attracted interest due to their potential to evaluate these aspects of the cartilage matrix.

Changes to proteoglycan content may be a sensitive indicator of cartilage injury and degeneration. Delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), has been shown to be effective in quantifying the content and distribution of glycosaminoglycan (GAG) in articular cartilage [2]. GAG is a proteoglycan whose charged carboxyl and sulfate groups lend cartilage its compressive strength [27]. When a charged contrast agent, such as Gd-DTPA^{2-} (Magnevist, Berlex Imaging), is allowed to penetrate cartilage tissue, it distributes in inverse relation to the fixed charge density of GAG in the extracellular matrix [1]. The content and distribution of the contrast agent can be determined from MRI measurement of tissue T1 (or spin-lattice) relaxation rate. Regions of high $T1_{Gd}$ value reflect relatively high GAG content, and regions of low $T1_{Gd}$ reflect relatively low GAG content [45, 48].

Other emerging techniques to evaluate cartilage proteoglycans include Na-MRI and T1ρ imaging. In Na-MRI, sodium imaging directly probes the sodium content and distribution of cartilage tissue by tracking the fixed charge density of the matrix [38, 42]. Sodium imaging requires special hardware optimized to capture signal from ^{23}Na ions. In T1ρ probes spin-lattice relaxation in the rotating frame. T1ρ signal is sensitive to water-proteoglycan interactions and has also been found to be sensitive to collagen content, however its specificity in remains controversial [14, 23, 28, 39].

MRI evaluation of collagen has been indirect and techniques such as T2 mapping and DWI are likely more sensitive to collagen structure than to collagen content [3]. DWI detects anisotropy in tissue by observing phase dispersion of protons moving according to Brownian motion. The translational motion of water protons is related to the amount and direction of diffusion hindering obstacles (e.g., collagen fibrils) present [29, 30].

In T2 mapping (Fig. 11.1b, 11.4c), the T2 relaxation rate, or transverse relaxation, is a material property of electron spins that can be probed with MRI [51]. Studies show that collagen structure and orientation are the important determinants of T2 relaxation in articular cartilage [3, 10, 30]. T2 is also known to be sensitive to tissue hydration. As such, T2 maps have been successfully used for both animal and human studies of cartilage degeneration and repair [36]. More recently, ultrashort TE sequences have been used to enhance T2 imaging of short T2 components [13].

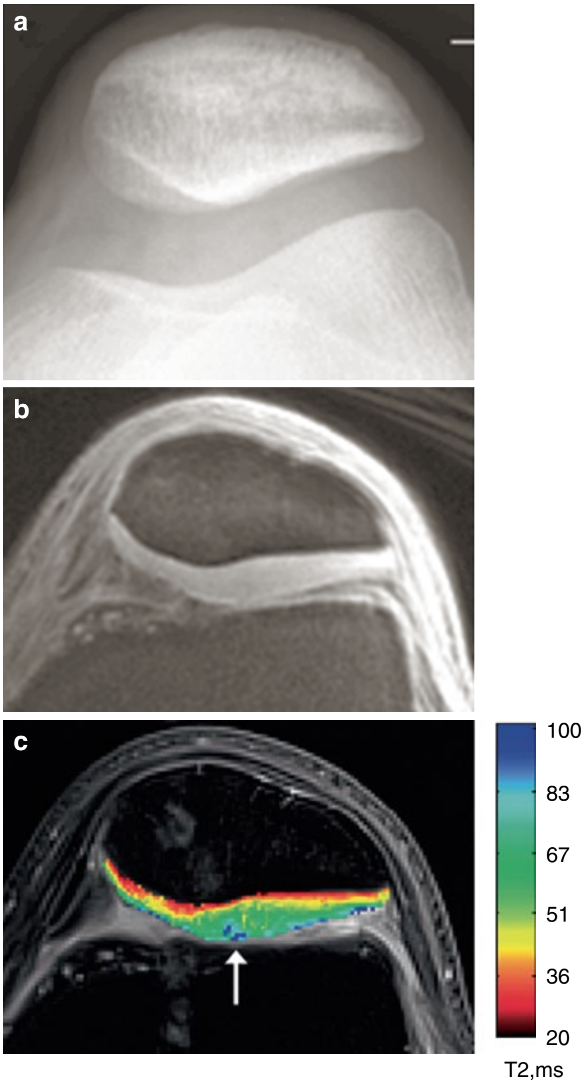

Fig. 11.4 Quantitative MRI T2 Map. (**a**) Radiographs and (**b**) structural MRI do not show signs of cartilage damage. (**c**) On the MRI T2 map, full-thickness focal lesion of high T2 values is noted to the central pole of the patella (*white arrow*). This finding shows chondromalacia patella. Although the cartilage appears quite thick, the lack of distinct laminae on T2 map further shows that the microstructure and the biochemical composition of the tissue is abnormal

11.2.4 Pitfalls in Imaging of the Patellofemoral Joint

MRI of articular cartilage is technically challenging due to the thin tissue, complex joint geometries, and the highly structured extracellular matrix. The appearance of even normal articular cartilage will vary depending on scan protocol and the orientation of the joint and the cartilage in the magnetic field [31]. The pulse sequence and related parameters can lead to a completely different appearance to the cartilage. Therefore, accurate interpretation depends on having a thorough understanding of the implications of each sequence and parameter to the appearance of the articular cartilage [50].

Knowledge of the collagen structure of articular cartilage is crucial to understanding the angle and orientation dependence of MR imaging [46]. Collagen fibrils are oriented parallel with the articular surface in the superficial zone, more randomly in the transitional zone, and perpendicular to the articular surface in the radial zone. The appearance of the laminae at MR imaging depends on the plane of section and all laminae are usually visible when the imaging plane is perpendicular to the cartilage surface (Fig. 11.1a). As a consequence, fewer discrete laminae are seen when the imaging plane deviates from the perpendicular one. Another orientation related pitfall is the ***magic angle effect*** where an elevation of T2 is observed due purely to the angular orientation between the cartilage imaged and the base magnetic field**.** T2 mapping of cartilage tissue is subject to magic angle effects where collagen fibrils are oriented 55° from the base magnetic field [32, 41]. Curved surfaces, e.g., the patellofemoral joint, are particular prone to these effects.

Truncation Artifacts, seen on MRI as an abrupt and marked change in signal intensity at interfaces can be observed for hyaline cartilage on 3D fat-suppressed spoiled gradient-echo images [18, 47]. Typically the appearance of the articular surface is not altered at cartilage fluid interfaces. However, truncation artifacts can obscure the cartilage surfaces where cartilage directly borders on fat. This effect can be reduced if a ***chemical shift*** presaturation is used.

Finally, close attention needs to be paid to ***Regional Anatomic Variation.*** Normally, the apex of the patella lacks articular cartilage. The anterior aspect of the distal femur abuts prefemoral fat. Irregularities at this interface can be mistaken for hyaline cartilage disease. Penetrating vessels may be mistaken for cysts. It also needs to be pointed out that the cartilage layer of the lateral femoral trochlear facet extends more proximally than the cartilage surface of the medial femoral trochlear facet. As such, the irregular surfaces from the interface between cartilage and synovium in the medial facet of the trochlea at the top of the proximal end could be misinterpreted as cartilage defects. For these and other reasons, trochlear cartilage may be better evaluated on sagittal MRI.

11.3 Summary

- MRI is useful for detection and longitudinal follow-up examination of cartilage lesions to the patellofemoral joint.
- Noninvasive, multiplanar capability and ability to discriminate other joint structures offer additional advantages.
- Fat-suppressed 3D spoiled or T1-weighted gradient-echo and FSE techniques are the most accurate.
- Newer MRI techniques allow imaging of the cartilage according to its morphologic/morphometric and physiologic properties
- These techniques may be even more specific for early detection of articular cartilage lesions of the patellofemoral joint.
- As cartilage imaging technologies improve, evaluation of cartilage injury patterns may prove useful in planning and assessing the effects of operative and nonoperative treatments to improve patellofemoral joint mechanics and in evaluating treatments to delay or prevent the development of osteoarthritis.

11.4 Conflicts of Interest

The authors did not receive any outside funding or grants in support of their research for or preparation of this work. They did not receive payments or other benefits from a commercial entity. No commercial entity paid or directed any benefits to any research or clinical organization with which the authors are affiliated or associated. The aforementioned also applies to the authors' immediate families.

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12 Patellofemoral Pain Syndrome: The Value of Pinhole and SPECT Scintigraphic Imaging and Quantitative Measurements of Bone Mineral Equivalent Density with Quantitative Computed Tomography

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12.1 Introduction

Scintigraphy is a sensitive imaging method to show increased osseous metabolic activity. Scintigraphy can be used as a dynamic method to show abnormal joint and bone hemostasis in the patellofemoral joint [4]. Dye [2, 3] first reported increased uptake in the bone scintigraphy in young patients with patellofemoral pain.

Are we able to show changes of the bone metabolic activity with routine bone scintigraphy? Or are we able to evaluate subchondral bone density changes with quantitative computed tomography?

Bone scintigraphy uses 99m-Technetium labeled methylene diphosphonate (MDP) which accumulates rapidly by absorption to the mineral phase of bone thereby detecting areas of high skeletal bone turnover. As a functional imaging, bone scanning reflects alterations in the metabolic activity of bone. In the patellofemoral joint disorders, conventional radiographic imaging is usually performed at the initial stage. It can detect only the advanced bone lesions including subchondral sclerosis, subchondral cysts and bone spurs, as well as joint space narrowing. But, it cannot detect the abnormalities of soft tissues, such as cartilage, tendon, ligament, and meniscus. It is often difficult to find the early lesion of the cartilage or the main sources of the pain in radiographic imaging. Bone scintigraphy has a sensitive modality, reflecting the early physiological changes of joints, such as increased blood flow and bone metabolism. Additionally, there is a good agreement between the degree of uptake and magnetic resonance imaging (MRI)-detected subchondral lesions. Moreover, semiquantitative evaluation is possible such as visually or computerized uptake comparison of joint compartment relative to the femoral or tibial shafts. However, scintigraphic images cannot give enough information for the anatomic localization, and the image is overlapped. Scintigraphic resolution is too low in the large and complex joints. Patellofemoral lesion is not easily detected, compared with medial and lateral compartments, and it has discordance with clinical findings. To compensate for the limitations of conventional planar imaging, special planar pinhole collimator imaging and single photon emission computed tomography (SPECT) method can be a useful tool for imaging complex joint abnormalities. By separating the overlying activity into sequential tomographic planes, bone SPECT increases image contrast and improves lesion detection and localization compared with planar scintigraphy. Pathological scintigraphic uptake pattern, localization and intensity in patellofemoral joint can be detected by using SPECT and pinhole

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imaging. Based upon the fact that subchondral bony changes precede morphological evaluation, bone SPECT seems to be a very useful tool to demonstrate in early patellofemoral pathology. But the clinical value of bone SPECT has attracted little attention as an index of disease activity.

In our previous study, results of the 28 young adults with patellofemoral pain were presented at the European Association of Nuclear Medicine Congress held in Strasbourg in 1989 (as an index patella to femoral ratio (PFI) was used to evaluate both symptomatic and nonsymptomatic knees), PFI was observed at a significantly increased value in symptomatic group.

Quantitative CT (QCT) is a fast, reproducible, and accurate method for measuring bone density, and has a radiation dose and accuracy equivalent to dual-energy.

Several methods have been developed for osteoporosis screening, the best known of which are DEXA [6–8, 15, 16, 19, 20] and QCT. Imaging techniques such as peripheral quantitative computed tomography (pQCT) and MRI are capable of assessing bone cross-sections. Hence, these imaging outcomes may provide insight as to the relative contributions of bone cross-sectional geometry and density to bone strength. In contrast to MRI, pQCT is more commonly used as it can assess cross-sectional geometry and the apparent volumetric bone mineral density of both cortical and trabecular compartments of the peripheral skeleton (radius and tibia) [12]. The tibial diaphysis provides a relatively simple model to characterize the effects of weight bearing on long bones and to monitor bone geometry and bending indices. Furthermore, the tibia is commonly used to evaluate bone strength during growth and in the aging skeleton [9, 13], as well as in response to diet [11] and exercise interventions [1, 10].

12.2 Methods

12.2.1 *Bone Scanning*

An intravenous injection of 99mTc-MDP 750 mBq was given. After 2–3 h of the injection, planar, pinhole planar and SPECT imaging was performed with gamma camera. Planar images were obtained in four positions; anterior, right and left lateral, tangential.

SPECT images were acquired in 128 × 128 frame matrix at four angular steps, each step being 30 s. Transaxial, coronal and sagittal slices were obtained. The intensity of radioisotope uptakes were graded 0–3 (0, normal; 1, mild; 2, moderate; 3, severe) compared with the uptakes of the femoral and tibial shafts. The uptake was localized to six sites, superior, inferior, medial and lateral subchondral area, femoral and tibial subchondral areas. Semiquantitative uptake values were also obtained from the same region of interests (Fig. 12.1).

12.2.2 *Quantitative Computed Tomography*

Toshiba Xvision computed tomography was used for the measurement of the bone mineral equivalent density. Calibration phantom was placed under the knee joint in supine position. Patella was entirely scanned in the cranio-caudal direction through the knee joint via 10-mm sections. As parameters, 120 kV and 100 m were used for x-ray.

Bone mineral density equivalent material was hydroxyapatite (HOA) in the calibration phantom. Bone Mineral Study application of the CT and V3.7C version of the program was used for the measurement of the bone mineral density. First, calibration of the system was performed at the cross-sectional images of the patella via measurement of the rounded HOA areas in the Calibration phantom. Afterwards, at the mid-section of the patella and without partial volume effect, the measurement was performed from the subcortical medullary and also the central cancellous region of the medial and lateral facets of both patellae. Results, as milligrams per cubic centimeter (mg/cm^3) and their standard deviations for each patient were recorded (Fig. 12.2).

12.3 Conclusion

Several imaging methods have been described for pathologies of patellofemoral joint and evaluation of patellofemoral pain [5]. Radiological examination is the main evaluation. In lateral position, localization of patella, quadriceps and calcifications and avulsions

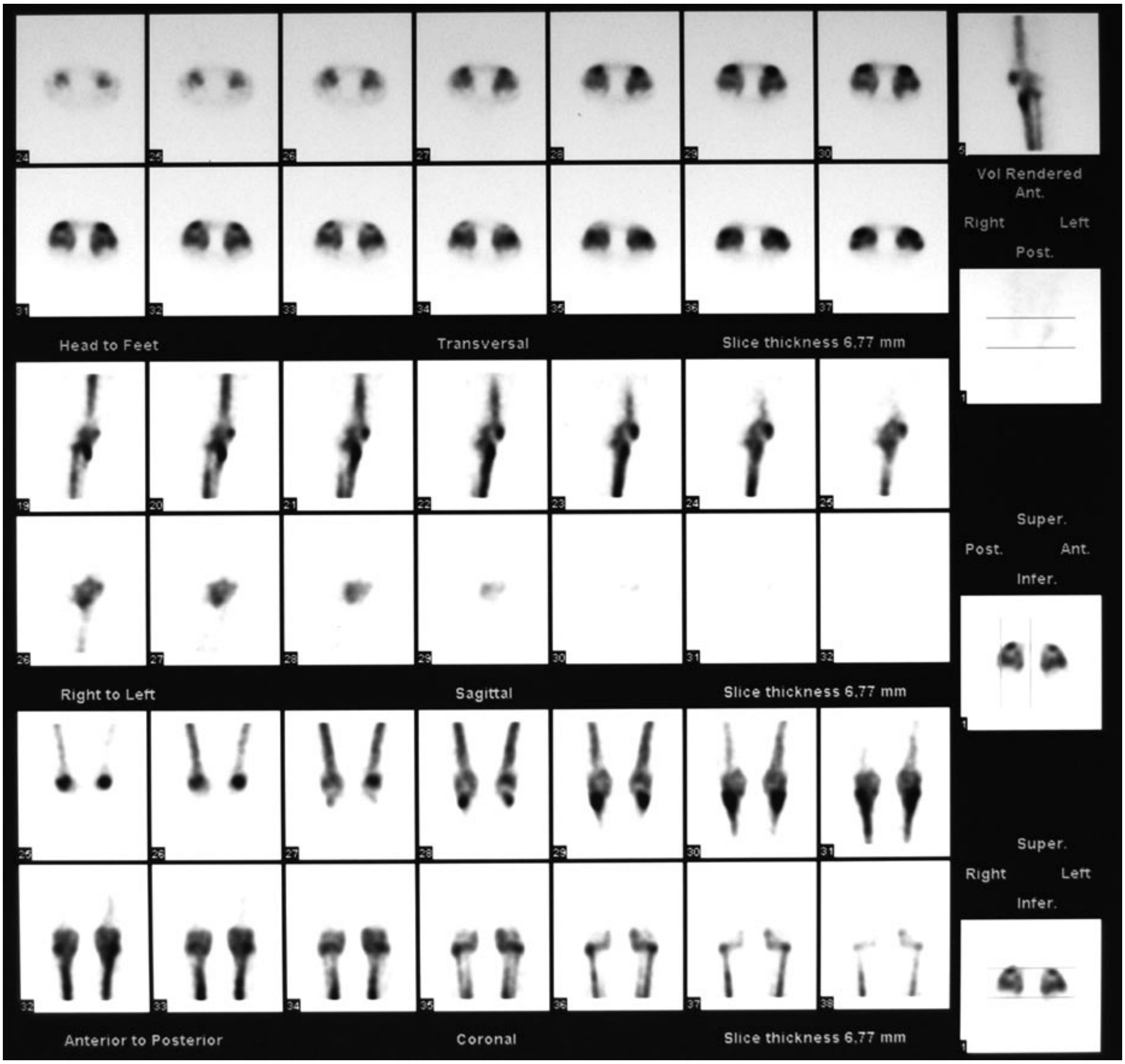

Fig. 12.1 SPECT images of the knee show bilaterally increased Tc99m MDP uptake in the patella. Transaxial (*upper images*), sagittal (*middle images*), and coronal views of the SPECT images

where patellar tendons adhere can be assessed, while with axial view, the shape of patella and patellar conformity with patellofemoral sulcus can be evaluated. Non-contrast CT and arthrography with CT are pretty useful techniques for evaluating patella, femoral condyles and joint cartilage. Malalignment patterns (subluxation without tilt, subluxation with tilt and tilt without subluxation) can be evaluated with CT [14]. MRI provides a detailed evaluation of the whole knee structure. With axial plane and sagittal plane, MR arthrotomography, articular surface geometry and osseous anatomy of patellofemoral joint can be examined [17, 18]. These methods are lacking in features to demonstrate changes in subchondral bone dynamic (metabolic) and bone density despite their potential benefit. As pointed out firstly by Dye [2–4], scintigraphy is a sensitive method to show metabolic changes in bone. Considering the limits of conventional planar scintigraphic method for knee and patellofemoral joint, SPECT method has been tried. Bone SPECT increases image contrast and improves lesion detection and localization compared with planar scintigraphy. Bone

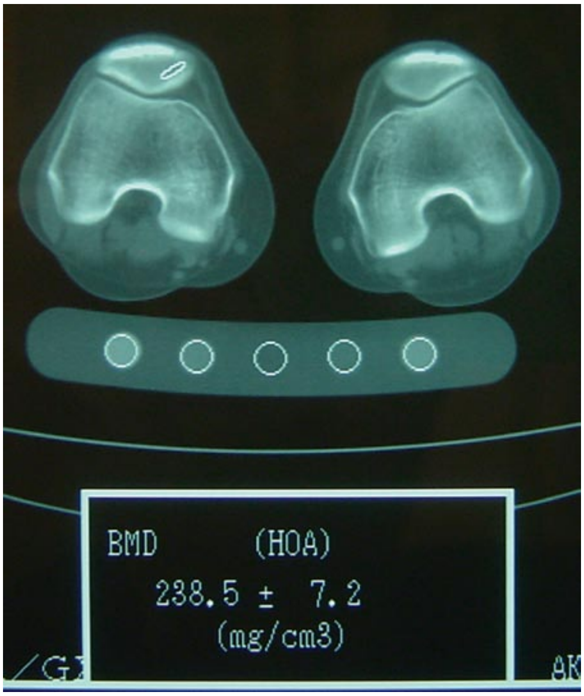

Fig. 12.2 Bone mineral density results in the subchondral bone of the medial facet of the right knee (calibration phantom was placed under the knee joint)

SPECT seems to be a very useful tool to demonstrate patellofemoral pathology expeditiously. QCT and pQCT yield results as much accurate as that of DEXA. This method has never been used for the evaluation of subchondral bone density in patella. We exhibited bone density difference by QCT evaluation in a limited number of patients with unilateral patellofemoral pain (for at least 3 months). We considered that this method could be used for the evaluation of bone density in patella.

We consider that scintigraphy and QCT exhibiting bone metabolism (dynamic) and bone density changes in subchondral bone are useful methods, especially for evaluating minor instabilities in which no pathology can be demonstrated by other imaging methods. Moreover, we believe that it can be used as an objective method for the evaluation of conservative methods (e.g., exercise, chondro-protective therapies).

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Gait Analysis in Patients with Patellofemoral Disorders

13

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13.1 Introduction

Patellofemoral disorders (patella instability and patellofemoral pain) are multifactorial conditions. Their successful treatment requires the understanding of the predisposing factors. Lateral tracking of the patella has been hypothesized to contribute to the development of patellofemoral pain [8, 9, 19]. In addition, increased patellofemoral joint stress has been identified in patients with patellofemoral pain [1].

In healthy individuals, during knee flexion the contact area between the femur and the patella moves along both the trochlear groove and the articular surface of the patella. In early flexion the contact is at the distal and lateral edge of the patellar articular surface and during flexion it moves proximally. The lateral facet of the trochlear groove counteracts subluxation of the patella during extension and early flexion. The patella engages the groove at 20° of flexion [2]. Thus, between 20° of flexion and full extension the function of the patella depends on other factors than the geometry of the patellofemoral joint.

This relationship may be disturbed due to a variety of anatomical factors such as dysplasia of the femoral condyles, Patella Alta, genu valgum, increased femoral anteversion, lower extremity malalignment with an increased Q angle, systemic hyperlaxity and a laterally positioned tibial tuberosity [37]. For example, patients with Patella Alta were shown to have greater lateral displacement and tilt as well as decreased contact area as compared with a control group [39]. Therefore, Patella Alta is certainly a strong risk factor for patellar instability. All these above mentioned patient characteristics should be considered prior to identifying the optimal treatment method for patellar instability and patellofemoral pain.

However, there is also an array of dynamic factors such as lateral torsion of the patella (tight lateral retinaculum), external tibial rotation, rear foot movements, internal femoral rotation and imbalance of the femoral muscles, that have been shown to relate to patellofemoral disorders [7, 13, 18, 24, 25, 27, 29, 32, 33, 38, 40]. The identification of these factors was due to gait analysis studies, using kinematic, kinetic and electromyographical (EMG) data. Gait analysis has contributed greatly to the understanding of these factors while they have also revealed possible compensatory mechanisms. In the next section we will attempt to review the available literature and provide the current status of knowledge in this area.

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13.2 Biomechanics in Patella Femoral Disorders

13.2.1 Factors Around the Knee Joint

It has been found that the function of the patellofemoral joint can be altered by the dynamic restraints imposed by the muscles that surround the knee. Specifically, research has focused on the medially and laterally directed muscular forces applied to the patella by the vastus medialis and vastus lateralis muscles [7, 13, 18, 24, 25, 27, 29, 32, 33, 40]. These studies focused on patellofemoral joint pain and had conflicting results concerning the relationship between vastus muscles activity and the onset of pain on abnormal patellofemoral joint function.

Karst and Willet [13] studied the timing of initial electromyographic (EMG) activity of the vastus medialis oblique and vastus lateralis muscle in nine asymptomatic subjects and in 12 subjects with patellofemoral pain, during reflexed and voluntary muscle activity (both weight bearing and non-weight bearing). No difference was found in the relative timing of vastus medialis oblique and vastus lateralis EMG for all conditions in both groups. Thus, this study refuted the hypothesis that altered timing of vastus medialis oblique and vastus lateralis activity may be responsible for patellofemoral pain. On the other hand Powers et al. [24] studied the influence of vastus muscle motor unit activity on patellar kinematics and suggested that increased vastus medialis activity might be related to abnormal patellar tilt in women (without necessarily causing it). Specifically, they examined 23 women with patellofemoral pain and 12 healthy controls using patellar kinematic magnetic resonance imaging and measuring vastus muscle EMG activity (with indwelling electrodes) during resisted knee extension. This contradiction may be the result of statistical power since Powers et al. utilized a much larger sample size. In addition, Powers et al. [27] suggested a “quadriceps femoris muscle avoidance gait” based on the decreased mean intensity of all vastus muscle EMG activity during level surface and ramp ambulation found in patients with patellofemoral joint pain.

With respect to joint kinematics and kinetics, Salsich et al. [30] examined ascending and descending in patients with patellofemoral pain. They identified a reduced cadence while descending, and decreased peak knee extensor moment during both ascending and descending, which is also suggestive of quadriceps avoidance. The authors claim that it could be due to a change in the location of the body’s center of mass (i.e., leaning the trunk more anteriorly would bring the center of pressure closer to the knee joint, reducing the external knee moment). Brechter and Powers [1] also examined knee joint kinematics and kinetics in ten patients with patellofemoral pain during ascending and descending. They also performed MRIs of the knee joint to estimate the patellofemoral contact area. They noted that there was a reduced cadence during both activities (as compared to a control group). During ascending there was a lower peak knee extensor moment. Although nonmeasured, the authors speculated that it could be due to a forward trunk lean that was observed. In addition, the patellofemoral joint reaction force was reduced during stair ascend. Finally they found that joint pressure during descending was greater than during ascending, which could explain the greater amount of pain reported by the patients during this activity. Grenholm et al. [11] also studied descending in women with patellofemoral joint pain and found that the knee joint angular velocity in the stance leg at foot contact was lower in such patients. In this study no difference in knee flexion was noted, which was also a finding supported by other studies [1, 4, 28, 30]. However, two studies reported reduced knee flexion [4, 10] during stair descent. Nadeau et al. [20] also demonstrated that there is decreased knee flexion during the stance phase of gait in patients with patellofemoral joint pain. It is of interest to note that Crossley et al. [3] improved knee flexion through taping and retraining of the vastii and hip muscle strengthening. The authors support that this improvement in kinematics is associated with the restoration of neuromotor control of the vastii (improvement in the onset timing of vastus medialis oblique relative to vastus lateralis).

In summary, no consensus has been achieved regarding the relationship between the vastus muscular activity and the onset of pain, or the abnormal movement of the patella [7, 13, 18, 24, 25, 27, 29, 32, 33, 40]. Interestingly, Powers et al. [27] found that patients with patellofemoral pain exhibit decreased activity of all vastus muscles during level walking and ramp ambulation and proposed the “quadriceps femoris muscle avoidance gait.” Quadriceps avoidance has also been identified in stair climbing [1, 30]. It has been advocated that it could be due to a forward trunk lean, which would bring the center of pressure closer to the knee joint. In addition no consensus exists regarding changes in knee flexion in patients with patellofemoral pain [1, 3, 4, 10, 20, 28, 30] while it has been shown that joint pressure is greater while descending than while ascending, which can explain the greater amount of pain reported by the patients during this activity [1].

13.2.2 Factors Concerning the Leg and Rear Foot

Tibial rotation can also affect patellar movement. Specifically, during external tibial rotation the tibial tuberosity moves laterally and the distal pole of the patella is pulled through the patellar tendon laterally. Therefore, external tibial rotation has been associated with patellofemoral disorders (i.e., instability and compression syndrome [7, 14]. External tibial torsion was also found greater than normal in patients with patellofemoral instability [38]. However, Seisler et al. [31] using fast-PC (dynamic) magnetic resonance imaging in healthy individuals performing knee flexion-extension (non-weight-bearing condition) showed that tibial external rotation did not predict lateral tilt of the patella. From these studies, it can be concluded that external tibial rotation may cause maltracking of the patella. However, further investigation is required in order to fully comprehend when and to which extent external tibial rotation has an actual impact on the tracking of the patella.

Tibial rotation, on the other end of the anatomic chain, is influenced by foot eversion and inversion. In particular, foot eversion is coupled to medial rotation of the tibia during the weight acceptance portion of the stance phase in running [22, 35]. In addition Nawoczenski et al. [21] studied the coupling pattern between tibial medial and lateral rotation and calcaneal eversion and inversion throughout stance phase in healthy individuals during treadmill running. They concluded that individuals with high arched feet showed magnitudes of rotations favoring tibial medial and lateral rotation over calcaneal eversion and inversion. In lieu of these findings, Dierks et al. [5] examined the relationship between arch structure and knee kinematics in runners after a prolonged run. However, no difference in arch height was noted between the runners with patellofemoral pain and the control group while no association was observed between arch height and peak knee adduction angle during running.

However, in a prospective study Thijs et al. [36] showed that runners who develop anterior knee pain have a heel strike in a less pronated foot position and roll over more on the lateral side as compared with healthy individuals. This decreased pronation results in decreased internal rotation of the tibia, thereby increasing the force applied on the patella by the quadriceps. These findings are in accordance with the findings of Duffey et al. [6]. The study by Thijs was followed by another prospective study that included 102 healthy recreational women runners. They examined the static standing foot posture of the subjects and the plantar pressure during running. Seventeen runners developed patellofemoral pain. These runners exhibited significantly higher vertical peak force underneath the lateral heel and at the second and third metatarsal. The authors suggested that these features may be linked to disproportionate impact shock during heel strike and at the propulsion phase of running which may lead to the development of patellofemoral pain. Importantly, Grenholm et al. [11] studied descending in women with patellofemoral joint pain and showed greater plantar flexion in the swing leg in preparation for foot placement, which was interpreted as a compensatory mechanism. From these studies, it can be concluded that modification in the biomechanics of the rear foot can actually have an effect on the biomechanics of the knee joint since it has been shown that during running increased inversion (less pronation and higher vertical peak forces underneath the lateral side of the foot) may be associated with the development of patellofemoral pain.

Concerning patella subluxation, Paulos et al. [23] used gait analysis to compare the results of derotational high tibial osteotomy and Elmslie-Trillat-Fulkerson proximal distal realignment procedures in patients with patella instability. They found that the patients that had undergone Elmslie-Trillat-Fulkerson proximal distal realignment spent less time on the surgical limb (shorter single-stance and longer double-stance phases). In addition, they exhibited less knee flexion at midstance. The amount of external rotation of the foot at heel strike was smaller in patients with high tibial osteotomy. These findings helped the authors confirm the superiority of derotational high tibial osteotomy, which also denotes the impact of tibial rotation in patella instability.

In summary, abnormal foot inversion during stance (less pronation and higher vertical peak forces underneath the lateral side of the foot) seems to have an effect on the development of patellofemoral pain in runners. In addition, tibial rotation may also cause maltracking of the patella. However, further investigation is required in order to elucidate the role of tibial rotation on the development of patellofemoral disorders.

13.2.3 Factors Concerning the Hip and Pelvis

Several scientists have also studied the other end of the kinetic chain and the relationship between patella disorders and hip and pelvis motion. Lee et al. [16] suggested that with internal femoral rotation, the lateral articular surface of the trochlea impinges upon the lateral articular facets of the retropatellar surface and thus pushes the patella medially. In a previous study [15], they demonstrated the relationship that exists between femoral rotation and patellofemoral pressure. However, significant increases in patellofemoral pressure were noted in femoral rotation greater that 20°. Therefore it is possible that there is an association between patellofemoral joint disorders and alterations of the biomechanics of the hip joint.

Mascal et al. [17] presented two patients with patellofemoral pain who were treated with an exercise program targeting the pelvis, hip and trunk musculature. Before treatment they both exhibited excessive hip adduction during weight acceptance, excessive internal hip rotation in early midstance and notable contralateral pelvic drop during midstance, while walking. Hip adduction, internal rotation (in the stance limb) and contralateral pelvic drop were noted in the step-down task as well. All these factors, as well as symptoms, were improved after treatment focusing on recruitment and endurance training of the hip pelvis and trunk musculature. Weakness in hip abduction and external rotation has been identified in females with patellofemoral pain using isometric strength measurement [12]. Willson and Davis [41] showed that in women with patellofemoral pain during single leg squat there is medial displacement of the knee which is associated with increased hip adduction and knee external rotation. Souza [34] also showed that there is increased internal femoral rotation in the same population during running, drop jump, and step-down movements. They also noted that this population is characterized by decreased hip muscle strength. However, they recorded increased gluteus maximus muscular activity. This was interpreted as recruitment of a weakened muscle perhaps in an effort to stabilize the hip joint.

Powers et al. [26] performed dynamic imaging of the patellofemoral joint using MRI in six female patients with lateral subluxation of the patella during knee extension (non-weight-bearing condition) and squatting (weight-bearing condition). Abnormal patellofemoral kinematics was noted during terminal knee extension in both tasks. In addition lateral patellar displacement was more pronounced during the non-weight-bearing knee extension as compared to weight bearing knee extension. This study demonstrated that in the non-weight-bearing task the patella rotates on the femur, while in the weight-bearing task the femur rotates underneath the patella, which emphasizes the role of femoral rotation on patellar malalignment.

Dierks et al. [5] examined the relationship between hip strength and hip kinematics in runners with patellofemoral pain before and after a prolonged run. They showed that there is a decrease in hip abductor and external rotator strength at the end of the run. In addition, this decrease in hip abductor strength is associated with an increase in hip adduction. Salsich et al. [30] showed that there are alterations in the activity of hip extensors in patients with patellofemoral pain during stair ambulation, which according to the authors seems to be a compensatory mechanism.

In summary, abnormal hip biomechanics are encountered in patients with patellofemoral pain. Specifically, increased hip adduction and femoral internal rotation have been observed in such patients during walking, running, drop jump, and step-down. In addition muscle strength measurements have demonstrated weak hip abductors and external rotators. Increased hip internal rotation seems to be implicated in patella subluxation as well. However, further studies are required to identify the hip joint biomechanics that exist not only in patients with patellofemoral pain but especially in patients with patellofemoral instability. Only then we can clearly identify whether these alterations have a causative or compensatory role. In addition, long prospective studies will reveal any conditions that predispose one to patellofemoral pain or patella instability.

13.3 Conclusion and Future Directions

Patellar instability is a multifactorial problem. Its proper treatment either conservative or surgical requires the knowledge and understanding of all the static and dynamic factors that contribute to the stability of patellofemoral joint. Gait analysis studies using kinetic, kinematic, and EMG data have already been performed and specific mechanisms have been reported. Specifically, a “quadriceps femoris muscle avoidance” mechanism has been described in patients with patellofemoral pain during level walking, ramp ambulation and stair climbing. It has been advocated that it could be due to a forward trunk lean, which would bring the center of pressure closer to the knee joint. Another important finding of these studies is the involvement of the hip joint. Specifically, increased hip adduction and internal rotation have been observed in patients with patellofemoral pain during walking, running, drop jump, and step-down while muscle strength measurements have demonstrated weak hip abductors and external rotators. Moreover, increased hip internal rotation seems to be implicated in patella subluxation as well. Furthermore it has been shown, that external tibial rotation and increased inversion (less pronation and higher vertical peak forces underneath the lateral side of the foot) may also be associated with the development of patellofemoral disorders.

However, the field of the biomechanical evaluation in patellofemoral disorders has not been fully explored. For instance, no consensus has been achieved regarding the relationship between vastus muscles activity and the onset of pain, or the abnormal movement of the patella. This is also the case for knee flexion. The lack of research work is greater with respect to patellofemoral instability. Further studies are required in order to recognize the changes that exist in patellofemoral pain and patella instability and to discover whether these alterations have a causative or a compensatory role. In addition, long prospective studies will reveal any predisposing factors. The understanding of the mechanisms that lead to patellofemoral disorders as well as the results of studies that compare different surgical and rehabilitation techniques or just conservative measures will lead us to the ideal treatment of each patient.

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14 Iatrogenic Anterior Knee Pain with Special Emphasis on the Clinical, Radiographical, Histological, Ultrastructural and Biochemical Aspects After Anterior Cruciate Ligament Reconstruction Using Ipsilateral Autografts

Jüri Kartus, Lars Ejerhed, and Tomas Movin

14.1 Introduction

At the present time, arthroscopic ACL reconstruction is one of the most common surgical procedures in sports medicine. Every year, only in Sweden, approximately 4,000 procedures are performed according to the Swedish National ACL Register (www.aclregister.nu). After the introduction of the arthroscopic technique and the opportunity to perform reproducible replacements of the ruptured ACL, the results in terms of restored laxity and a return to sports activities have generally been found to be good. However, persistent donor-site morbidity such as tenderness, anterior knee pain, disturbance in anterior knee sensitivity and the inability to kneel and knee-walk is still a problem and is present in approximately 40–60%, of patients who have undergone arthroscopic ACL reconstruction using patellar tendon autografts [44]. Despite efforts to utilize synthetic materials [21] and allografts [36], the use of autografts probably remains the best option for the replacement of the torn ACL. Common autograft alternatives for reconstruction or augmentation of the ACL include the use of the hamstring tendons [11], the patellar tendon [22] and the quadriceps tendon [18, 32].

The amount of information about the donor site after the use of patellar tendon autografts is fairly extensive. Recently the amount of information about donor-site problems following the use of hamstring autografts has increased. The information describing the problems, which can occur after ACL reconstruction using quadriceps tendon autografts, has also increased recently.

The purpose of this work is to give an overview of the clinical, radiographic, histological, ultrastructural and biochemical aspects of the donor site and its problems after ACL reconstruction using patellar tendon, hamstring tendon and quadriceps tendon autografts.

14.2 Postoperative Restriction in Range of Motion and Loss of Strength

There appears to be agreement in the literature that the restoration of full extension compared with the noninjured side after ACL reconstruction is essential in order

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to avoid postoperative discomfort in the anterior knee region. Irrgang and Harner [34], and Kartus et al. [42] have stated that the loss of extension contributes to anterior knee pain. Recently Steadman et al. [72] reported that anterior scarring and flexion contracture after ACL reconstruction and other procedures caused anterior knee pain and could be successfully treated with arthroscopic release.

The influence of loss of flexion on anterior knee pain is controversial. Stapleton [71] and Kartus et al. [42] have stated that the loss of flexion causes significantly more anterior knee pain than the loss of extension. However, Irrgang and Harner [34] found that a loss of flexion rarely matters, unless the knee flexion is less than 110°.

Although these reports are all concerned with the use of patellar tendon autografts or allografts [34], we can generalize and state that the return of full range of motion (ROM) including full hyperextension is essential to reduce anterior knee problems after ACL reconstruction using any type of graft. However, the return of full range of motion might not always be possible. Kartus et al. [47] reported more pain and loss of motion both in flexion and extension after ACL reconstruction using both patellar tendon and hamstring tendon autografts if the patients underwent concomitant meniscal resection, than if the patients had intact menisci.

In line with this information, we recommend that it is essential to regain normal strength in the lower extremity to avoid future pain in the anterior knee region. Risberg et al. [64] have reported that pain and strength are the most important variables, which affect the results after ACL reconstruction using patellar tendon autografts. The corresponding can be said about regaining proprioception and neuromuscular control [79].

Several reports on strength deficits after ACL reconstruction using autografts are found in the literature. Muneta et al. [60] reported that the patients' subjective evaluation of the results after ACL reconstruction using either hamstring or patellar tendon autografts was worse if the quadriceps or hamstring strength was decreased compared with the contralateral side. Hiemstra et al. [33] reported that at 1 year the patients had substantial strength deficits in extension both after reconstruction using patellar tendon and hamstring tendon autografts. Feller et al. [26] reported a larger quadriceps peak torque strength deficit up to 1 year postoperative after harvesting the patellar tendon compared with harvesting the hamstring tendons. Adachi et al. [1] reported that the harvest of both semitendinousus and gracilis tendons causes more loss of active flexion angle and peak torque than the harvest of semitendinousus alone. After using quadriceps tendon autografts Lee et al. [51] reported a loss of quadriceps strength of 13% compared with the contralateral side at 1 year after surgery. At 3 years Lee et al. [50] reported approximately a 10% decrease of the peak torque compared with the contralateral side.

14.3 Dissection Studies in the Knee Region

Arthornthurasook and Gaew-Im [3] and Kartus et al. [38] (Fig. 14.1) have shown in dissection studies that the infrapatellar nerve is in danger when incisions are made close to or above the tibial tubercle and the medial side of the knee joint. Kartus et al. dissected 60 knees and found that in 52/60 specimens the infra patellar nerve passed between the tibial tubercle and the apex of the patella as one or two branches which could be jeopardized during patellar tendon harvest [38].

In a dissection study of 40 cadaver knees Boon et al. [9] have recommended using oblique incisions medial to the tibial tubercle when harvesting hamstring

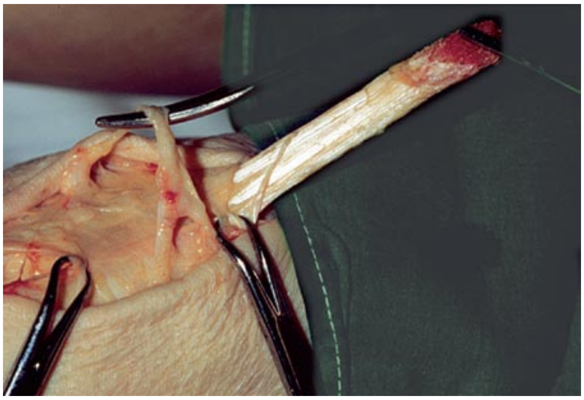

Fig. 14.1 The infrapatellar nerve splits into two branches, right in the center of a central anterior 8 cm incision. The towel clamps indicate the paratenon. The patellar tendon autograft in this specimen was harvested using the two-incision technique with the aim of sparing the infrapatellar nerve(s) and the paratenon. In this specimen, the two incisions have subsequently been conjoined in order to examine the result of the harvesting procedure [35] (Copyright Elsevier Publication, published with permission)

tendons to avoid sensory nerve damage. Sanders et al. [68] dissecting 11 specimens found that the saphenous nerve was “intimately involved” with the gracilis tendon approximately 10 cm proximal to its insertion. Correspondingly, medial knee incisions even during hamstring harvest can jeopardize the saphenous nerve [68].

14.4 Knee Surgery and Sensory Nerve Complications

Johnson et al. [37] and Swanson [73] have described postoperative morbidity, such as numbness and problems with kneeling, after injury to the infrapatellar branch(es) of the saphenous nerve after open medial meniscectomies. Ganzoni and Wieland [29] have shown a difference in postoperative sensory loss, depending on whether the infrapatellar nerve(s) were protected during medial knee arthrotomies.

Mochida and Kikuchi [58] have described the possibility of injury to the infrapatellar nerve(s) during arthroscopic surgery and Poehling et al. [62] have described the development of reflex sympathetic dystrophy after sensory nerve injury in the knee region. The importance of the sensory nerves in the knee region was further stressed in the reports by Gordon [31] and Detenbeck [19] on prepatellar neuralgia after direct impacts to the anterior knee region. Slocum et al. [69] have discussed the possibility of damage to the nerves in the anterior knee region during a pes anserinus transplantation, which requires an incision similar to the one used for harvesting hamstring tendon autografts.

There are a few reports in the literature with regard to discomfort after injury to the infrapatellar nerve or its branches in conjunction with ACL surgery. Berg and Mjöberg [6] have reported that the difficulty in kneeling was correlated with the loss of sensitivity in the anterior knee region after open knee ligament surgery and they, therefore, recommend a lateral parapatellar skin incision. In two studies involving 90 [45] and 604 [42] patients respectively Kartus et al., have reported that the inability to kneel and knee-walk after arthroscopic ACL reconstruction using patellar tendon autografts harvested through a 7–8 cm vertical incision was correlated with the area of disturbed or lost anterior knee sensitivity (Fig. 14.2). Kartus et al. [38] further, presented a method using two 25 mm vertical incisions to reduce the risk of injury to the infrapatellar nerve(s) when harvesting patellar tendon autografts (Fig. 14.3). This technique was first tested in cadavers

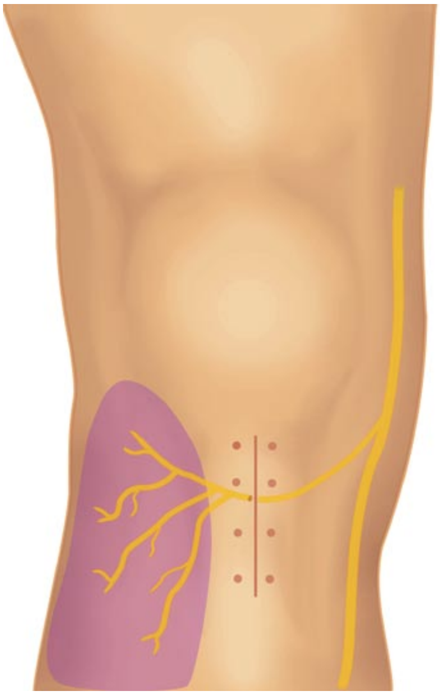

Fig. 14.2 After the use of a central one-incision technique to harvest a patellar tendon autograft, the discomfort during the knee-walking test correlated with the area of disturbed sensitivity in the anterior knee region [39, 42] (Redrawn with permission from Catarina Kartus, published with permission)

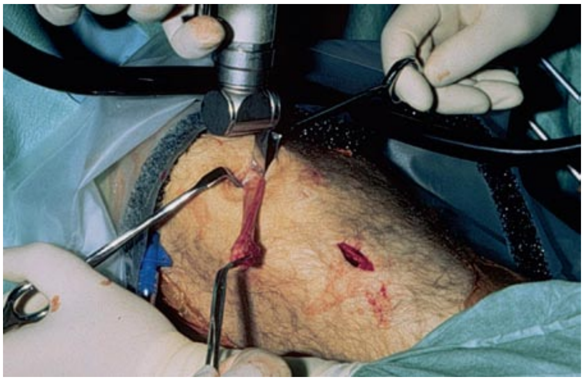

Fig. 14.3 The use of the two-incision technique to harvest a patellar tendon autograft resulted in less discomfort during the knee-walking test than the use of the central one-incision technique (Copyright Elsevier Publication, published with permission)

[38] and was subsequently proven in two clinical studies [39, 41] to produce less loss of sensitivity and a tendency towards less knee-walking discomfort than the use of a vertical 7–8 cm incision.

When hamstring tendon autografts are harvested, a branch of the infrapatellar branch of the saphenous nerve might also be jeopardized and occasionally numbness in the skin area supplied by the saphenous nerve may also occur [27, 68]. Bertram et al. [8] in a case report described saphenous neuralgia after arthroscopically assisted ACL reconstruction using semitendinous and gracilis tendons. Eriksson [23] as well as Ejerhed et al. [20] have shown that the area of disturbed sensitivity after harvesting either semitendinosus or patellar tendon autografts is comparable. However, both studies suggested that the area of disturbed sensitivity after harvesting semitendinosus autografts is of less clinical importance.

It appears that the same amount of disturbance in sensitivity in the knee region after harvesting hamstring tendon autografts causes fewer kneeling and knee-walking difficulties than after harvesting patellar tendon autografts. This can be due to the fact that, after patellar tendon harvest, the pressure when kneeling is applied directly on or close to the incision where the injured nerve is located as suggested by Ejerhed et al. [20]. Spicer et al. [70] have reported that sensory changes in the whole anterior knee region after hamstring tendon harvest are possible and 50% of their patients reported such changes. However, this rarely limited the activity of their patients. Sanders et al. [68] reported that 74% of their patients had sensory disturbance after hamstring tendon harvest during ACL reconstruction, which is higher than previously reported.

After harvesting quadriceps tendon autografts, the risk of nerve injuries appears to be low and no such reports are found in the literature to our knowledge.

Naturally these findings have implications for other surgical procedures in the anterior knee region such as patellar stabilization and knee replacements.

14.5 Local Discomfort in the Donor-Site Region

In a prospective, randomized study, Brandsson et al. [10] have shown that suturing the patellar tendon defect and bone grafting the defect in the patella did not reduce anterior knee problems or donor-site morbidity. It therefore appears that suturing and bone grafting the defects after patellar tendon harvest is of minor importance when it comes to reducing donor-site problems. Tsuda et al. [77], on the other hand suggested bone grafting of the defects in order to decrease donor-site problems. However, in their study the grafts were harvested subcutaneously and no control group was available.

Kartus et al. [39] reported that 65% of the patients had difficulty or were unable to perform the knee-walking test 2 years after patellar tendon harvest using a central vertical 7–8 cm incision. The corresponding value after the use of a two-incision technique with the aim of sparing the infrapatellar nerve(s) was 47% [39]. Rubinstein et al., [66] found that the isolated donor-site morbidity was negligible after ACL surgery, when the contralateral patellar tendon was used as a graft. In contrast Mastrokalos et al. [56] found that more than 70% of the donor knees had knee-walking problems regardless of whether the patellar tendon graft was harvested from the ipsi- or contralateral side.

Preoperatively, as well as 2 years after the use of hamstring autografts, approximately 20% of the patients reported that they had difficulty or were unable to perform the knee-walking test as shown by Ejerhed et al. [20] in their prospective randomized trial. In a randomized study Feller and Webster [26] reported that 67% of patients operated on using patellar tendon autografts and only 26% of patients operated on using hamstring tendon grafts had kneeling pain at 3 years after surgery. These findings suggest that the use of hamstring autografts causes only minor morbidity in the anterior knee region compared with the use of patellar tendon autografts. However, Liden et al. [53] in a randomized study involving 68 patients reported that after approximately 7 years, the difference in donor-site morbidity was no longer statistically significant between patellar tendon autografts and hamstring tendon autografts. It appears that in the long term the subsequent development of degenerative changes in the patellofemoral joint and the knee joint means more than the choice of graft for anterior knee pain.

Chen et al. [14] reported that 1 in 12 patients had mild harvest-site tenderness after an average of 18 months, and in another study they reported the corresponding in 3/34 patients at 4–7 years [15]. Fulkerson and Langeland [28] reported no early quadriceps tendon morbidity in their series of 28 patients. Lee et al. [51] reported 12% moderate or severe anterior knee pain in their study involving 67 patients. In another study Lee et al. [50] reported that only 1/247 patients had moderate harvest-site tenderness at approximately 3 years after the index procedure. De Angelis and Fulkerson [18] have stated that the quadriceps tendon autograft "may be the least morbid of the currently used ACL autograft reconstruction alternatives" Gorschewsky et al. [32] reported that the use of quadriceps tendon autograft for ACL reconstruction renders significantly less donor-site problem than the use of patellar tendon autograft in controlled studies.

14.6 Radiographic Assessments

Reports by Coupens et al., [16] Meisterling et al. [57], Kartus et al. [46] and Svensson et al. [75] using MRI assessments of the patellar tendon at the donor site have all shown that the thickness of the patellar tendon increases, at least up to 6 years postoperatively, irrespective of whether the defect is sutured. Wiley et al. [78] and Kartus et al. [43] have made corresponding findings using ultrasonography 1–2 years after the harvesting procedure.

Reports in the literature on the healing of the donor-site gap in the patellar tendon after harvesting its central third and leaving the defect open are contradictory. Using MRI assessments, Berg et al. [5] and Nixon et al. [61] claimed that the defect had healed, 8 months and 2 years respectively after the index operation. Rosenberg et al. [65] have demonstrated persistent defects using CT and MRI, approximately 2 years after the index operation. Kartus et al. have found persistent defects in studies using MRI [40, 45] and in one study using ultrasonography [43] after leaving the defect open. However, even if the defect was still present 2 years after the harvesting procedure it showed a significant decrease over time in the prospective studies by Kartus et al. [40] and Bernicker et al. [7] using MRI and by Wiley et al. [78] using ultrasonography. After 6 years the defect had healed in the majority of patients, however, a thinning of the central part of the tendon was still present as shown by Svensson et al. [75] in a prospective long-term study of 17 patients (Fig. 14.4a–d). Correspondingly Liden et al. [52] found radiographic abnormalities and a persistent defect using MRI 10 years after reharvesting the patellar tendon autograft. Kartus et al. [41, 45] have shown that the kneeling and knee-walking problems did not correlate with any MRI findings in the patellar

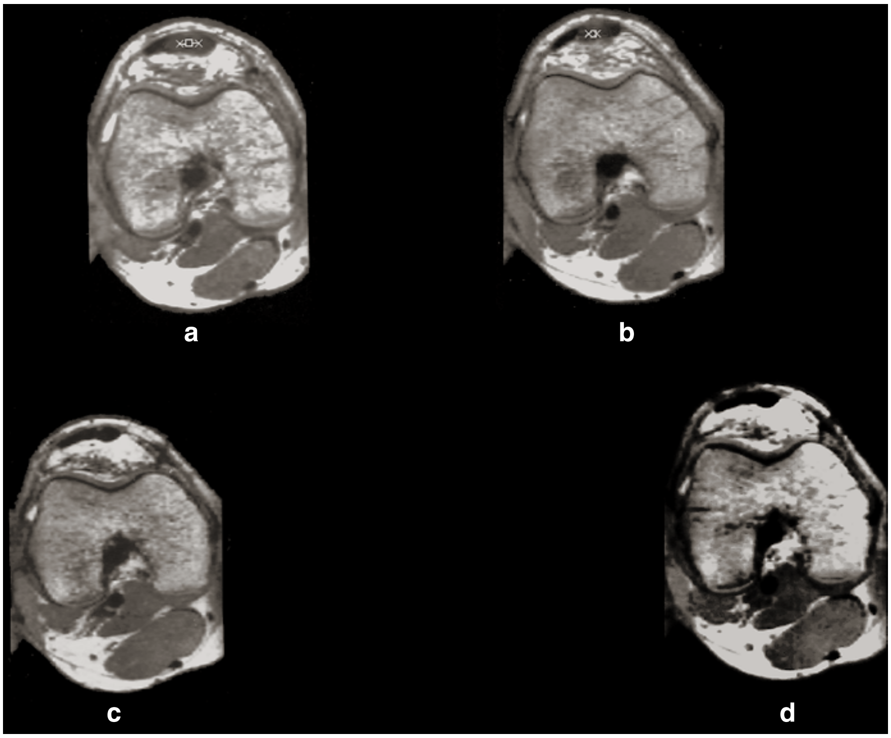

Fig. 14.4 (**a**–**d**) The serial MRI examinations demonstrate that the donor-site gap was 7 mm at 6 weeks, 2 mm at 6 months and completely healed at 27 and 6 years. Furthermore, the thickness of the patellar tendon decreased over time. This is a male patient who, at the time of the index operation, was 18 years old (Copyright Jüri Kartus, published with permission)

tendon at the donor site. The corresponding finding in terms of patellar tendon pain was made by Kiss et al. [49], using ultrasonography.

After harvesting hamstring tendon autografts, it appears that there is at least some regrowth in the semitendinousus and gracilis tendons as reported by Cross et al. [17] and Eriksson et al. [24, 25] using MRI. However, the insertion of the tendons appears to be approximately 3–4 cm more proximal compared with the normal anatomic position.

Lee et al. [50] reported that the thickness of the quadriceps tendon at the donor site was significantly increased compared with the preoperative findings until 24 months postoperatively as seen on MRI.

14.7 Histological Examinations

Reports on donor-site histology in humans are few in number [4, 5, 43, 61]. Histological descriptions of the donor-site area after ACL reconstruction using central patellar tendon autografts in a goat model have been given by Proctor et al. [63] They found ill-defined fascicles, woven collagen fibrils, poorly aligned with the longitudinal axis of the patellar ligament, in the central part of the tendon 21 months after the harvesting procedure. Correspondingly, in a study of lambs, Sanchis-Alfonso et al. [67] found that the regenerated tissue in the harvest-site defect did not have the histological appearance of normal patellar tendon. In a dog model, Burks et al. [13] found that the entire patellar tendon was involved in scar formation 3 and 6 months after harvesting its central third. In contrast, Nixon et al. [61] obtained biopsies from two patients 2 years after the harvesting procedure and found tissue that was indistinguishable from normal tendon using polarized light microscopy. Battlehner et al. [4] obtained open biopsies from eight humans, a minimum of 24 months after ACL reconstruction using patellar tendon autografts and found using light microscopy that the patellar tendon did not regain the appearance of normal tendon. However, in their study the donor-site gap was closed during the ACL reconstruction. In a biopsy study of 19 patients, 27 months after harvesting the central third of the patellar tendon and leaving the defect open, Kartus et al. [43] revealed tendon-like repair tissue in the donor site. However, histological abnormalities in terms of increased cellularity, vascularity and nonparallel fibers were present in both the central and peripheral parts of the tendon. The same patients underwent biopsies once again at 6 years after the harvesting procedure and still the same pathology was found [74]. No correlation between the histological findings and the donor-site discomfort was found (Figs. 14.5 and 14.6) (Kartus et al. 2005).

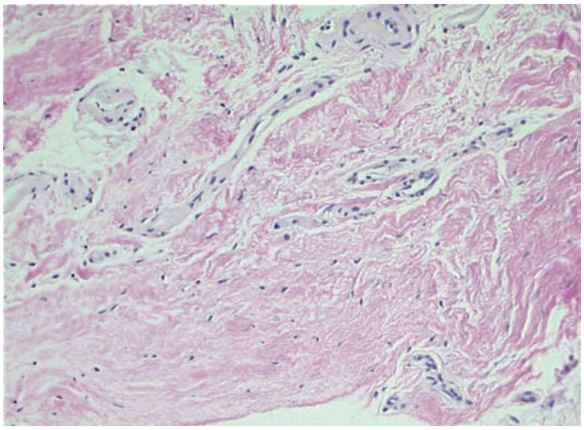

Fig. 14.5 A high-power view of a biopsy obtained from the central part of the patellar tendon 6 years after the harvesting procedure showing increased cellularity, vascularity and nonparallel fibers [43] (Hematoxylin and eosin staining; original magnification, ×200) (Copyright Springer Verlag)

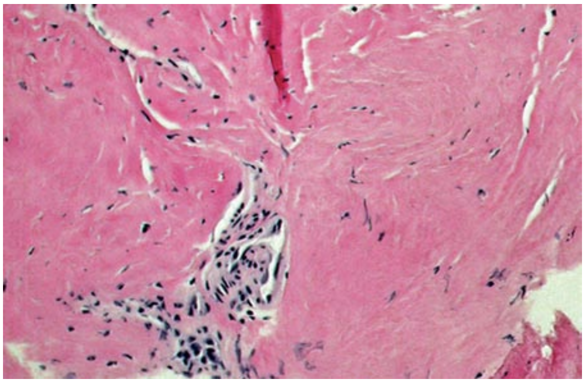

Fig. 14.6 A high-power view of a biopsy obtained from the peripheral part of the patellar tendon 6 years after the harvesting procedure showing increased cellularity, vascularity and nonparallel fibers [43] (Hematoxylin and eosin staining; original magnification, ×200) (Copyright Springer Verlag)

The finding of histological abnormalities in the human patellar tendon up to 6 years after the primary harvest strongly suggests that reharvesting the central third of the patellar tendon cannot be recommended.

Moreover, in a clinical study by Kartus et al. [46] patients who had undergone revision ACL reconstruction using reharvested patellar tendon autograft displayed significantly worse results, especially in terms of anterior knee problems, than patients in whom the contralateral patellar tendon autograft was used. The patients in the above study by Kartus et al. [46] who underwent revision ACL surgery using reharvested patellar tendon autograft were re-examined by Liden et al. both clinically [52] and histologically [54] 10 years after the reharvesting procedure. At 10 years the clinical results were bad and an abnormal histology with an increase cellularity and vascularity as well as a deteriorated fiber structure were found both in the central and the peripheral part of the tendon.

Eriksson [24] obtained open biopsies from the regenerated tendon in five humans at a mean 20 months after the harvest of a semitendinosus autograft. Surprisingly, the biopsies revealed tissue resembling normal tendon. Interestingly in a rabbit model Gill et al. [30] found normal cellularity and collagen I, 9–12 months after harvesting the semitendinosus tendon.

No histological data from the donor site after harvesting quadriceps tendon autografts are available to our knowledge.

14.8 Ultrastructural Examinations

Proctor et al. [63] in a goat model reported abnormal tissue composition when biopsies were evaluated ultrastructurally in the transmission electron microscope (TEM), 21 months after the harvesting procedure. Correspondingly, Battlehner et al. [4] reported that the patellar tendon in humans does not restore *ad integrum* a minimum of 2 years after harvesting its central third. Svensson et al. [76] reported that the patellar tendon did not regain a normal ultrastructure as seen on biopsies examined in TEM 6 years after the harvesting procedure. The fibrils were less regularly oriented and significantly more small fibrils compared with normal control tendons were found (Figs. 14.7a–c, 14.8a–f). The corresponding was found by Liden et al. [54] 10 years after reharvesting the central third of the patellar tendon.

Taken together, there is evidence in the literature to suggest that the patellar tendon does not regain normal ultrastructure after harvesting or reharvesting its central third in both animals and humans, at least not up to 10 years.

In a rabbit model using the electron microscope Gill et al. [30] found "regeneration of organized collagen tissue that simulated native tendon, but with a smaller cross-sectional diameter" 9–12 months after harvesting the semitendinosus tendon.

No ultrastructural data from the donor site after harvesting quadriceps tendon autografts are available to our knowledge.

14.9 Biochemical Investigations

Sulfated glycosaminoglycans (GAGs) possess a very high water-retaining capacity and they appear in low concentrations in the normal patellar tendon [2].

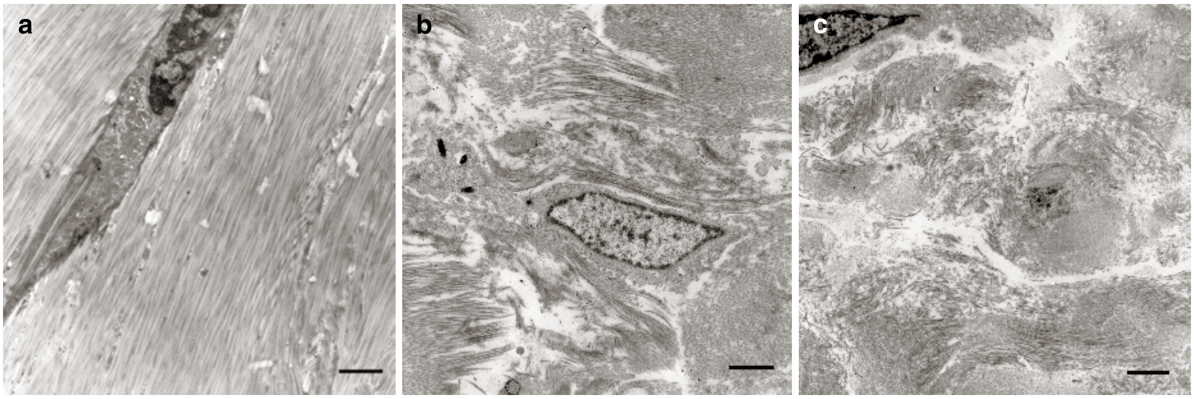

Fig. 14.7 Transmission electron micrographs from control tendons (**a**), lateral parts (**b**), and central parts (**c**) of the tendons in the study group 6 years after the harvesting procedure. The fibrils were less regularly orientated in both the central and lateral part of the harvested tendon compared with normal tendon (bar = 2 µm, original magnification, ×3,000) (Copyright Jüri Kartus, published with permission)

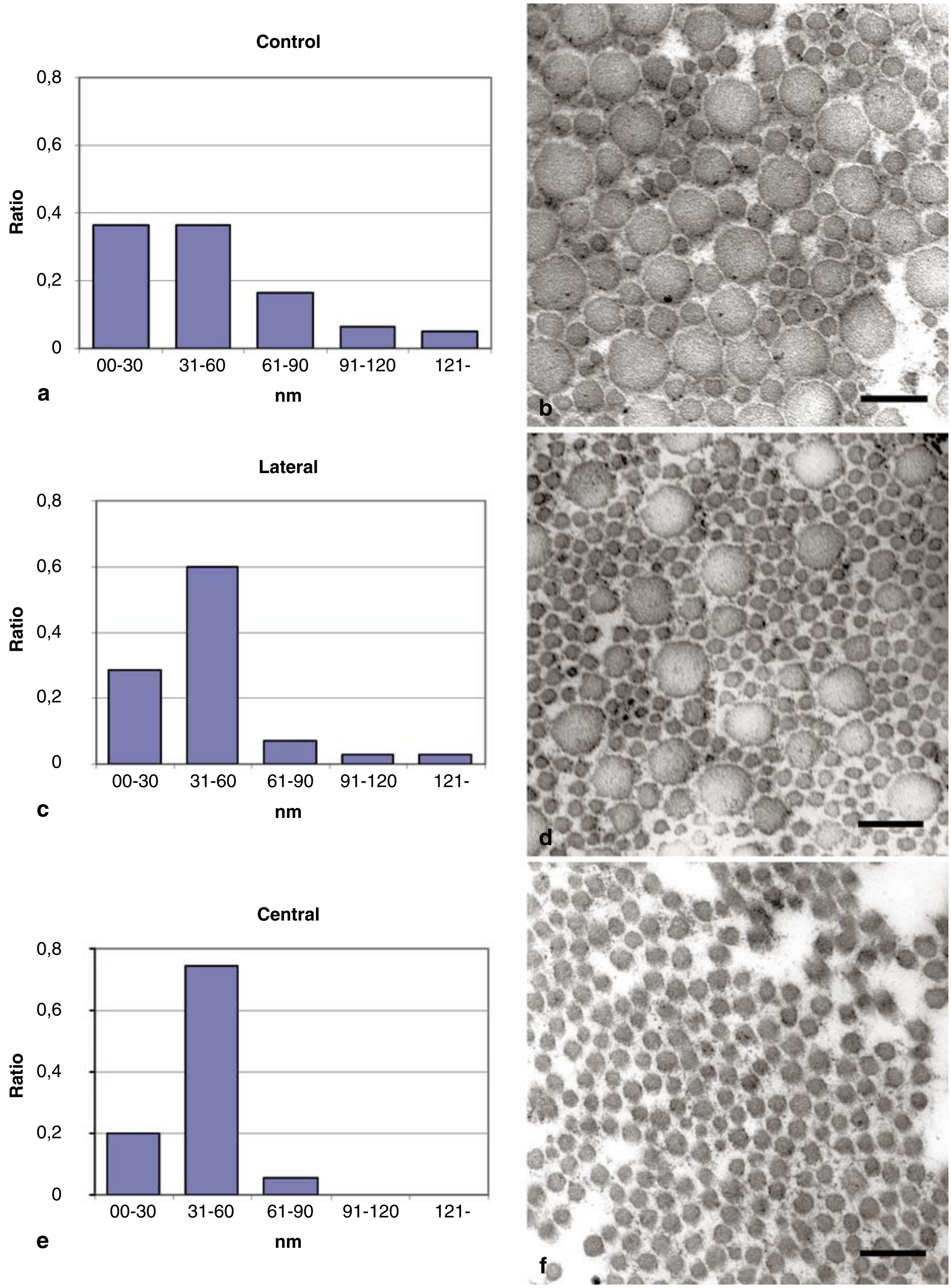

Fig. 14.8 Relative distribution and transmission electron micrographs of the fibril diameter size in human patellar tendon from controls (**a** and **b**), lateral (**c** and **d**), and central parts (**e** and **f**) 6 years after the harvesting procedure (bar = 200 nm, original magnification, ×101,000). These figures show that there was a significant difference in fibril size distribution between the groups which was more heterogenous in the control group [76] (Copyright Jüri Kartus, published with permission)

Increasing concentrations of GAGs are seen in areas of tendons which are subjected to compression forces, as described by Vogel et al. [80] in pathological scar tissue in the Achilles tendon, as described by Movin et al. [59] and in the patellar tendon in "jumper's knee" (tendinosis) disease, as described by Khan et al. [48] Kartus et al. [43] showed that there were undetectable amounts of GAGs in the biopsies obtained from the patellar tendon at 27 months after the harvesting procedure. The corresponding finding at 6 years was reported by Svensson et al. [74] This suggests that factors other than retained water contributed to the increase in the cross-sectional area of the patellar tendon. Therefore, in terms of the GAG content the repair tissue did not display similarities with the tendon pathology that has been found in achillodynia and jumper's knee [48, 59]. Correspondingly Liden et al. [54] reported that at 10 years after reharvesting the central third of the patellar tendon no increase in the amount of GAGs was found compared with normal control tendon.

The presence of collagen type III is associated with early collagen synthesis in a repair process in tendons, as described by Liu et al. [55] in rat models. Collagen type III has the capacity rapidly to form cross-linked intermolecular disulphide bridges [12]. This capacity is supposed to be a great advantage in the development of repair tissue [12]. Collagen type III fibers are also known to be thin, with inferior mechanical properties, compared with collagen type I. Kartus et al. [43] failed to demonstrate increased amounts of collagen type III in the central and peripheral parts of the patellar tendon, which indicates that no early collagen synthesis was present 27 months after the harvesting procedure.

Eriksson has shown that the immunoreactivity for collagen types I and III in regenerated semitendinousus tendon was similar to that of normal tendon at mean 20 months after the harvesting procedure [23, 24].

14.10 Summary Statement

- Reduced strength and loss of ROM are correlated with anterior knee pain after ACL reconstruction using all kinds of autografts.
- Efforts should be made during the surgical procedure and the rehabilitation process to regain full ROM and full strength.
- Intraoperative injury to the infrapatellar nerve(s) in conjunction with patellar tendon and hamstring tendon harvest should be avoided.
- Due to long-term radiographical, histological and ultrastructural abnormalities in the patellar tendon after primary harvest, reharvesting cannot be recommended.
- Prospective randomized studies have shown that the use of hamstring tendon autografts for ACL reconstruction produce laxity restoration comparable to patellar tendon autografts, the authors recommend the use of hamstring tendon autografts due to fewer donor-site problems.

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Non-operative Treatment of Patellofemoral Pain: Role of Physical Therapy

15

Andrew D. Lynch, Suzanne Werner, and Lynn Snyder-Mackler

Nonoperative treatment of patellofemoral pain has been the subject of numerous research reports in the literature. Nonoperative treatment includes education, exercise including quadriceps strengthening, patellar taping and bracing and foot orthoses as the primary attempts at management of anterior knee pain. When these treatment attempts fail, potential surgical management is then considered.

Systematic reviews on the topics of bracing, taping and exercise therapy for the treatment of patellofemoral pain have been conducted, however, limited conclusions were able to be drawn from these reviews [2, 29, 42, 88]. The majority of published material on nonoperative treatment of PFPS has focused on patellar bracing and taping, exercise and physical therapy and the use of foot orthoses to attempt to alleviate pain and restore patients to full-functioning status.

The specific evaluation of each aspect that potentially contributes to knee pain has been supported in the literature [5, 98]. Due to the variety of treatment options available to address patellofemoral pain, Witvrouw et al. published a classification system on the behalf of the European Rehabilitation Panel to attempt to guide nonoperative management [98]. As each patient presents with a unique set of impairments, each patient will require a unique treatment program. The areas of assessment proposed by Witrouw are divided into issues of alignment and muscular dysfunction. Alignment should be assessed from the aspect of the patellofemoral joint itself and the lower extremity as a whole. Muscular dysfunctions are subdivided into strength deficits, neuromuscular deficits and impaired flexibility. While this classification has not been validated in the literature, treatment aspects which address each of these deficits have been investigated.

Comprehensive evaluations have been suggested [81] to include measurements such as Q-angle, leg length, knee, hip and ankle range of motion, rear foot angles, arch height indices, and radiographic features of the patella although no differences were noted between subjects with and without symptoms [82]. A systematic review of the potential risk factors for developing patellofemoral pain syndrome yielded conflicting evidence for the diagnostic accuracy of foot morphometry, lower extremity muscle tightness, lower extremity weakness and patellar mobility and positioning [89].

Correlations have been reported between tightness of the hamstring and quadriceps muscles and patellofemoral pain [62, 74, 93]. Tightness of the lateral muscle structures such as the tensor fascia lata and iliotibial band is also associated with patellofemoral pain [32, 44, 69]. Correlational studies have also linked patellofemoral pain to lateral patellar structure restrictions, impaired patellar mobility, hip musculature weakness and foot morphometry, however causation has not been shown [19, 39, 45, 50, 52, 70]. While authors propose the use of the quadriceps angle as an indicator of patellofemoral dysfunction, the validity and reliability of the measurement are in question [75] and the effect of height may account for the difference between genders [89].

Functional tests have been proposed as a measure of lower extremity performance, and four functional

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tests have been shown to be reliable and to have a high correlation with pain – the step-down test, the antero-medial lunge, the single leg press and the balance and reach test. These tests challenge multiple aspects of lower extremity performance and give a representation of the overall function of the lower extremity [48].

Patients with patellofemoral pain often present with a weakened quadriceps muscle [90]. Manual muscle testing performed as a side to side comparison solely gives a rough awareness of quadriceps strength, while an isokinetic measurement gives a considerably more reliable result [60]. However, isokinetic testing must be carried out cautiously [37] and it seems prudent to recommend submaximal warm-ups prior to maximal testing [60]. Furthermore, in order to obtain valid torque results, e.g., obtaining torque produced by muscle contraction during resisted movement, the isokinetic record has to be corrected for the effect of gravitational force due to weight of the limb and the lever arm, which aids movement during knee flexion and opposes during knee extension [38]. It should be pointed out that patients with patellar hypermobility should not be measured eccentrically during fast angular velocities (>90°/s) due to risk of subluxation or even dislocation [91]. In order to make sure that pain inhibition does not interfere with a "true" muscle torque value twitch interpolation technique could be added during the isokinetic measurements [53]. Borg's pain scale [11] or the visual analogue scale [16, 36, 68] are other methods to evaluate possible interference of pain.

Alternatively, isometric evaluation of muscle torque is also a valid option. Using an isometric dynamometer, consistent and reliable measurements of quadriceps torque can be made. With the addition of electrical stimulation via a burst superimposition or twitch interpolation technique, inhibition can be quantified. Summaries of these techniques can be found in the work of Rutherford [71] and Snyder-Mackler [76]. The choice of isometric angle for testing should be based on patient comfort. Sixty degrees provides the optimal length tension relationship of the quadriceps, however at this angle, a significant amount of the patellar surface is in contact with the femur, potentially causing pain. An angle of pain free testing should be sought, typically into more extension, however, this will be patient specific. Extra care should be taken in those patients who have impaired medial stability or those who have had an episode of patellar luxation, as this will pre-dispose them to recurrent instability. To maximize safety, an increase in knee flexion angle should be used to further seat the patella in the trochlear groove.

15.1 Patellar Bracing and Taping

One theoretical cause of patellofemoral pain is a static malpositioning of the patella which leads to dynamic maltracking of the patella in the trochlear groove. McConnell suggested three aspects of patellar misalignment that could contribute to patellofemoral pain: glide, tilt and rotation (see Figs. 15.1, 15.2 and 15.3 from Aminaka and Gribble). McConnell also proposed the use of tape to exert a force on the patella to improve alignment and tracking, therefore decreasing pain [52]. The use of corrective taping has thus become known as McConnell taping. Additionally, braces have been constructed to impose a similar force (Fig. 15.5). As a

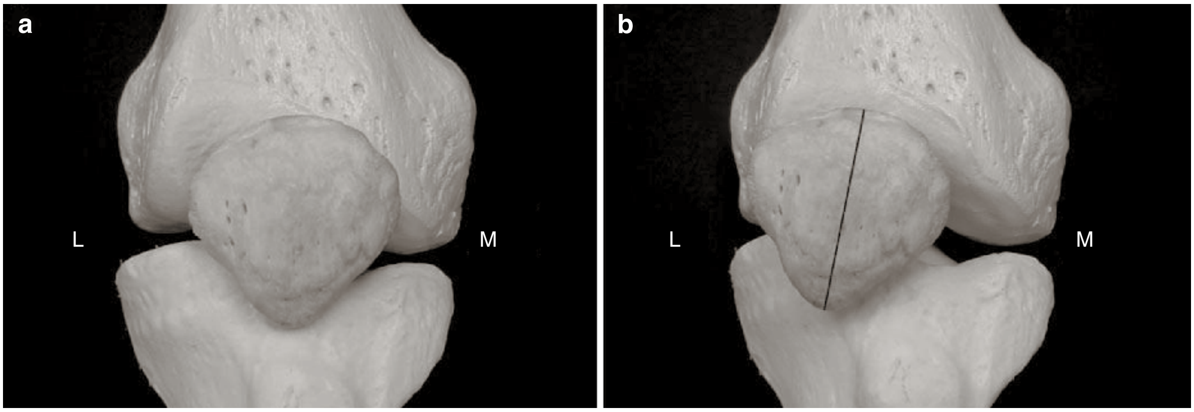

Fig. 15.1 (**a**) A patella in neutral alignment. (**b**) Laterally positioned patella (From [2])

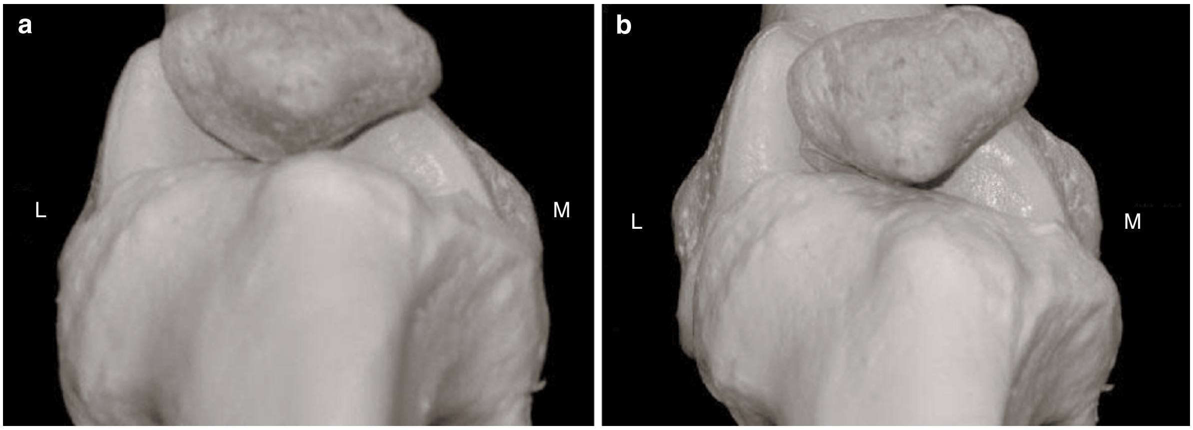

Fig. 15.2 (**a**) A patella in neutral alignment. (**b**) Laterally tilted patella (From [2])

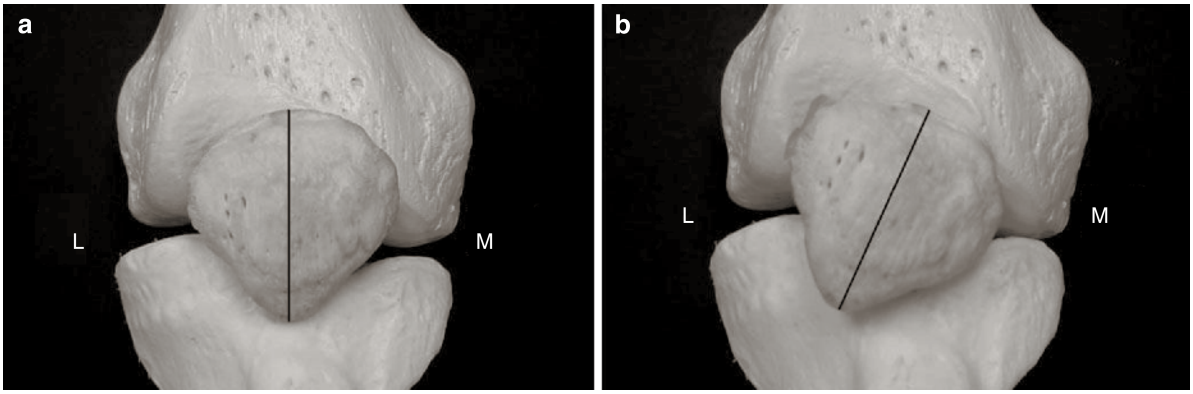

Fig. 15.3 (**a**) A patella in neutral alignment. (**b**) Laterally rotated patella (From [2])

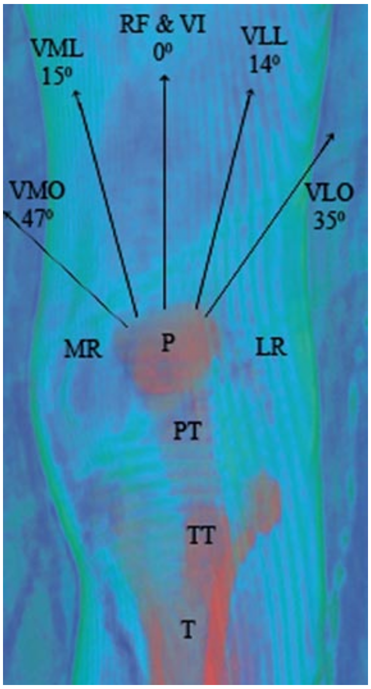

Fig. 15.4 Line of action for the quadriceps (From [89])

general concept, the brace or tape is meant to correct a patella with a pathological physical position, including rotation, glide or tilt, usually trying to medialize the patella [66] (see Fig. 15.5 – Medial Patellar Taping). In a systematic review of articles concerned with the ability of tape to produce alterations in patellar positioning, Aminaka and Gribble found conflicting evidence for the physical relocation of the patella after taping, with many studies showing no difference after the application of tape [2, 8].

Also frequently implicated in the etiology of patellofemoral pain syndrome is the relative activation of the vastus medialis and the vastus lateralis. Theoretically, the delayed onset muscle timing of the vastus medialis creates a preferential lateral pull of the vastus lateralis, thus disrupting the tracking of the patella[15, 24, 52] (see Fig. 15.4 for the relative pull of each head of the quadriceps). There is conflicting evidence in the published research in support of [23, 24, 28] and against altered timing [12, 51]. The results of a systematic review and meta-analysis on this topic by Chester et al.

Fig. 15.5 Medial patellar taping of right knee. Begin with tape on lateral aspect of knee and pull medially

resulted in no significant findings in this area, although there was a trend toward delayed onset of vastus medialis muscle firing [15]. Similarly, there is contradictory evidence in the research performed on the effects of taping and bracing on muscle timing. Some authors support the notion of changes with taping [22] and some do not [26].

While the ability of taping and bracing to produce altered patellar positioning or neuromuscular timing is in question, its ability to provide pain relief is well established. In a study of British Army recruits, Whittingham et al. investigated the effect of daily patellar taping with exercise, sham taping with exercise and exercise alone on pain and a self-report questionnaire, the Functional Index Questionnaire. Pain was reported on a VAS for average pain in the last 24 h and during an 8 in. step test with and without tape (see Fig. 15.6). While pain in all conditions in all three groups decreased across the 4 weeks of the study, at weeks 2, 3 and 4, the group with a medial taping showed significant improvements over the other two

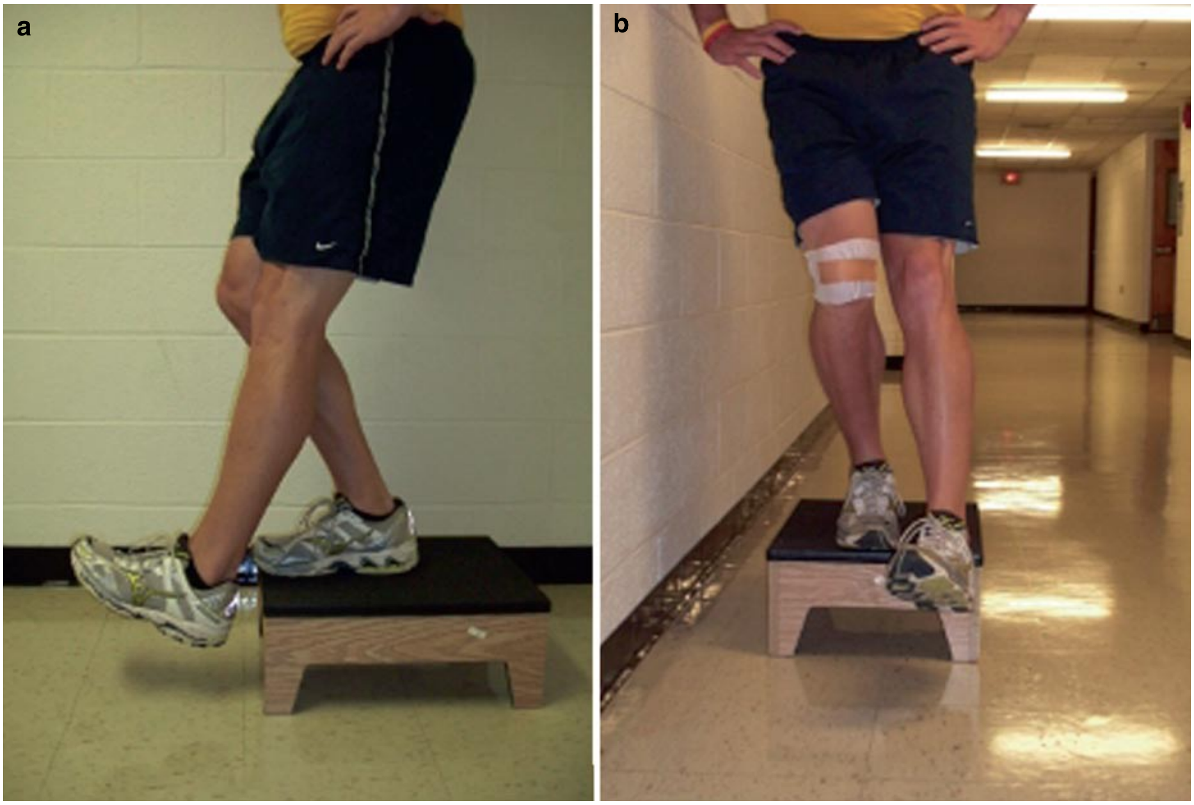

Fig. 15.6 Forward step-down test. After medial taping of the patella, the test is performed with and without tape to determine the effect of tape on pain

groups. Functional Index Questionnaire results followed the same pattern. The results of this study display the positive effect of a medial patellar taping on pain over the course of the day as well as in an aggravating task [94]. Similarly, Bockrath found a more than 50% decrease in pain with taping during an 8 in. step task [8].

Wijnen et al. performed a cross-over study comparing the effectiveness of the McConnell regimen of taping with a Coumans bandage on pain caused by functional activities. The Coumans bandage also attempts to influence tracking while providing massaging effects to the peripatellar structures. Both interventions improved the self-report of pain during stair navigation, sitting and squatting without significant differences between treatments. No differences were noted between treatments for isokinetic quadriceps strength at either 60° or 300°/s. When standardizing the force of application at a load of 1.5–2 kg, Ng and Cheng found a significant reduction in pain with taping. Pain rating decreased nearly 50% in the taped condition during a single leg squat to 30° of knee flexion [58].

Aminaka and Gribble compared PFPS patients with healthy controls on the Star Excursion Balance Test in an attempt to quantify the effect of taping on dynamic balance control. This test is thought to be a good measure of dynamic balance. Using both taped and untaped conditions for both groups, an anterior reach was measured with distance normalized to leg length and pain as outcome measures. The control group demonstrated significantly less pain and farther reaching distances than the PFPS group. However, the amount of pain and the distance reached significantly increased with the application of medial taping. Interestingly, kinematic variables were not impacted through the application of tape despite the increase in reach distance [1].

The majority of studies that show an improvement in pain reports with taping of the patella used a medially directed force. To investigate the effect of tape application as the method of decreasing pain, Wilson measured pain during an 8 in. step-down task (Fig. 15.6) under four conditions: no tape, tape providing a medial glide, tape providing a lateral glide and tape providing no glide. Pain was rated on Numeric Pain Rating Scale (NPRS: 0–10). All taped conditions produced a significant decrease in patellofemoral pain during the step task, however, neutral and lateral taping conditions produced a significantly greater reduction in pain than a medially directed taping [95].

In a similar experimental design, Christou used the same taping conditions to investigate the effect of taping on pain measured during an isokinetic leg press. All three taping conditions reduced overall levels of pain. In this case, medial and neutral taping techniques produced significant ($p < .05$) decreases in pain, while the lateral taping showed a trend toward decreasing pain ($p = .06$) when compared to an untaped condition [17].

Attempting to develop a clinical prediction rule to identify those patients who would immediately receive a 50% reduction in patellofemoral pain with a medial patellar taping, Lesher et al. measured eighteen clinical variables and twelve subjective questions. The results of Receiver Operator Characteristic analysis resulted in four variables having a tendency to predict those who would benefit from patellar taping, including degree of tibial angulation, soleus muscle length, patellar tilt test and relaxed calcaneal stance. Through the use of a logistic regression, a positive patellar tilt test and tibial angulation greater than 5° of varus (Fig. 15.7) were identified as the tests that best predicted success with taping. With a positive result in

Fig. 15.7 Tibial angulation test. Measure the angle between the horizontal and a line bisecting the Achilles. Tibial varum is identified as the distal tibia being more medial than the proximal

either of these tests, a 50% reduction of pain during step tasks and squats was 83% likely [47]. These results still need to be validated in a larger cohort.

Patellofemoral pain has been found to have an impact on gait, resulting in decreased knee flexion in stance and altered joint moments at the hip and knee, as well as decreased gait velocity and decreased muscular activity [30, 55]. During stair climbing tasks, patients with patellofemoral pain exhibited decreased knee extensor moments as compared to healthy controls [73]. Ernst and colleagues investigated the effect of patellar taping on knee moments and powers. They demonstrated increased knee extensor moments and powers compared to untaped and sham conditions [34]. After the application of tape, an increase in knee flexion during loading response in free and fast walking as well as ramp negotiation was observed [65]. In analysis of the effect of patellar taping on stair climbing variables, Salsich et al. found increased cadence, knee flexion and knee extensor moments. These results were found with a reduction of pain of 92.6%, to which the authors attributed the improvements in gait variables [72]. Through the application of a brace, Powers et al. concluded that the stress on the knee decreased in ambulation due to greater increase in patellofemoral contact area compared to patellofemoral joint reaction forces after bracing. Thus, the area over which the joint reaction forces acted increased, decreasing the stress imposed on the patella [67].

In 2004, Powers et al. investigated the effect of two off the shelf knee braces purported to improve alignment and decrease pain associated with PFPS. The on-track brace (OTB) and patellar tracking orthosis (PTO) are both designed to exert a medially directed force on the patella, in an attempt to improve dynamic tracking of the patella. Through serial MRIs at 0°, 20°, 40°, and 60°, the effectiveness of patellar realignment and the resultant pain were measured. During the measurement, a load of 25% body weight was applied to activate the quadriceps. With the application of the brace, measurements of pain on the VAS decreased by an average of 2.3 mm (OTB; ±1.8 mm, $p < 0.05$) and 2.6 mm (PTO; ±1.9 mm, $p < 0.05$). Both braces were effective in decreasing pain in an isometric condition at various angles [66]. Powers et al. also investigated the effects of the Bauerfield Genutrain P3 knee brace on pain and gait characteristics. In a sample of 16 females with PFPS, there was no significant effect on pain, although 50% (8/16) of the subjects did experience pain relief. There was no significant change in cadence or speed, and a small but significant increase in knee flexion was noted in loading response. The authors explained their lack of results in kinematic and kinetic measures due to a lack of pain reduction [64].

While tape has been found to decrease pain, its effects of utilization of Physical Therapy services has not been investigated as thoroughly. In 2000, Clark et al. investigated the effects of various combinations of exercise, taping and education. Those patients who had exercise included in their physical therapy treatment were more likely to be discharged from physical therapy at 3 months than those whose program did not include exercise. There was no association between using therapeutic tape and discharge from physical therapy at 3 months. Limitations of this study included only six physical therapist visits in the 3 month duration of the study, thus making this a directed self-treatment as opposed to true physical therapy intervention [20].

The mechanism for pain relief and improved function that is associated with the use of therapeutic taping or patellofemoral bracing is not clear. However, the potential for these interventions to cause decreases in anterior knee pain, the hallmark symptom, is more apparent. Conflicting evidence is provided for the appropriate direction of tape application, however improvements have been shown with many different application techniques. Therefore, the use of tape can be recommended for the relief of anterior knee pain to allow for increased comfort in completion of activities of daily living and for increased comfort in the completion of associated physical therapy treatments aimed at addressing impairments associated with patellofemoral pain.

15.2 Foot Orthoses for Treatment

The use of foot orthoses has many different proposed aims including injury prevention, biomechanical alignment, cushioning and comfort [59], however, the biomechanical changes caused by orthoses are typically small and not systematic in nature. The use of foot orthoses for the treatment of patellofemoral pain does not have the breadth of research that interventions such as bracing and taping have. However, the creation of a clinical prediction rule for the use of orthoses has already been formulated. Vicenzino and colleagues produced a positive likelihood ratio of 8.8 when three of the four following variables were found: age > 25, height < 165 cm, worst pain less than 53.25 mm and midfoot width difference > 10.96 mm. The authors point out that the four variables encompass three important considerations: patient characteristics (age, height), foot morphometry and pain [87]. Previous work by Sutlive et al. found the best predictors of success only in foot measurements, including limited great toe extension, forefoot valgus angle and low navicular drop [79]. The utility of either prediction scheme has not been established in a larger randomized clinical trial, however, the measurements obtained in the two studies tend to recommend orthoses for patients with a more planus foot. Typically, those patients who have been referred for orthoses are those with flat feet. Nigg and Tiberio each noted the relation of excessive eversion with knee injuries due to pathological tibial and femoral rotation, providing a theoretical link between orthoses and knee pain [59, 83, 84].

The data for the clinical prediction rule created by Vicenzino et al. were drawn from a randomized clinical trial investigating the efficacy of orthoses as compared to flat inserts and their additive benefit to physical therapy. At 6 week follow-up, flat inserts were significantly less successful in improving pain as compared to orthoses, physical therapy or the combination of both. There was no additive benefit of foot orthoses to physical therapy. At 52 weeks, the groups receiving PT, orthoses or the combination reduced worst and usual pain by more than 20 mm each, however, the insert group did not achieve that clinically meaningful difference in usual pain. These results show that both PT and orthoses hasten the reduction of patellofemoral pain and produce greater effects than typical flat inserts in the long term. However, the effects of treatment are not additive. This led to the development of an a priori classification of those who would benefit from orthoses [21].

In a repeated measure of the effect of custom orthoses on those patients with patellofemoral pain who demonstrated excessive pronation, Johnston and Gross found a significant improvement in self-reported stiffness and pain after 2 weeks of orthotic use. After 3 months, self-reports of physical function had also improved. Despite the lack of a control group, the subjects were followed for 2 weeks without change prior to the issue of orthoses. The mean duration of their knee pain was 35 months, signifying an extended duration with significant knee pain. While the sample size of 16 is not overwhelming, the fact that there was a significant improvement in pain and stiffness after 2 weeks of intervention compared to 35 months of pain lends some support to the benefit of orthoses for those with excessive pronation and knee pain [46]. Still, further research is required.

15.3 Exercise Therapy/ Physical Therapy

Normalization of the strength of the quadriceps has been shown to be an important predictor of long-term success in the rehabilitation of patellofemoral pain [57]. This is supported by the finding of significantly decreased strength ratios between limbs compared to healthy controls (18.4% difference vs 7.6%). However, this impaired strength was not associated with quadriceps atrophy even with a mean duration of symptoms of 34 months [14]. Because quadriceps strength is typically impaired and its improvement is important in the resolution of symptoms, many studies have attempted to identify the exercise protocol best able to improve quadriceps strength in patient with PFPS. As stated previously, there is conflicting evidence as to whether or not there is truly a difference in the activation of the vastus lateralis prior to the vastus medialis. Regardless of the activation order of the vasti and the ability to selectively train the vastus medialis, improvements in strength have led to improvements in pain and function. It is important to determine the most effective ways to improve strength and function in those patients presenting with anterior knee pain.

Witvrouw et al. compared the effects of 5 weeks of exercise with open kinetic chain quadriceps strengthening (Fig. 15.8) versus closed kinetic chain strengthening (Fig. 15.9). Both groups significantly decreased their pain ratings after the 5 week strengthening program and at the 3 month follow-up. The closed kinetic chain group did demonstrate a significantly lower frequency for night pain, joint locking, joint clicking and lower pain during isokinetic testing. The groups both showed strength gains at the immediate follow-up,

Fig. 15.8 Examples of open kinetic chain exercise. (**a**) Short arc knee extensions; (**b**) straight leg raise; (**c**) long arc knee extensions

however, at the 3-month test, the closed chain group demonstrated a nonsignificant strength decrease, while the open chain group demonstrated a nonsignificant strength increase. The frequency of symptom-free completion of step tests and squat tests also increased significantly throughout the duration of the study. These results do not clearly favor one treatment paradigm over the other [96, 97]. When compared to a control group receiving no treatment, Herrington also found significant improvements in both open and closed chain exercises with differences between treatment programs [43]. Most often, the least aggravating exercises should be used to allow the patient to improve quadriceps strength with as little pain as possible, since neither produces a significantly greater improvement than the other. Using both methods in combination should allow for the patient to improve overall quadriceps strength in all aspects of function.

Stiene and colleagues compared closed kinetic chain exercises with subjects performing isokinetic exercises (Fig. 15.10). The main outcomes of interest were completed repetitions of the step test, isokinetic strength and self-report of function. Those subjects who completed closed chain exercises improved scores on the isokinetic test, the step test and the self-report. The group only training isokinetically only improved in their isokinetic strength. Confounding the functional test results are the specificity of training of the closed chain training group, who specifically trained with the step-down task. Regardless of functional results, the closed chain group improved more in their self-reported function. This very well could be due to the variety of training mechanisms, as opposed to only training the quadriceps in one manner [78].

McMullen et al. found no differences between static open chain quadriceps strengthening and isokinetic

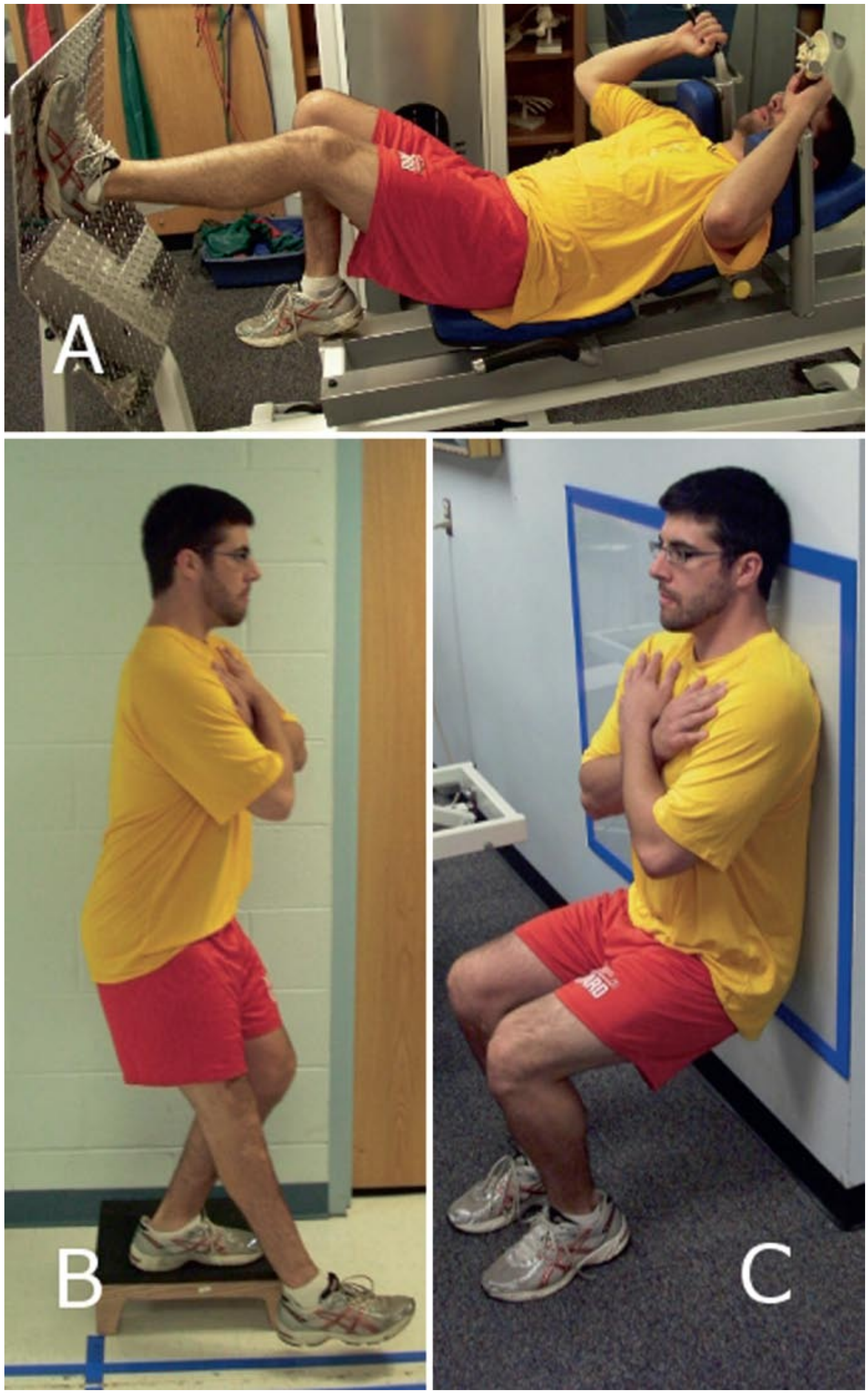

Fig. 15.9 Examples of closed kinetic chain exercises. (**a**) Leg press; (**b**) step downs; (**c**) wall sits

strengthening. Both groups showed significant functional improvement, including improved quadriceps strength, over a control group. The authors provided evidence that neither treatment paradigm is superior to the other, but also offered that static therapy may be superior due to its cost effective nature [54]. Thomee investigated the potential influence of concentric versus eccentric exercises to strengthen the quadriceps. After 12 weeks of

Fig. 15.10 Isometric and isokinetic set up

training, both treatments decreased pain and increased quadriceps strength. Both groups returned 90% of subjects to sporting activity with only one subject in each group experiencing pain with sports [81].

Dursun et al. showed significant increases in activation values of both the vastus medialis and vastus lateralis after a nonoperative treatment approach including both open and closed kinetic chain exercises, general muscle flexibility exercises and endurance training. The addition of electromyographical biofeedback did not augment the activation of the vastus medialis, although no true measurements of strength were conducted [33]. Similarly, Yip and Ng showed no significant improvements in outcomes when biofeedback with visual feedback was added to a home exercise program. Regardless of biofeedback, isokinetic extension strength was significantly greater, and a statistical trend for decreased pain was present, despite the attempt to selectively strengthen the vastus medialis with the use of biofeedback [99]. While biofeedback was not effective in improving outcomes, the use of neuromuscular electrical stimulation resulted in significant strength gains and decreased pain [13].

To investigate the effectiveness of purported vastus medialis targeted rehabilitation exercises, Syme and colleagues compared the selective vastus medialis program with a general quadriceps strengthening program and a control group. The exercise programs were similar, except the selective group was augmented with biofeedback to monitor and increase vastus medialis activity. After the training sessions, both treatment groups showed improvements in the step-down task and decreased pain, however, no difference was seen in knee excursion during stance phase of gait, the primary outcome measure. This again shows little value in a quadriceps strengthening program specifically aimed at strengthening the vastus medialis. The authors close with a recommendation to avoid selective activation as a treatment goal [80].

In a randomized controlled trial comparing basic elements of treatment (taping, education, exercise, exercise, and tape), Clark and colleagues found increased patient satisfaction and discharge as well as quadriceps strength at 3 months in patients treated with some form of exercise. These improvements were attributed to the manual stretching and guided strengthening received by the exercise groups [20]. Harrison and colleagues found that a comprehensive physical therapy program including exercise, taping and biofeedback showed more rapid improvements in self-report of function and pain as well as improvements in the step test [40].

Isokinetic quadriceps training has been suggested as a possible treatment for quadriceps strengthening [5, 6, 38, 91]. Isokinetic training provides optimal loading of the muscles and allows muscular performance at different angular velocities [4]. There are less compressive forces on the joint surfaces during high angular velocity. This means that isokinetic training at high angular velocity (≥120°/s) may be preferred in patellofemoral pain patients in terms of concentric actions. However, performing eccentric actions are more difficult because of unfamiliarity with decelerating movements when coordinating the different portions of the quadriceps muscles during knee extensions [91, 92]. Therefore, isokinetic eccentric training should initially be performed at 90°/s or lower angular velocities in patellofemoral pain patients. Eccentric quadriceps strengthening is particularly important in patients with patellofemoral pain [90, 91], with isokinetic quadriceps training as a viable method for improving eccentric muscle torque. Those patients that present with maltracking of the patella at the "patellar tracking test" should avoid isokinetic training at high angular velocities during eccentric actions due to risk for possible patellar subluxation or even dislocation [91]. Furthermore, it has been shown that in patients with patellofemoral pain isokinetic training improves proprioception as well as muscular strength [41].

In order to reduce the patellofemoral joint reaction forces closed kinetic chain exercises, such as leg press and step exercises, should be trained during the last 30° of knee extension, while open kinetic chain exercises, such as sitting knee extensions, should rather be trained between 90° and 40° of knee flexion [31, 77]. Recent biomechanical research advocates somewhat extended range of motion of the closed kinetic chain exercises squat and leg press [7].

The current evidence does not allow for any one method of improving quadriceps strength to be recommended as superior. Isometric, isokinetic, concentric and eccentric contractions are all capable of providing overload to the quadriceps, therefore improving strength. Improved activation also seems to play a role in the reduction of PFPS symptoms, however, the ability to selectively train the vastus medialis is in question. In one study, exercise was shown to be superior to the use of tape for the treatment of patellofemoral pain. While this may be true, the use of taping has been shown to immediately decrease the severity of patellofemoral pain, therefore allowing the patient to exercise with less pain and presumably allowing the patient to increase the load to a therapeutic level.

Recent attention has been paid to the effects of strengthening the hip musculature to assist in control of the knee in patients with patellofemoral pain. Theories have been presented which implement poor neuromuscular control of the femur or abnormal rotation of the tibia. It has been proposed that excessive hip adduction and internal rotation can allow for the rotation of the femur beneath the patella, causing the improper interface of the trochlea with the patella [50, 63]. It has been shown that females with PFPS demonstrate significantly decreased hip abduction and external rotation compared to asymptomatic controls and asymptomatic limbs [9, 19, 45, 70], however, results showing insignificant differences have also been published [62]. Delayed onset of gluteus medius activation has also been shown in patients with PFPS [25]. Aside from these correlational studies, no randomized controlled trials could be identified for review in a recent systematic review, thus providing no evidence for the effectiveness of utilizing hip strengthening paradigms in the treatment of patellofemoral pain syndrome [35].

Since the publication of that review, two small randomized clinical trials have been published. Through the addition of hip abduction and external rotation strengthening to a standard quadriceps strengthening program, significant improvements were produced in worst pain, usual pain and pain during activity. However, these results were not seen in the group only undergoing quadriceps strengthening. Interestingly, activation of the gluteus medius increased, but no improvements in eccentric hip abduction or external rotation strength were seen [56]. In a randomized pilot study, no difference was found between groups undergoing quadriceps strengthening, hip strengthening and a combination group. All three groups showed significant decreases in pain and increases in self-reported function [3].

A combination of increased hip flexion strength and normalization of iliotibial band and iliopsoas length has also been correlated with a clinically significant decrease in pain in a cohort based design. However, the successful and unsuccessful treatment groups both improved hip abduction and adduction strength significantly, without effect on treatment outcome [85]. Improvements in pain have been seen in combined quadriceps and hip strengthening programs, however, one has not been proven to be more effective than the other [10].

The level of evidence to recommend hip strengthening for the treatment of patellofemoral pain is currently lacking. The highest quality trial [56] showed greater improvements in the group undergoing hip strengthening, but showed no change in hip strength. The positive effect of hip flexion strength increases was purported by Tyler, but no biomechanical rationale could be offered [85]. Despite the notion that increased abduction strength would result in positive effects on anterior knee pain, this study did not demonstrate this effect. At this time, there is no concrete evidence to support the use of hip strengthening for anterior knee pain. Further research is required.

In addition to advocating for corrective taping and quadriceps strengthening, McConnell recommended stretching of tight lateral knee structures, meant to correct abnormal compressive forces on the lateral facet of the patella. This can be done through manual mobilization by the therapist, or through a low load, long duration stretch using tape [52]. In a small, cross-sectional comparison of patients with patellofemoral pain and asymptomatic individuals, White et al. found decreased hamstring length as measured by the popliteal angle in the PFPS group, although a cause and effect relationship could not be established [93]. Using an objective apparatus to determine the excursion of the patellar glide, Ota et al. showed no difference in the patellar mobility of those subjects with and without patellofemoral pain [61]. Hudson et al. found increased tightness in the bilateral iliotibial bands of those patients with PFPS, with the difference being significant in the symptomatic knee [44]. While these studies are strictly correlational in nature, all address impairments typically treated in physical therapy sessions. Currently, there is limited evidence in support of the explicit treatment of these impairments and the potential effects on pain.

Manual therapy including friction massage to the lateral retinaculum, patellar tilt stretches and medial patellar glides proved effective in increasing knee flexion by 10º and improving the ability of subjects to climb stairs. There was a trend to decrease usual pain and stair climbing pain after only six sessions [86]. Successful resolution of patellofemoral pain was achieved through manual hip rotation stretches and hip rotational strengthening exercises in six visits in a single case design [18].

In validation of the proposed McConnell treatment paradigm, Crossley et al. conducted a randomized clinical trial comparing sham treatments with physical therapy including patellar taping, lateral tissue mobilization and strengthening. Significant improvements were seen in all pain and disability scores in the physical therapy group [27]. In a case series of five patients, all were treated with a multimodal approach including patellar mobilizations, open and closed kinetic chain exercises and stretching to address their knee pain, with 80% experiencing pain relief after therapy [49]. In studies such as these, the exact mechanism of pain reduction and functional improvement cannot be determined due to the multiple treatments used to address impairments. A clinical prediction rule for the use of lumbopelvic thrust manipulation has been formulated through pilot testing. If there exists a difference of at least 14° of internal rotation range of motion between limbs, a nonspecific lumbopelvic thrust manipulation produced a 50% reduction in pain in 80% of cases. However, similar to other prediction rules created to determine a priori which patients will benefit from specific interventions, this rule has not been validated further in the literature.

15.4 Guidelines When Rehabilitation Is Completed

Towards the end of the treatment period it is recommended to stimulate the patient either to return to some kind of physical activity/sport or to start with a suitable regular physical exercise, where long walks could be an alternative. The reason for this is that the improved muscle function and balance that have been gained through the rehabilitation need to be maintained by physical exercises. We have found that patients, who start or continue with some kind of physical training following a treatment program, were the ones with good long-term results of knee function (Werner et al., 1993; Werner and Eriksson, 1993).

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16 Lateral Release of the Lateral Patellar Retinaculum: Literature Review for Select Patellofemoral Disorders

Peter C. Verdonk, Francis Bonte,
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16.1 Introduction

Recent articles have ranked lateral release (LR) 47th among all procedures by orthopedic surgeons [13,19]. Despite its frequency the indications and results of a LR remain controversial. The acceptable results (good and excellent) have a wide range from 14% to 99% [1,7,17,19].

In the literature, four diagnoses can be found, for which several retrospective studies on the outcome after LR surgery have been set up. These four diagnoses include: episodic patellar dislocation (EPD), patellofemoral osteoarthritis (PF OA), excessive lateral hyperpression syndrome (ELHS) and total knee replacement (TKR). In this review, only the first three will be discussed (Fig. 16.1).

LR can be subdivided as an isolated or an associated procedure (as part of a proximal or distal realignment; Figs. 16.5 and 16.6). The procedure can also be performed as an open, mini-open or arthroscopic procedure [19]. O'Neill et al. proved that there is no significant difference in outcome between arthroscopic versus open LR [23]. In arthroscopic LR, however, the risk for postoperative hemarthrosis and swelling is considered higher. The use of electrocautery is advised to prevent this major complication. Until today, this study is the only prospective randomized clinical trial concerning LR.

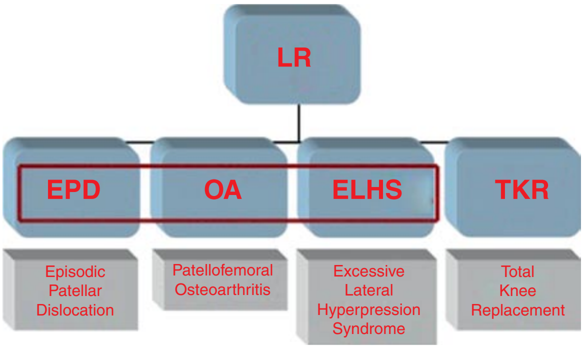

Fig. 16.1 Lateral release has been described in the treatment of four different diagnoses. In this chapter the authors will review EPD, OA and ELHS

16.1.1 Anatomy of the Lateral Retinaculum

The lateral retinaculum consists of two separate layers (Fig. 16.2). The superficial oblique layer originates from the iliotibial band and interdigitates with the longitudinal fibers of the vastus lateralis. The deep layer consists of the deep transverse retinaculum with the epicondylopatellar ligament proximally and the patellotibial ligament distally. Beneath the deep transverse retinaculum is the thin capsulosynovial layer that gives little retinacular support to the lateral side of the knee. Immediately posterior to the oblique and transverse

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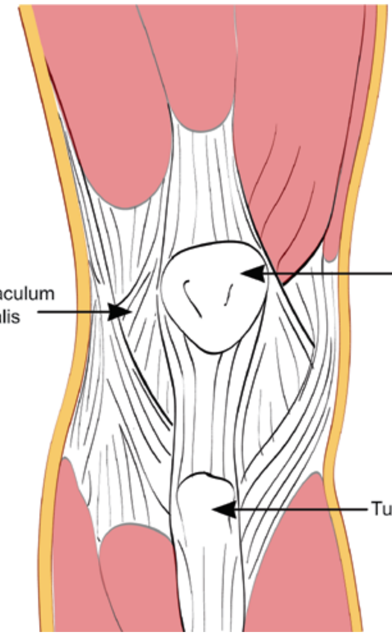

Fig. 16.2 Superficial anatomy of the lateral retinaculum

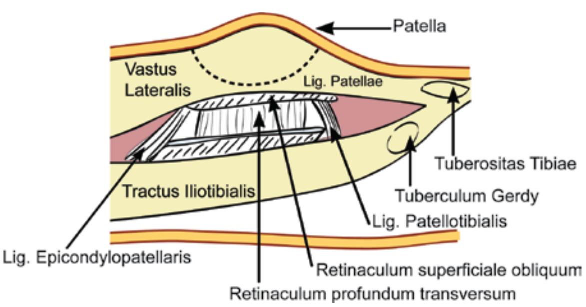

Fig. 16.3 Deeper anatomy of the lateral retinaculum

retinacular ligaments lies the fascia lata. It is fixed proximal and distal to the lateral joint line, lending static as well as dynamic support to the lateral knee [15].

Important structures are well described by Merican and Amis [20] (Fig. 16.3):

- Deep fascia: not attached to the patella. It thickens laterally to become the iliotibial band.
- Quadriceps aponeurosis and iliotibial band: the bulk of the fibres of the iliotibial band run in a longitudinal direction to Gerdy's tubercle. The anterior fibres curve anteriorly to meet the descending fibres of the quadriceps aponeurosis. The fibres on the superficial surface proceed obliquely. They fuse with the aponeurotic layer of the quadriceps.
- Vastus lateralis obliquus.
- Deeper transverse fibres of the iliotibial band: connect to the patella and vastus lateralis obliquus. There is no attachment to the lateral epicondyle of the femur.
- Lateral patellofemoral and patellomeniscal ligaments: these capsular ligaments vary considerably and are not always found.
- Patellotibial ligament: the same as the quadriceps aponeurosis layer.
- Lateral superior genicular artery.

Merican and Amis also describe the lateral retinaculum as a complex structure which is difficult to delineate because of converging and interdigitating structures. The lateral retinacular complex of the knee is subdivided into superficial, intermediate and deep layers.

- Superficial: deep fascia
- Intermediate: quadriceps aponeurosis and iliotibial band
- Deep: joint capsule

The deeper, more transverse fibres from the iliotibial band may be termed the iliotibial band-patella fibres; they are not lateral patellofemoral fibres.

16.2 Materials and Methods

Using Pubmed, 30 relevant articles were found. Relevance was based on subject (abstract), language (English) and cited index.

Key words: lateral release, knee, patellofemoral pain, lateral tightness, patellar dislocation, chondromalacia patellae.

16.3 Physical Examination

Physical examination includes preoperative passive patellar tilt (also postoperative), medial and lateral patellar glides, measurement of the tubercle-sulcus angle, the lateral pull sign, and lower extremity alignment [17]:

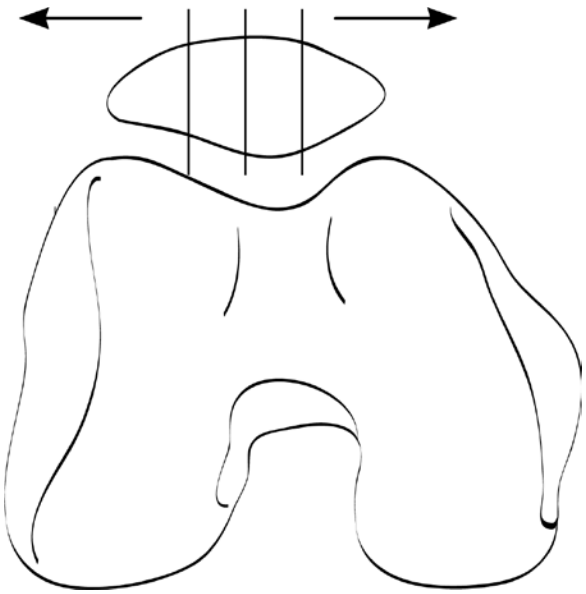

Fig. 16.4 Patellar quadrants

- Standing position: weight bearing alignment, rotational deformities, foot position.
- Seated position, with the knees flexed 90°: effusion, patellar position (Alta, Baja, lateralization), tibial torsion, tubercle-sulcus angle.
- Supine position with the knee extended and the quadriceps relaxed: passive patellar tilt test to diagnose an excessively tight lateral restraint, subjective estimate of patellar crepitation, medial or lateral facet tenderness, retinacular tenderness.
- Supine position with the knees flexed 20°–30° and the quadriceps relaxed: patellar glide (Fig. 16.4) test to diagnose medial or lateral retinacular tightness and/or integrity.
- Lateral patellar glide of three quadrants

Incompetent medial restraint

- Lateral glide of four quadrants

Deficient medial restraint

- Medial glide of one quadrant

tight lateral restraint

- Medial glide of three or four quadrants

Hypermobile patella

- Supine position with the knees flexed 90°: Q-angle for evaluation of the distal restraint vector. A normal tubercle-sulcus angle is 0°, while greater than 10° is definitely abnormal.
- Supine position with the knee in extension: the lateral pull sign is useful to determine the vector of an active quadriceps contraction. The patella should be pulled in a straight superior direction or superior and lateral in equal proportions.

16.4 Surgical Options

Before considering surgery an aggressive, non-operative approach with rehabilitation, of at least 6 months, should be attempted.

Proximal realignments, distal realignments or combinations of these two are the surgical possibilities (Figs. 16.5 and 16.6):

16.4.1 *Episodic Patellar Dislocation*

Patellar dislocation, also known as patellar instability, is a commonly used term. Recently EPD was introduced by Fithian and Neyret [12]. This new terminology avoids the word "instability" and clearly indicates the history of dislocation(s). Instability is moreover a symptom (subjective) and not a disease (objective) [30].

In the EPD patient population, several morphologic anomalies have been identified that facilitate or allow patellar dislocation [10]. Radiographic examination will detect, in more than 96% of cases, at least one of the four following features in EPD group: (1) trochlear dysplasia, (2) Patella Alta, (3) tibial tubercle-trochlear groove distance (TT-TG) > 20 mm, and (4) patellar tilt >20° [10].

16.4.1.1 Studies Concerning EPD

To date there are no published randomized controlled clinical trials (level 1 evidence) assessing the effect of an isolated lateral retinacular release on the outcome of patellar instability. All currently available material is at best level 4 evidence (retrospective case series, or review articles) [19].

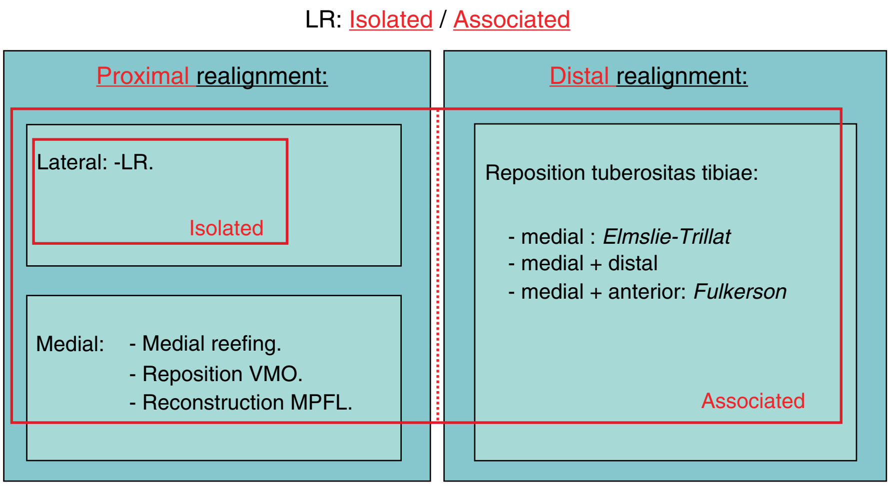

Fig. 16.5 Lateral release can be performed isolated or associated with other surgical realignment options (*LR* lateral release, *VMO* vastus medialis obliquus reposition, *MR* medial reefing, *MPFL* medial patellofemoral ligament reconstruction, *TT* tuberositas tibiae reposition)

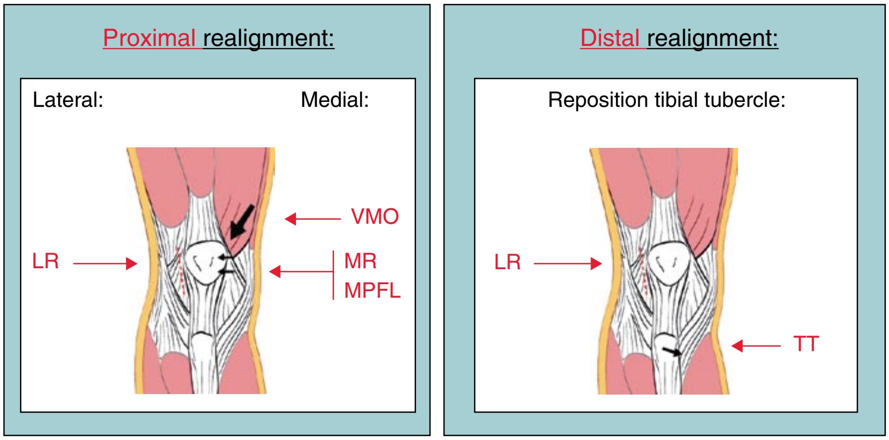

Fig. 16.6 Schematic representation of the different surgical options and the position of lateral release (*LR* lateral release, *VMO* vastus medialis obliquus reposition, *MR* medial reefing, *MPFL* medial patellofemoral ligament reconstruction, *TT* tuberositas tibiae reposition)

Lateral Release: Isolated

Panni [26] set up a long-term retrospective clinical follow-up study, with two groups. The outcomes of lateral release were evaluated after 5 and 12 years. Each group contained 50 patients. Group I contained patients with patellofemoral pain Group II, patients had patellofemoral instability.

Compared with the 5 year follow-up evaluation, the percentage of satisfactory Lysholm scores after 12 years in group I remained stable: 71% vs 70% ($p = 1.0$) whereas the percentage of satisfactory scores in group II decreased: 72% vs 50% ($p < 0.5$).

Conclusion: isolated LR is a procedure offering a good percentage of success in the management of a stable patella with excessive lateral pressure and elective location of pain on the lateral retinaculum. In patellar instability the results are less favorable in long-term follow-up evaluation. The presence of high-grade joint surface injury is a poor prognostic indicator for lateral release.

From a mechanical perspective, isolated LR cannot correct the actual causes of patellar instability whether the cause is a deficient trochlea, deficient ligamentous tethers, or deficient or abnormal vastus medialis.

In his review, Lattermann [19] evaluated several published case series. While some authors initially reported acceptable success of isolated LR for patella instability, most studies showed disappointing mid and long term results. The average percentage of satisfaction of patients with more than 4 years follow-up is only 63,5% whereas the short-term (<4 years) satisfaction is 80%.

Conclusion: isolated LR has little or no role in the treatment of acute or recurrent patella instability. LR may be added as an adjunct procedure to a proximal or distal realignment of the extensor mechanism. Isolated LR can be a successful procedure in patients with isolated lateral patellar tightness (ELHS).

Lateral Release as Adjunct to Patellofemoral Alignment Procedures for Patellar Instability: Associated

Scuderi [29] compared two groups of 52 patients (60 knees). Group I consisted of 21 patients (26 knees) who had had one or more patellar dislocations. Group II comprised 31 patients (34 knees) who had knee pain (anterior, anterolateral, anteromedial, or occasional popliteal).

All patients had an operation consisting of a lateral release and proximal realignment of the patella.

In group I, postoperative results were excellent in 18.6% and good in 62.5% on short term (<5 years). On long term (>5 years), results were excellent in 40% and good in 40%. Group II showed similar results in the short term but, worse results in the long term: <5 years: 36% excellent – 48% good results; >5 years: 0% excellent – 66.7% good results.

A poor outcome was always associated with progression to PF OA in both groups.

Ricchetti [27] reported a systematic review of level III and IV studies to compare surgical success of lateral release or lateral release with medial soft-tissue realignment (MR) for recurrent lateral patellar instability. In total, there were 467 knees in 14 studies: 247 knees with a minimum 2-year follow-up after LR and 220 after LR with MR. The frequency-weighted mean success with respect to instability in the LR studies was 77.3% compared with 93.6% in the LR with MR studies.

Conclusion: isolated LR yields significantly inferior long-term results with respect to symptoms of recurrent lateral patellar instability compared with LR with MR.

Conclusion: isolated LR does not restore normal orientation of the malalignment extensor mechanism and thus results in long term inferior results compared to a combination of LR and proximal realignment of the patella [19].

Distal or Combined (Proximal ± Distal) Realignment Often Added by LR: Associated

LR after tubercle transposition (Elmslie-Trillat/Fulkerson) to allow a free passage of the patellar tendon throughout the entire range of motion [19].

To date, there are no published studies comparing patient groups with tubercle transposition combined with LR and patient groups with only tubercle transposition.

16.4.2 Isolated Patellofemoral Osteoarthritis

16.4.2.1 Studies Concerning LR for Isolated PF OA

Osborne and Fulford [24] compared two groups of patients: 70 patients in Outerbridge Grades I and II were placed in group A. Five patients with more severe changes of Grades III and IV were placed in group B. Seventy-four patients were reviewed at 1 year and again at 3 years after lateral release for established chondromalacia patellae.

At 1 year, 61 of 70 patients in group A had a good result, giving an initial success rate of 87%. Only one of the five patients in group B gained relief. Review at 3 years showed that only 26 of the 70 patients in group A (37%) continued to have a good result from the operation. 28 patients (40%) had poor results at 3 years. In group B, all five patients had undergone patellectomy and are therefore considered to have had poor results from lateral release.

Conclusion: in the early stages of chondromalacia, release of the lateral retinaculum was successful in relieving the symptoms for a year or more; review at 3 years showed a significant number of relapses.

Christensen [8] published a study comparing two groups with 58 patients in total, treated with isolated lateral release for symptoms of patellofemoral pain. All knees exhibited signs and symptoms of chondromalacia patellae (grades I–IV). Patients in group I had recurrent subluxation of the patella, whereas those in group II had no symptoms of instability.

In group I (30 knees) the initial response after 1 year was good in 36.7%, but 0% after 4.5 years. The number of poor results increased from 27% after 1 year to 70% after 4.5 years. In group 2 the number of poor results increased from 21% after 1 year to 24% after 4.5 years. Thus, at follow-up evaluation, the results of lateral release were significantly better in group 2 ($p < 0.01$).

Conclusion: lateral release is an acceptable short-term treatment of chondromalacia patellae without patellar subluxation when the disease does not respond to conservative treatment with isometric quadriceps exercises. In cases with patellar subluxation the release is unable to correct the basic instability.

Aderinto and Cobb [1] set up 1 group of 50 patients that all underwent lateral release for symptomatic PF OA. Lateral release was only performed in those for whom the anterior knee pain of patellofemoral arthritis appeared to predominate. None of the patients had patellar malalignment, patellar instability or tight lateral retinaculum. Despite 80% of patients' reporting an improvement in pain (VAS, OKS), 42% were dissatisfied, which may be due to high expectations or reflect an initial improvement followed by deterioration with time.

Conclusion: LR provides temporary benefit, delaying the need for alternative surgical intervention such as patellofemoral resurfacing or TKR.

Isolated LR does not result in a significant long-lasting improvement for the treatment of frank isolated PFOA. A high number of failures and relapses of pain have been observed in most studies.

16.4.2.2 Lateral Facetectomy in PFOA

The goal of this procedure is to relieve patients' patellofemoral symptoms: anterior knee pain (in rest and in motion) due to isolated lateral PFOA.

Isolated lateral PFOA or loss of cartilage at the lateral facet of the patella shifts the patella more laterally and causes tilt. Increased pressure occurs at the lateral facet while overriding the lateral femoral condyle [30]. In lateral facetectomy, a cut is made at an angle to the vertical axis of the patella to remove less of the anterior surface of the patella, using an oscillating saw (open procedure). The angle of the cut has to be great enough to prevent articulation of the exposed subchondral bone with the trochlear groove [23]. The procedure can also be performed arthroscopically.

The open lateral facetectomy is proven to be an appropriate procedure for patients with isolated lateral PF OA. Martens and De Rycke showed this in their prospective study with a 2-2-year mean follow-up: 20 well selected cases were treated with lateral facetectomy and open lateral release. Satisfying results were obtained in 90% of all cases. A poor subjective rating was seen in only two cases due to progression of osteoarthritis [22]. Similar results were seen in the previous study by McCarroll et al. Lateral facetectomy yielded satisfactory results in 57 cases with grade III and IV PFOA [23]. Yercan et al. reviewed 11 knees in 11 patients at a mean follow-up of 8 years in which partial lateral facetectomy was performed. A significant improvement in pain and function was observed. A retrospective, intermediate (5 year) term study by Paulos et al. on lateral facetectomy in combination with a lateral release reported on 66 knees. The mean Kujala score was 45.6 preoperatively and 72.0 postoperatively. Also the subjective level of satisfaction was very satisfying. The combination of lateral release and lateral facetectomy for end-stage patellofemoral disease provides up to 5 year symptomatic relief in over 80% of carefully selected patients [26].

A combination of partial lateral facetectomy, lateral release and medialization of the tibial tubercle in isolated PFOA of young and middle-aged patients is not recommended. In their study, Becker et al. proved that some improvement of patellofemoral symptoms may be seen after the combined surgical procedure. According to the WOMAC score, considerable improvement in pain and function was seen in 51 knees, 20 months after surgery. However, compared with other surgical procedures such as isolated facetectomy or tibial tubercle transfer, the clinical results seem to be inferior [4].

Compared with the open approach, arthroscopic intervention obviously is a less invasive approach to severe isolated PFOA. Jones and Rumack examined 39 consecutive patients pre- and postoperatively. All patients complained of patellofemoral pain due to severe isolated PF OA. In this procedure an arthroscopic burr was used to resect the overriding lateral patella facet osteophyte. Visual Analogue Scale outcomes showed significant pain relief that was maximal 6 months postoperatively and remained consistent at 1 year. These results confirm the hypothesis that arthroscopic lateral patella facetectomy provide improvement in patients with severe isolated patellofemoral arthritis [18].

Conclusion: partial lateral facetectomy of the patella is a simple treatment that allows quick recovery of function [30]. It does not realign the patella in the trochlear groove. It only gives relief of pain by preventing contact between the lateral patellar facet and the lateral femoral condyle during motion. This procedure carries a small risk and allows further reconstructive surgery of the knee (patellofemoral arthroplasty or TKA) [22]. It is an appropriate solution for relatively young and active patients.

Isolated (open or arthroscopic) lateral facetectomy seems to provide good pain relief, as well as lateral facetectomy combined with release of the lateral retinaculum. A combination with transposition of the tuberosities tibiae does not show similar results and thus is not indicated.

The success of this procedure depends largely on relief of pain. It does not provide any functional improvement, but maintains preoperative functional capacity of the patient [30].

16.4.3 Excessive Lateral Hyperpression Syndrome

ELHS is a condition of lateral tightness of the lateral patellar retinaculum and decreased lateral patellar tilt because of hypertrophy of the lateral retinaculum [11]. The main symptom is lateral retinacular pain. It is important to distinguish ELHS from any other cause of patellofemoral pain. There are six major anatomic structural sources of patellofemoral pain: subchondral bone, synovium, retinaculum, skin, muscle, and nerve [14].

16.4.3.1 Studies Concerning ELHS

Ceder and Larson [7] performed an isolated lateral release in 52 patients (64 knees) with ELHS. Results were rated as excellent, good, fair or poor, regarding subjective relief of pain, grating, giving way and swelling, and ability to return to desired activities. Preoperatively, there was moderate pain in 77%, moderate swelling in 15%, moderate giving way in 6% and moderate grating in 31%. Postoperatively, most complaints were reduced: moderate pain in 10%, moderate swelling in 1.5%, only 1 case of severe giving way and grating in 9%.

Conclusion: Isolated LR provides relief of symptoms in EHLS. It is a satisfactory initial procedure in cases not responding to conservative therapy.

Lattermann [8] published a review of nine studies concerning lateral release for anterior knee pain. A total of 450 patients were included in the review.

Outcome parameters were: improvement of pain postoperatively, incidence of excessive postoperative bleeding, incidence of postoperative infections and number of subsequent operative procedures on the involved leg.

Overall 76% of all treated patients reported less pain after the procedure. Postoperative bleeding appeared in 2%. In 0.9% of the cases infection was reported. Revision surgery was required in 12% of the cases.

Conclusion: If done in an appropriate population an isolated lateral release has a good chance for success. The overall number of patients that qualify for this procedure, however, is low. Less than 15% of all patients that are being seen in the office for anterior knee pain require surgical treatment.

16.4.4 Combination: EPD–OA–ELHS

Including 70 patients with mild lateral tracking and lateral compression of the patella (group I), recurrent patellofemoral dislocation (group II), and intact or defective cartilage of the patellofemoral joint (group III), Schneider [28] presents the results for the lateral release and medial imbrication of the vastus medialis obliquus. In group I (ELHS), patients complaining of a retropatellar pain syndrome were satisfied postoperatively in 77%, using VAS. The results of the patients in group II (EPD) were also good (68%). Distinctly worse results were attained in the patients in group III (PF OA), only 45% of these patients were satisfied with their postoperative outcome ($p < 0.05$).

Conclusion: ELHS without PF OA and patients with EPD are good candidates for LR and LR + medial imbrication. A high subjective satisfaction rate (VAS) was found in patients with ELHS (isolated LR), as well as in patients with EPD (LR + medial imbrication).

16.5 Summary Statement

Based on the conclusions of the available studies, it is acceptable to say that there is only one indication to perform an isolated lateral release: ELHS. In case of EPD, there is no literature support for the role of an isolated lateral release. Hyperlaxity with hypermobility of the patella (medial and lateral patellar glide of three quadrants and more) is also an absolute contraindication for lateral release (isolated or associated). In EPD, lateral release may only be performed in combination with proximal realignment (associated lateral release). This should be done when there is physical exam evidence of a tight lateral retinaculum after patella relocation.

In PF OA, lateral release only provides temporary benefit and delays the need for alternative surgical intervention such as patellofemoral resurfacing or TKR. Lateral release (isolated or associated) in PF OA is thus not indicated. In lateral PFOA, a partial lateral facectomy results is a reliable clinical improvement and may be associated with a lateral release.

Before performing a lateral release, it is very important to know that the release has to be done judiciously and has to be gauged by the desired effect. Overreleasing can lead to potentially devastating medial patellar instability.

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17 Medial Side Patellofemoral Anatomy: Surgical Implications in Patellofemoral Instability

Elizabeth A. Arendt

Historically, surgical procedures aimed at stabilizing the patella against lateral dislocations involved altering its dynamic stabilizers, most specifically the vastus medialis obliqus muscle. This procedure was often performed in combination with altering the distal bony alignment (medial tibial tubercle transfer). The importance of the medial static patella stabilizers, in particular the medial patellofemoral ligament (MPFL), has more recently been recognized as playing an important role in patellofemoral biomechanics [2, 3, 6]. Multiple studies have supported injury to this ligament with lateral patella dislocation [8, 9, 11].

The medial static stabilizers of the patella can be divided into the medial patellofemoral ligament, the medial patellotibial ligament (MPTL) and the medial patellomeniscal ligament (MPML). Together they form a triangular medial retinacular buttress with fibers more horizontally oriented (MPFL), more obliquely oriented (MPML), and more vertically oriented (MPTL) (Fig. 17.1). This triangular arrangement is capable of limiting lateral and superior/lateral translation of the patella.

The MPFL is a vertically oriented ligament found in the same layer and the Medial Collateral Ligament, and serves as a restraining ligamentous structure between the proximal patella and the femur. It is the prime soft tissue restraint to lateral patella translation [2,6]. The MPFL attaches to the femur 10 mm proximal and 2 mm posterior to the medial epicondyle, in the saddle between the medial epicondyle and the adductor tubercle (Fig. 17.2). During surgical

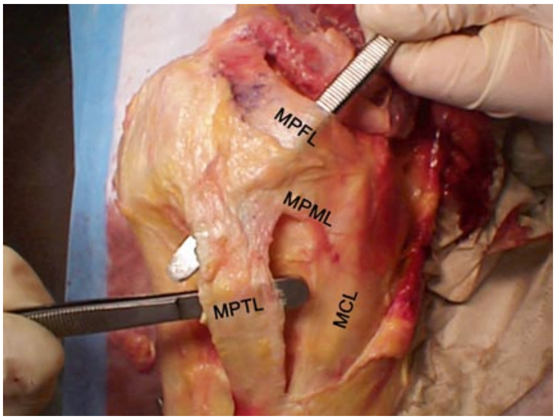

Fig. 17.1 Anatomic dissection of the medial aspect of the knee using a fresh frozen cadaveric specimen. One can see the relationship between the three medial-sided patellar ligaments. MPTL is in a more superficial layer than the MPML and MPFL (*MPFL* medial patellofemoral ligament, *MPML* medial patellomeniscal ligament, *MPTL* medial patellotibial ligament, *MCL* medial collateral ligament)

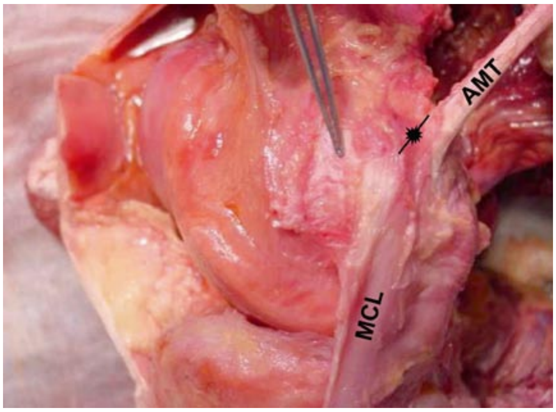

Fig. 17.2 Anatomic dissection of a fresh frozen cadaveric knee with muscles and capsule stripped from the medial side. The asterisk (*) shows the approximate "isoanatomic point" of the MPFL (*MCL* medial collateral ligament, *AMT* adductus magnus tendon)

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dissection, it is perhaps easiest to reference the MPFL from the location of the adductor tubercle, as the adductor tubercle is a readily palpable bony prominence and a more discrete anatomical point. The MPFL attaches ~2 mm anterior and 4 mm distal to the adductor tubercle [7] (Fig. 17.3).

The patella attachment of the MPFL is wider than the femoral attachment, and is approximated at the junction of the upper and middle thirds of the patella, typically at the location where the perimeter of the patella becomes more vertical. As a percentage of the longitudinal length of the patella, Nomura et al. [10] reports the MPFL insertion 27 ± 10% from the proximal tip of the patella, while LaPrade et al. [7] places the mid-point insertion of the MPFL 41.4% from the proximal tip of the patella.

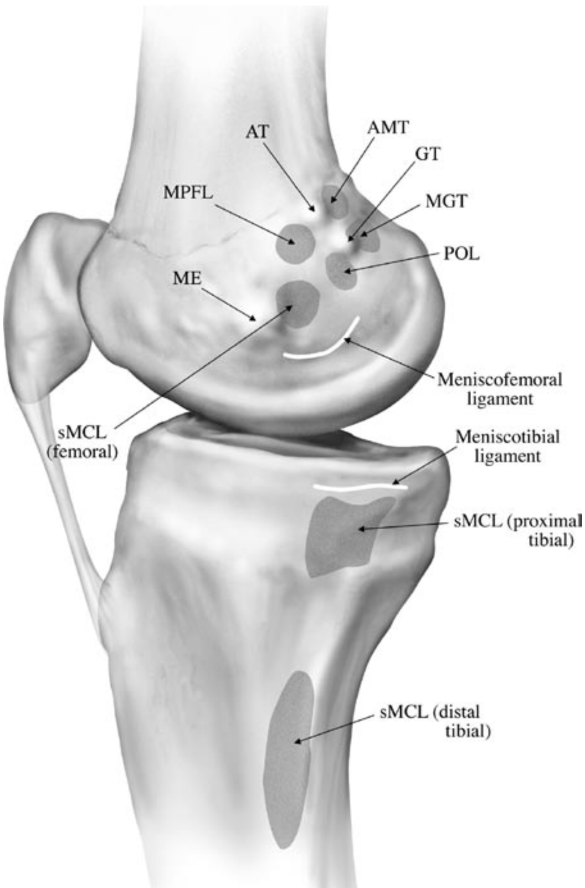

Fig. 17.3 Illustration of the femoral osseous landmarks and attachment sites of the main medial knee structures. *AT* adductor tubercle, *GT* gastrocnemius tubercle, *ME* medial epicondyle, *AMT* adductor magnus tendon, *MG*T medial gastrocnemius tendon, *sMCL* superficial medial collateral ligament, *MPFL* medial patellofemoral ligament, *POL* posterior oblique ligament. (Copyright permission: Journal of Bone and Joint Surgery American, 2007, 89, The Anatomy of the Medial Part of the Knee, LaPrade, 2000–2010)

The degree in which the MPFL is "covered" by the vastus medialis obliques (VMO) muscle fibers varies, depending on the distal extent of the oblique VMO fibers. In cases of VMO dysplasia, the anterior/superior fibers of the MPFL would coalesce with the distal/medial fibers of the quad tendon (Fig. 17.4a). In cases where the VMO had a more distal extent, more of the MPFL was "covered" by the VMO fibers (Fig. 17.4b).

The MPTL is an oblique condensation of the medial retinaculum inserting on the tibia ~1.5 cm below the joint line, close to the insertion of the tibial collateral ligament

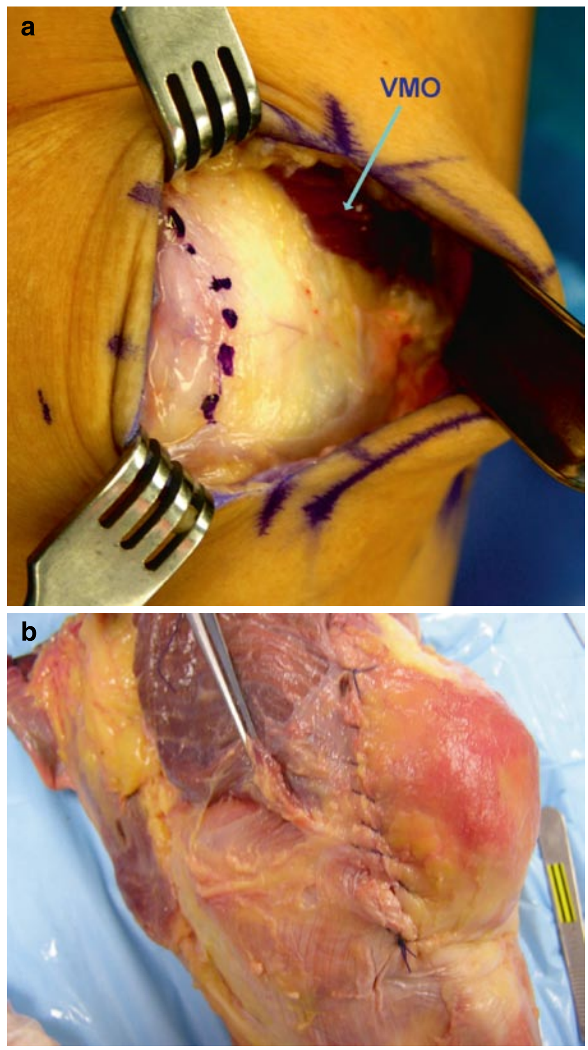

Fig. 17.4 (**a**) This is a surgical intraoperative photo of the medial aspect of a right knee, showing extreme vastus medialis dysplasia. The Medial patella is outline. One can see the medial retinaculum coalesce with the fibers of the quadriceps tendon. (**b**) This is a cadaver knee specimen. The distal and posterior fibers of the vastus medialis muscle are retracted, revealing the fibers of the MPFL that are "covered" by the muscle

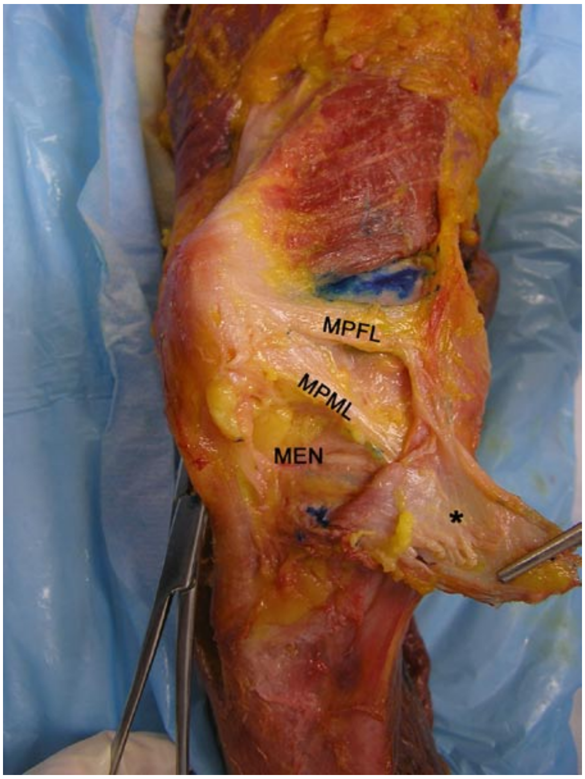

Fig. 17.5 Anatomic dissection of the medial aspect of the knee using a fresh frozen cadaveric specimen. The asterisk (*) indicates the reflected medial retinaculum which includes the MPTL. The distal portion of the medial meniscus is visualized. The MPML can be seen to extend over the meniscus and insert on the proximal aspect of the tibia in the close proximity to the coronary ligament insertion (*MPFL* medial patellofemoral ligament, *MPML* medial patellomeniscal ligament, *MPTL* medial patellotibial ligament, *MEN* meniscus)

(Fig. 17.1). Due to the more vertical orientation of its fibers, the MPTL is uniquely positioned to help resist lateral and anterolateral translation of the patella. There is debate as to the role of the MPTL in resisting lateral patella displacement, ranging from being an important secondary stabilizer [6] to being functionally unimportant [2]. MPTL is in a more superficial plane than MPFL, although Warren's three-layer anatomic concept of the medial retinaculum is more difficult to individually assess as dissection extends anterior and distal [15].

Extending distally in the same plane as the MPFL, there is a thickening of tissues whose fibers are obliquely oriented 45° from the vertical. This tissue plane originates from the patella just distal to the patella insertion of the MPFL; the only distinction between the two sites is a change in the fiber orientation, and anatomically is called the MPML (Fig. 17.5). Its bony insertion to the tibia just distal to the coronary ligament is consistent, more variably some fibers attach to the meniscus itself. In one cutting study, the MPFL was found to contribute 22% of the restraining force against lateral patella dislocation [2].

17.1 Surgical Implications

Though the MPFL is the prime soft tissue restraint to lateral patella translation, this structure, together with its medial-sided retinacular complex, provides significant restraint to lateral translation only in early knee flexion. As the knee progresses in flexion, trochlear geometry, patellofemoral congruence and in particular the slope angle of the lateral trochlear wall provides the major restraints to lateral patellar displacement [5]. In trochlear dysplasia, the groove is often not only flattened, but shortened. The shortened trochlear groove, when combined with a high riding patella (Patella Alta), will create a larger arc of motion before the patella is protected by the confines of the lateral trochlear wall, increasing the importance of the medial soft tissue restraints in stabilizing the patella against lateral dislocation.

When considering MPFL reconstruction, the ideal tissue for the graft would have similar stiffness, but greater strength, than the native MPFL. The current tissue choice used to reconstruct the MPFL is semitendonosis or gracilis tendon, either allograft or autograft. These tendons are significantly stiffer than the native MPFL [1].

MPFL reconstructions with stiff grafts can produce large increases in patellofemoral joint loading when small errors in graft length and/or attachment site are present [4]. This will have its biggest consequence if the graft length is "too short" for its arc of motion, and the length change through an arc of motion is restricted. This will result in reduced patellar mobility, and/or increased forces on the medial patellofemoral joint.

There is no evidence to date that the MPFL functions isometrically. The MPFL is most loaded (longest) in full extension with the quadriceps mechanism contracted. With the quadriceps mechanism relaxed, the "longest" length of the MPFL through a knee range of motion is debated and may vary with the position of the patella in the sagittal plane (Patella Alta). For one cadaver study [13], the femoral attachment site was most sensitive to position change, especially superior and anterior. The reconstruction ligament was "longest" at 60° of flexion.

There is some evidence that the reconstructed graft length tension pattern depends mainly on the femoral attachment point. The least change in graft length was with a point more distal on the patella and more proximal on the femur [14]. This was also the site that had the longest length between the two points.

The graft length and attachment sites should allow the patella to enter the trochlear groove from a lateralized position, as dictated by normal patellofemoral kinematics, and allow the slope of the lateral trochlear wall and the lateral patella facet to engage its trochlear position gradually. Its length should allow full knee flexion, with ~2 quadrants passive lateral glide of the patella in full extension, with a firm check rein to further lateral patella translation.

During surgery, the femoral insertion point should be exacting and documented. This can be done utilizing fluoroscopic visualization of a true lateral of distal femur identifying the appropriate femoral location [12], or by referencing off the adductor tubercle.

There is no objective evidence for an MPFL reconstruction graft tensioning protocol. This must be a compromise between overconstraint, causing medial patella pressure, versus slackness, which allows patella subluxation in early flexion. It appears prudent to tension a MPFL reconstructed graft with the patella contained in the groove at the knee flexion angle where MPFL graft length is the longest. During surgical reconstructed, one should document the angle of knee flexion and the tensioning protocol used to adequately assess outcomes of the procedure matched against one's surgical technique.

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Arthroscopic Medial Reefing in Acute Patellar Dislocation

18

Rainer Siebold and Nico Sartory

18.1 Introduction

An acute lateral patellar dislocation is a complex injury to the knee joint. It is often caused by a combination of valgus force with a planted foot and an internal rotation of the femur or an external rotation of the tibia [29]. The severity of the injury ranges from elongation to complete rupture of the medial parapatellar soft tissue structures. Most often it may be associated with a rupture of the medial parapatellar retinaculum and the medial patellofemoral ligament (MPFL) as well as, more rarely, an osteochondral flake fracture [19, 27]. According to the literature a combined injury to the medial retinaculum and the MPFL may be present in approximately 65% of cases (Fig. 18.1) [25, 28].

Treatment options are controversially discussed in the literature. There is evidence of recurrent patellar dislocation and degenerative patellofemoral changes for both – conservative and operative treatment [1].

A conservative approach to first time acute patellar dislocation is considered to be a valuable treatment option. However, depending on the literature the redislocation rate is reported to be in the range between 15% and 44% [5, 6, 12, 15, 25]. In comparison- acute surgical repair of the medial parapatellar retinaculum and/or MPFL with various methods has been described to have a recurrence rate between 10% and 20% [3,4,14,26,27]. The technique of arthroscopic reefing of the medial parapatellar structures was introduced either alone or in conjunction with lateral release or other procedures [9,10,12,23,30] to reinforces the medial patellofemoral soft tissue structures [2,8,11,18].

The aim of this chapter is to describe the indications and surgical technique of proximal arthroscopic reefing and to discuss operative versus nonoperative treatment options according to the literature.

Fig. 18.1 Axial MRI with proximal rupture of the medial retincaculum and MPFL from the medial patella rim

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18.2 Clinical Results of Conservative Versus Operative Treatment: A Literature Review

A recent literature review on patellofemoral instability was published by White and Sherman in 2009 [29]. They reviewed and described treatment options for acute and chronic injuries with or without predisposing factors. They concluded that based on the literature, initial acute patellofemoral dislocations may be best treated with immobilization and rehabilitation, as the majority of patients will do well without surgery.

However given the high rate of recurrence with nonoperative treatment between 15% to 44%, many investigators White and Sherman [29] refer to may also recommend early surgery to decrease the incidence of re-instability. Unfortunately the literature addressing early surgical repair is limited, as it is retrospectively in nature, involves a small group of patients and has limited follow-ups. An MRI is recommended to assess for osteochondral lesions, as they are associated with a poor prognosis if they are not addressed [29]. White and Sherman [29] concluded that accepted indications for surgery in the acute setting to be osteochondral fragments, persistent patellar subluxation and detachment of the VMO and medial retinaculum from the medial aspect of the patella Schepsis et al. [22] resumed that surgery may only be directed toward the above problems and may not necessarily include realignment surgery.

The only prospective randomized clinical trial on conservative versus operative treatment after acute patellar dislocation was published in 1997 by Nikku et al. [17]. Two to 5 years postoperatively they did not find any significant difference between groups in recurrent instability. Their recommendation was that patients be best treated initially with nonoperative management. Additionally they noted that between 2- and 5-year studies, an additional one third of their patients had a subsequent episode of instability. According to White and Shermann [29] this highlights the need for long-term follow-up studies to determine the true usefulness of a procedure in reducing recurrent instability.

Arthroscopic medial capsular and retinacular repair in acute patellar dislocation was first reported by Yamamoto et al. in 1986 [30]. They described the surgical details of the arthroscopic repair of the medial retinaculum combined with a lateral release in 30 cases with no previous patellar dislocation and a clinical follow-up of 1–7 years. The results of repair were gratifying in all instances with the exception of one traumatic redislocation. The authors concluded that the procedure was successful in the stabilization of the acute dislocation of the patella and that their technique may be a safe and beneficial alternative to open surgical techniques to achieve early accurate restoration of the natural medial capsular and retinacular anatomy in this most difficult problem [30].

A second technical note described the technique of arthroscopic assisted proximal extensor mechanism realignment of the knee [24]. The authors followed up 27 knees in 24 patients with a minimum of 18 months after surgical treatment consisting of an arthroscopic controlled placation of the medial patellar retinaculum and oblique fibers of the vastus medialis combined with a lateral release. The indication included recurrent and acute patellar instability with a concomitant fracture of either the patella or the lateral margin of the intertrochlear sulcus. 92.5% of the knees were subjectively rated good or excellent by the patients. Objective criteria also indicated a high success rate. However two recurrent dislocations and one arthrofibrosis out of 27 operations were reported. Small et al. [24] concluded that this procedure should be considered in patients with recurrent patellar instability or an osteochondral fracture of either the patella or lateral margin of the intertrochlear sulcus. Another potential indication may be a first time dislocation in an athletic individual wishing to return to full sports with improved patellofemoral stability within a reasonable short period of time [24].

Another surgical description of arthrocopic proximal patella realignement and stabilization for acute instability with capsular defects, recurrent disloctions and subluxations in conjunction with a lateral release was reported by Henry et al. in 1995 [13]. Their experience after 6 years showed that the procedure was of low technical demand, consistency of results and it was associated with a low morbiditiy and cosmesis making it a "worthwhile" technique. They did experience no recurrent patellar dislocations and a significant improvement in patellofemoral pain. The authors concluded that the technique addressed the difficult treatment of patellofemoral pain secondary to patellar dislocations, subluxations, maltracking, and instability.

In selective patients it may reduce the necessity for an arthrotomy and may decrease hospitalization and postoperative morbidity [13].

Good clinical results of a retrospective study were also reported by Halbrecht and coworkers [9]. They examined 29 knees 2–5 years after an all-inside arthroscopic medial reefing (knot tied arthroscopically in the joint) combined with a lateral release for acute patellar dislocation ($n=23$) or subluxation ($n=6$). Ninety-three percent of the patients reported a significant subjective clinical improvement for pain, swelling, stair climbing and their ability to return to sports. The Lysholm Score was reported to be improved from 41.5 to 79.3 points and there was a significant improvement of the congruence angle, lateral patellofemoral angle and lateral patella displacement on postoperative radiographs. There was no complication or redislocation. The authors concluded that an arthroscopic all-inside patella realignment may be recommended and may offer comparable or superior results to published open arthroscopically assisted repairs. It eliminates the need for medial incisions for knot-tying with all its problems [9].

In 2002 Haspl et al. [10] presented their arthroscopic technique for the treatment of patellofemoral instability. It consisted of a placation of the medial patellar retinaculum and release of the lateral patellar retinaculum. Indications were acute- but also recurrent patellar dislocation. The procedure was performed in 17 patients between the ages of 14 and 27 years. The short-term results with an average follow-up of 13.3 months did not show any recurrent dislocations or subluxations. They recommended the procedure for patella maltracking as well as acute- and recurrent patellar dislocations particularly in adolescents and young adults [10].

The influence of predisposing factors on clinical results after conservative treatment was described by Cash and Hughston [5]. They reported a redislocation rate of 50% after conservative treatment in patients with patellofemoral instability and predisposing factors such as insufficient trochlear shape, but the redislocation rate was only 20% in patients without predisposing factors [5]. Similar findings were reported by Mäenpää and Lehto in 1995 [16] describing a family disposition for patellar redislocation after open medial reefing. In a retrospective study they reviewed 284 knees with acute patellar dislocation treated operatively with open medial reefing combined in 243 cases with lateral release. The mean follow-up was 4.1 years. The subjective results were better and the redislocation rate lower if the injury mechanism was traumatic rather than non-traumatic and if there was no history of family occurrence of patellar dislocations [16].

The influence of predisposing factors was assessed on radiographs by Rillmann et al. in 1999 [20]. They reported results of arthroscopic repair of the medial retinaculum after first time dislocation in 38 knees. Patella Alta (according to Caton index) was seen in 37% of patients and trochlear dysplasia (TD) (according to lateral x-ray) in 15% respectively. The redislocation rate after a mean follow-up of 25 months was only 10% and two out of three redislocations occurred in patients with predisposing factors. This is similar to the findings of Schäfer et al. [21] who described 10 redislocations out of 11 patients with predisposing factors. However Rillmann et al. [20] reported that 84% of their patients showed a very good or good result and only 16% a fair result including the cases with redislocations. Based on these findings the authors concluded that an arthroscopic repair of the medial retinaculum after first time dislocation is a minimal invasive method with very low peri- and postoperative morbidity. Furthermore they stated, that the redislocation rate can be reduced to at least 50% compared to the published data on conservative treatment [20].

The influence of underlying bony trochlear dysplasia (TD) on clinical outcomes of arthroscopic medial retinacular repair was further described by Schöttle et al. [23]. Ninety-one patients were included and the trochlear dysplasia was assessed according to H. Dejour [7] in 48 patients on axial CT scans. The overall redislocation rate was 8.3%. Patients without or grade A trochlear dysplasia had a significant better postoperative outcome than those with a grade B or C TD. All redislocations occurred with severe TD. From these results they concluded that the reefing of the medial retinaculum is an effective treatment for patients who suffer from a patellar dislocation without having a severe trochlear dysplasia. However in patients with underlying TD, patellofemoral stability cannot be completely restored and clinical results are less successful. They advised to perform a precise preoperative radiologic determination of trochlear geometry to predict short-term outcome in patients with patellofemoral instability [23].

18.3 Indications and Contraindications for Arthroscopic Medial Soft Tissue Reefing

Accepted indications for an early surgical intervention in acute patellar dislocation are the strong suspicion of an (osteo)chondral flake fracture, persistent patellar subluxation and visible detachment of the vastus medialis, the medial retinaculum or MPFL from the medial aspect of the patella [9,29].

Relative indications may be a first time dislocation in an athletic individual wishing to return to full sports with improved patellofemoral stability within a reasonable short period of time. [22] and an early failure of the conservative treatment with recurrent patellar instability [8].

However a relative contraindication for an arthroscopic retinaculum reefing may be in patients with underlying TD grade B or C according to H. Dejour et al. [7] as the patellofemoral stability cannot be completely restored and clinical results are less successful [23]. A contraindication for a proximal soft tissue repair at the patella is a rupture of the medial retinaculum or the MPFL nearby its femoral insertion. This should be excluded by a preoperative MRI or latest during the diagnostic part of the arthroscopy. In these cases an acute femoral repair or MPFL reconstruction may be considered.

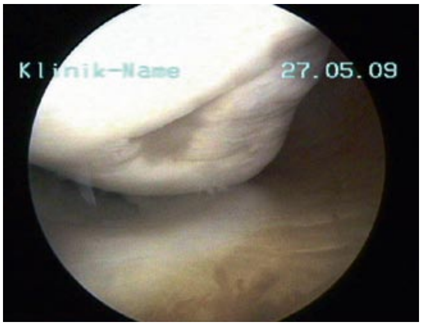

Fig. 18.2 Arthroscopic aspect of typical posttraumatic cartilage damage at lateral femoral condyle after acute lateral patellar dislocation

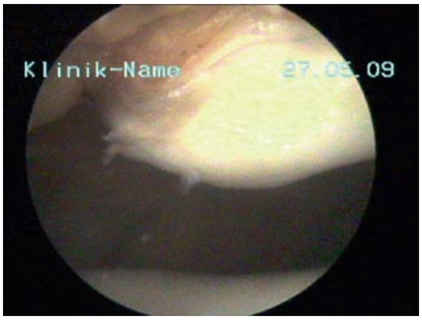

Fig. 18.3 Arthroscopic view of proximal rupture of the medial retinaculum from the medial aspect of the patella

18.4 Surgical Technique of Arthroscopic Medial Soft Tissue Reefing

Surgery is performed with a tourniquet and a tight leg holder in place. Standard medial and lateral arthroscopic portals are created and the routine arthroscopic examination is performed to identify possible concomitant pathologies. Patellofemoral congruity and dysplasia as well as damage to the cartilage, to the medial retinaculum and/or the MPFL is assessed (Figs. 18.2 and 18.3). A femoral rupture of the medial soft tissue structures is excluded on MRI and (if possible) arthroscopically.

To increase healing of the soft tissue structures the proximal rupture is treated by rasping or gently shaving. To start arthroscopic reefing a percutaneous epidural needle is introduced through the periosteum at the medial patella rim and advanced under arthroscopic control in the upper gutter. A No. 1 PDS suture is passed manually through the needle into the joint. A second percutaneous epidural needle with a closed No. 2-0 PDS loop is placed 2 cm distally (anatomically posterior) to the rupture of the medial retinaculum under arthroscopic control (Fig. 18.4). The No. 1 PDS is pulled through the No. 2-0 PDS loop arthroscopically with a grasper and the loop with the No. 1 PDS is retrieved from the joint. This creates a No. 1 PDS loop suture crossing the defect of the medial retinaculum (Fig. 18.4). The two ends of the No. 1 PDS are clamped for later reefing of the medial retinaculum, the capsula and the MPFL. The process is repeated until approximately 5 No. 1 PDS sutures are in place (Fig. 18.5).

Before knot tying we recommend to place the sutures under tension to assess the degree of medialisation (Fig. 18.6). The sutures are then tied through a 5 mm skin incision in 30° of knee flexion and blunt dissection between the suture strands down to the capsula [13]. Finally the result of the repair is assessed and

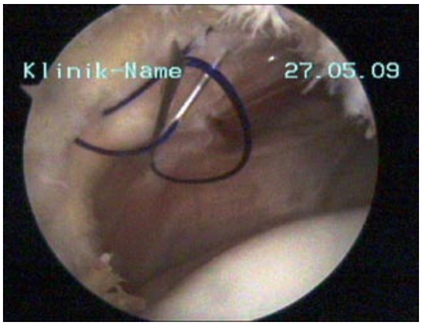

Fig. 18.4 Arthroscopic aspect of PDS suture for medial reefing

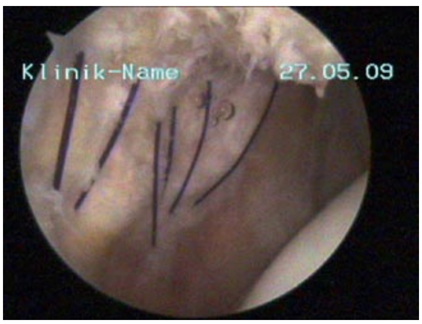

Fig. 18.5 Arthroscopic aspect of six placed No. 1 PDS sutures before knot tying subcutaneously

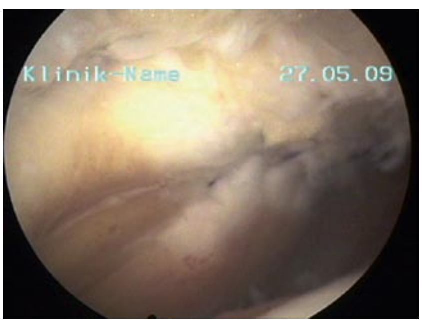

Fig. 18.6 Arthroscopic aspect of medial retinaculum after arthroscopic reefing

documented arthroscopically. When the correction is inadequate a repositioning of the sutures or additional sutures may be required or the correction may be completed by an open approach through the skin incision.

A lateral release is only performed in case of a tight lateral retinaculum and/or capsula with persisting lateralisation of the patella. It may not be necessary in patients with a mobile patella or a general hyperlaxity.

Postoperatively the knee is placed in a brace to avoid damage to the repair. Gentle physical therapy, such as lymph drainage may be started on the first postoperative day. The brace is adjusted to 0°–0°–60° to enable patients to begin ROM exercises. Flexion is limited to 90° during the 3–4 postoperative weeks. Full ROM may be permitted thereafter. Partial weight bearing is permitted directly after surgery and progresses from simple touchdown to full weight bearing after 2 weeks when tolerated.

18.5 Conclusion

According to the literature an acute patellofemoral dislocation may initially be best treated conservatively, as the majority of patients will do well. Given the above indications arthroscopic medial reefing may be performed to reduce the risk of recurring patellofemoral instability. Radiographs and MRI should be used to assess for osteochondral lesions and predisposing factors for redislocation as they are associated with a poor prognosis if not addressed. Patients with severe trochlear dysplasia may be treated with a more extensive procedure.

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19 Medial Reefing in Chronic Potential Patellar Instability

Alfredo Schiavone Panni, Simone Cerciello, Michele Vasso, and Andrea Palombi

19.1 Introduction

Patellar problems are relatively frequent in young and active patients. Since they include different situations a precise classification is needed. We believe that the one proposed by Dejour [4] is useful for a precise diagnosis and correct treatment. It includes three groups: the objective patellar instability (OPI), the potential patellar instability (PPI) and the painful patellar syndrome (PPS).

The PPS group is defined by anterior knee pain, subjective instability, and popping with no evidence of patellar dislocation. Moreover no major anatomic anomalies may be found.

The OPI group is defined by the presence of one or more patellar dislocations (objective instability) and some major anatomic anomalies. These may be considered as predisposing factors such as: excessive patellar height, excessive tibial tuberosity-trochlear groove distance (TT-TG), vastus medialis obliquus (VMO) dysplasia, and trochlear dysplasia

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The PPI group is a mix of the previous two groups: patients report symptoms like the painful patellar group but have one or more of the anatomic anomalies.

This means they may develop a true objective instability.

Recently several studies have investigated the anatomy and biomechanics of the medial stabilizers [5,8,11,13]. The anterior aspect of the knee is formed by different layers: subcutaneous layer, superficial fascia (arciform layer), intermediate oblique layer, deep longitudinal layer, deep transverse layer and deep capsular layer [13]. The medial transverse retinaculum is basically formed by fibers of the deep transverse layer and consists of a tough fibrous structure where some ligaments can be identified: the medial patellofemoral ligament (MPFL), the medial patellotibial ligament (MPTL), and medial patellomeniscal ligament (MPML). These structures offer a medial restraint to lateral patellar displacement. Panagiotopoulos investigated the relative contribution of these different structures: the MPFL contributes to more than 50% while the MPML, the MPTL and the MR contribute to 24%, 13% and 13% of the medial restraint force respectively [8].

These studies stress the role of passive stabilizers, which is more important than that of dynamic forces and this contribution is even greater in case of Patella Alta or patellofemoral dysplasia. On the other hand the lateral retinaculum makes a 10% contribution to lateral stability [5] This justifies the actual concerns about lateral release, which is indicated only in case of clinical or radiographic evidence of an abnormal lateral patellar tilt [11].

Finally the importance of the medial structures and particularly of the MPFL is witnessed by clinical evidence. Some authors report medial structures damage after patellar dislocation [1,5]. Fithian demonstrated that even in the presence of the predisposing factors patellar dislocation does not occur if the MPFL is

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intact [6]; while Sallay reports a rupture rate of the MPFL of 94% after patellar dislocation [14].

According to these data and to the Dejour classification some considerations may be proposed. There is a huge difference in terms of prognosis and treatment between patients that have had a previous dislocations and patient who have not.

In case of a previous dislocation one or more of the predisposing factors is altered and the MPFL is probably damaged. Conservative treatment could be proposed and consists of stretching exercises and VMO strengthening. Unfortunately there is a recurrence rate of redislocations following conservative treatment up to 44% [2]. Moreover persistent chronic retropatellar pain and instability are experienced in 40–70% of patients [10]. Young and active subjects seem more prone to recurrence while there is no evidence of factors that predispose one to develop chronic symptoms. Therefore surgical treatment is indicated even after the first episode.

In patients with potential instability or PPS if anatomic predisposing factors are grossly normal and medial structures are intact conservative treatment seems a reasonable option. In case of failure of a well performed rehabilitation protocol for at least 6 months surgical options shall be considered.

19.2 Materials and Methods

From April 2001–2006 we performed 36 surgical procedures of medial reefing 36 in patients with (PPI) and (PPS).

Twelve Patients were male and 24 were female. Right side was involved in 20 cases. Mean age at the time of surgery was 26.6 years. All patients underwent unsuccessful conservative treatment for 3–6 months. All patients were evaluated both preoperatively and postoperatively with physical examination and with complete imaging study. This consisted of AP and LL X-ray views with patients under weight bearing conditions and with the Merchant view (to assess patellar height and trochlear displasya). Moreover a CT scan was performed to assess the TT-TG distance and the patellar tilt in static conditions (dynamic CT scan was not possible in all patients). Finally Kujala, Fulkerson, Larsen and Tegner questionnaires were administered to all patients.

19.3 Surgical Technique

We perform this procedure under general or loco-regional anesthesia. With the patient under anesthesia an accurate knee exam is performed: passive ROM, patellar tilt, and a medial/lateral patellar glide are recorded (Fig. 19.1). The surgical procedure is then performed with the tourniquet inflated. A first arthroscopic look is sometimes performed. Patellar tracking is evaluated with repeated flexion-extension movements, chondral damages are investigated. A gentle shaving is performed to enhance the healing process of the medial retinaculum (Fig. 19.2). Medial sutures are passed percutaneously through a

Fig. 19.1 Accurate evaluation of the patellofemoral joint is performed with the patient under anesthesia and with the tourniquet deflated

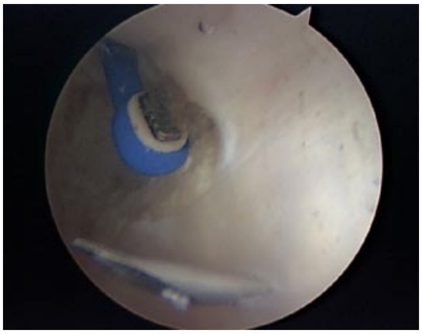

Fig. 19.2 The gentle abrasion of the medial capsule right in the site where the three stitches are positioned increases the healing response on the soft tissues

Fig. 19.3 Three vertical stitches are sufficient to achieve a good correction of the patellar tilt and subluxation. The distance between the stitches is usually 1.5 cm

Fig. 19.4 The wider the tissue included in each stitch the greater the recentering effect of the reefing

spinal needle. First the most distal needle is positioned at the distal third of the patella just adjacent to the patella. A No. 1 PDS suture is passed through the needle and then retrieved from a more posterior access. Two more sutures are then passed more proximally at 1.5 cm distance over each other (Fig. 19.3). The two edges of each suture are finally retrieved from the posterior access and the knot is tied at 60°–70° of flexion under arthroscopic control to avoid hypercorrection (Fig. 19.4).

Additional lateral release is never performed as in our experience it offers uncertain results and may increase patellar hypermobility. The tourniquet is deflated and an abundant wash out is performed. No skin suture is performed. Postoperative treatment consists of, elastic compressive casting in extension, immediate passive motion from 0° to 50°, and complete weight bearing after 4 weeks.

19.4 Results

At the last FU (32–92 months) 26 patients were reviewed for both clinical and imaging examination. Average Kujala score improved from 73 to 98 average Larsen score from 15 to19, average Tegner from 65 to 98 and average Fulkerson score from 69 to 97. No intraoperative complications were seen. No difference in patellar height was seen comparing the preoperative and postoperative X-rays. Patellar tilt decreased from 12° preoperatively to 8° postoperatively.

19.5 Discussion

Patellar instability is a complex issue and several factors may contribute to its development. We agree with the Dejour classification that proposes three groups: the OPI, the PPI and the PPS. Beside the classic risk factors: increased TT-TG distance, Patella Alta, trochlear dysplasia and VMO dysplasia the role of the medial stabilizers (first of all the MPFL) must be considered. They include several structures: the medial retinaculum (MR), the MPFL, the MPTL and the MPML. They act as a restraint to lateral patellar displacement [5,8,11,13]. Clinical evidence demonstrates a high incidence of medial structure damage after patellar dislocation [1,5,14].

According to these results we strongly believe that MPFL reconstruction is recommended in case of patellar dislocation. It may be performed as an isolated, or in association with, other procedures to correct the severely altered predisposing factors.

Medial reefing is another option in patients with patellofemoral disorders. Most authors suggest this procedure in case of patellar instability (patellar subluxation or dislocation) that have failed a period of 3–6 months of conservative therapy [9,11,12]. Nam reports the results of a mini-open medial reefing associated with lateral release in the treatment of recurrent patellar dislocation showing 91% good or excellent results. He reports recurrent dislocation in 4% of patients and recurrent subluxation in 4% [12].

Miller reports his arthroscopic technique in patients with a previous dislocation or subluxation which have failed conservative treatment. 96% of patients were satisfied with their result and no recurrent dislocation was noted. Moreover he reports an improvement in congruence angle, lateral patellofemoral angle and lateral patellar displacement [11].

Halbrecht describes an all inside arthroscopic medial reefing in patients with patellar dislocation or subluxation. Ninety-three percent of patients showed significant subjective improvement. X-ray findings showed significant improvement also. No complications were noted [9].

Coons reports the results of his arthroscopic technique consisting in a medial capsule shrinkage and a lateral release in patients with recurrent instability. He performed this procedure at least 6 weeks after the last dislocation either in patients with no medial retinacular tenderness assuming in this two conditions the complete healing of both the medial retinaculum and MPFL: Following these criteria he reports 90% good or excellent results at 53 months FU with 9% recurrence [3].

According to these studies we found the two controversial issues are the degree of knee flexion for knot tying and the postoperative rehabilitation protocol.

Nam proposes to tie the knots in full extension. In the postoperative period, he protects the reefing with a knee immobilizer in full extension allowing weight bearing as tolerated. At 2–3 weeks he begins gradual passive and active ROM exercises as well as quadriceps strengthening [12]. Halbrecht does not give any information about the degree of knee flexion; he applies a brace blocked in full extension to the involved knee. Weight bearing is immediately allowed. The brace is unlocked after the first week to start ROM exercises (below 90°) and maintained for 3–4 weeks [9]. Miller suggests tying the knots at 20° of flexion. He protects the knee with an immobilizer with weight bearing as tolerated. ROM exercises start after 1 week while strengthening exercises after 4 weeks [11].

Despite these excellent results we still have some concerns.

The first one refers to the terminology: the word dislocation is quite simple and clear. Conversely the term subluxation is rather unclear. In fact it may be referred to as a subjective sensation or to an abnormal patellar lateral glide. In both cases it seems to us a concept which is difficult to define and identify for both the patient and surgeon. Therefore we still prefer the classification proposed by Dejour in which three precise groups may be easily identified [4].

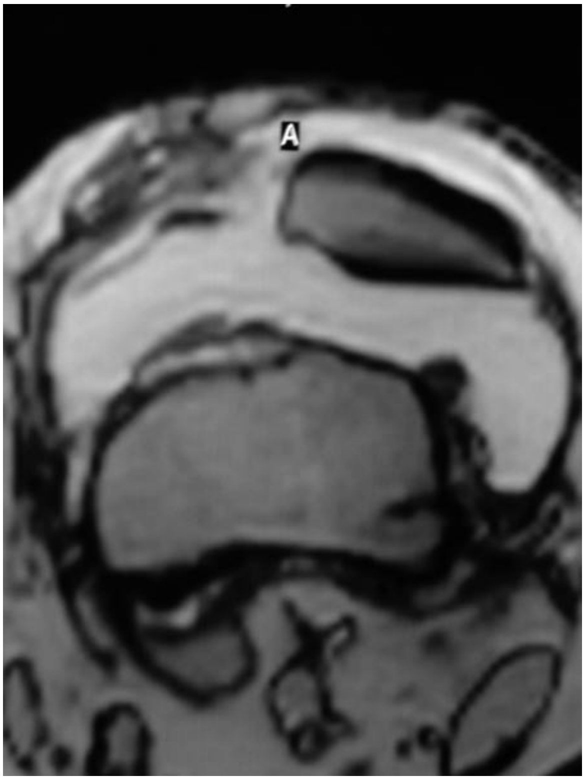

Fig. 19.5 The evidence of MPFL ligament rupture after patellar dislocation necessitates more aggressive surgical options rather than medial reefing alone

The second one concerns the indication for medial reefing. We believe the ideal indication of medial reefing is PPS or PPI with nearly normal predisposing factors. In case of patellar dislocation the evidence of MPFL rupture necessitates its reconstruction as its predominant role as passive medial stabilizer has been clearly demonstrated [8] (Fig. 19.5). Medial reefing alone does not address this lesion with no restoration of its essential role. Moreover we believe that the role of a lateral release alone or in association with medial reefing is very limited. The evidence of the deterioration of clinical results at long FU after lateral release and the risk of creating additional instability forced us to stop performing this procedure [14,15].

19.6 Conclusion

Recent studies have investigated the biomechanics of the medial stabilizers and their role has been stressed. This evidence has lead to a great interest for MPFL reconstruction in cases of OPI and toward medial reefing in cases of PPI and PPS. This last procedure represents a safe and reproducible option. We disagree with the authors that suggest this option in case of previous dislocation. In this situation the lesion of the MPFL is constant and reefing alone does not allow us to treat it, thus exposing the patient to the risk of recurrence. We have changed our attitude and we perform reefing without the lateral release. We believe in cases of PPI and PPS the lateral release may increase patellar glide thus worsening the instability. We believe that great care should be taken to not over tension the stitches and to follow a correct postoperative rehabilitation protocol.

19.7 Summary Statement

- Arthroscopic medial reefing is indicated in case of failure of a proper conservative treatment in patients with PPI and painful patella syndrome.
- It consists of a minimally invasive arthroscopic assisted reefing of the medial capsule.
- Three resorbable stitches are passed percutaneously and then tied with the knee at 60°–70° of flexion.
- Postoperative rehabilitation program consists of immediate passive motion from 0° to 50°, and full weight bearing after 4 weeks.
- This procedure is absolutely contraindicated in cases of a previous patellar dislocation.

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Medial Patellofemoral Ligament Reconstruction Indications and Surgical Technique

20

Justin J. Gent, Brian D. Johnson, and Donald C. Fithian

20.1 Historical Background

20.1.1 Patellar Instability

Patellar instability has been shown to be associated with four major factors. These factors are trochlear dysplasia, patellar height, lateral offset, medial retinacular restraint [22]. As other chapters will concern themselves with these first three factors, we will focus on the soft tissue medial retinacular restraint. It is the authors' view that medial retinacular restraint must be addressed to provide patellar stability, either in isolation or in conjunction with other procedures as indicated. Studies have demonstrated that soft tissue reconstructions are sufficient to reestablish patellar constraint. For instance systematic review of eight studies was performed to determine if medial patellofemoral ligament (MPFL) reconstruction is an appropriate procedure for patient with patellar instability [51]. Although the techniques, indications and follow-up outcome measures varied, of the 155 knees, only six had postoperative patellar dislocation or subluxation episodes.

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20.1.2 The Role of the MPFL in Patellar Stability

It is recognized that lateral patellar mobility is increased in knees with a history of patellar dislocation [24, 29, 30, 41, 49, 55]. The increased mobility appears to be attributable to medial retinacular deficiency [24, 55]. In studies done on cadaver knees, the MPFL is consistently the most important retinacular structure resisting lateral patellar motion [10, 14, 27]. In the study by Hautamaa et al. [27], repair of the MPFL was both necessary and sufficient to restore lateral patellar mobility to within a normal range. As a result of this body of research, a growing number of clinical studies have focused on restoration of a competent MPFL when stabilizing the patella following dislocation.

Several authors have advocated acute repair of the MPFL after first-time patellar dislocation [1, 37, 42, 43]. Advocates of this approach cite magnetic resonance imaging (MRI) and/or surgical evidence that, at the time of initial patellar dislocation, injury to the MPFL can be seen in the majority of knees [26, 28, 35, 42, 58]. Most of these reports have suggested that the posterior (femoral) MPFL attachment site is the most frequent location of the MPFL tear. One study showed that the MPFL may be injured at several sites along its length as the result of acute first-time dislocation [16].

Advocates of acute MPFL repair have not demonstrated that it actually yields improved outcomes. The mere fact that the MPFL may be injured during initial patellar dislocation does not in itself constitute an indication for surgery. In a natural history out of our institution [25], only 17% of first-time dislocators suffered a second dislocation within the next 2–5 years. Furthermore, in that study MRI evidence of MPFL tear was not associated with increased risk of dislocation.

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Several level 1 and 2 prospective studies have shown no benefit of operative compared to nonoperative treatment after initial patellar dislocation [2, 9, 34, 48]. One recent level 1 study demonstrated that repair of specific, isolated tears of the MPFL resulted in lower risk of recurrent instability and better subjective outcomes than nonoperative treatment [7]. All of these studies varied in the timing and specifics of nonoperative care as well as the technique and timing of operative care, so the evidence is not conclusive. However, as of this writing advocates of immediate MPFL repair have not provided convincing evidence that operative care is worthwhile following the first dislocation.

On the other hand, patients presenting with recurrent patellar instability are much more likely to have subsequent dislocations than patients who have had only one dislocation episode. In contrast to the rather low risk of redislocation after initial patellar dislocation, the risk of an additional dislocation within 2–5 years is around 50% in a patient with a history of prior patellar instability [25]. In these cases of *recurrent* patellar instability, surgical stabilization generally is recommended if the patient wishes to reduce his or her [54] risk of further dislocations. Based on laboratory evidence that the MPFL is the primary ligamentous stabilizer against lateral patellar displacement, current techniques usually include an attempt to restore a functional MPFL. In this chapter, the authors provide an overview of indications and a technique for MPFL reconstruction. Our indications and technique are described in the context of other approaches to medial retinacular soft tissue repair and reconstruction, so that the reader may better understand current controversies in the surgical treatment of episodic patellar dislocation.

20.1.3 Published Techniques of Medial Patellofemoral Ligament Repair and Reconstruction

Restoration of the MPFL has been described by primary repair alone, primary repair with augmentation, and by reconstruction alone. Primary MPFL repair has been approached in various ways. The repair may be done acutely [34] or after a period of initial healing [23]. Repair has been described at the patellar insertion of the MPFL [23, 44] or at its origin between the adductor tubercle (AT) and medial epicondyle of the femur [1, 34, 42]. Recently there have been reports of medial retinacular reefing by arthroscopic approach, though in these cases it is not clear that the MPFL is actually being repaired in isolation because there is no attempt to dissect the ligament. In the acute setting, the surgical approach must be determined by the location(s) of retinacular injury if repair is to be successful. If acute repair is done, failure to identify any and all locations of disruption may jeopardize the success of the operation. This may explain the relatively low rate of successful repair in the study by Nikku et al.[34] as well as the high rate of success in the paper by Camanho et al. [7]. If one undertakes an acute repair, the entire ligament should be inspected carefully, and all sites of injury should be repaired or reinforced. Preoperative MRI is of value [28, 42][7], as is arthroscopy, in determining the nature of the injury (midsubstance tear versus avulsion). Acute midsubstance repairs may be difficult to address surgically because of the small cross-section of the MPFL, whereas an avulsion may be addressed more easily with a suture anchor. Garth et al. [26] described exploration of the medial retinacular tissues for the purpose of identifying and repairing stretched or torn tissues.

Avikainen et al. [3] describe a technique of primary MPFL exploration and repair with the addition of an adductor magnus tenodesis in acute and chronic cases of patellar instability. Their approach is similar to the approach of Garth et al. with an extensile longitudinal incision which is more posteriorly based along the adductor tubercle. Layer 1 is incised and the interval between the vastus medialis obliquus and MPFL is explored digitally. The MPFL is cut at its femoral origin for later reinsertion. The adductor magnus is then located at its insertion slightly proximal to the origin of the MPFL and under the medial intermuscular septum. An 8-cm segment of adductor magnus tendon is harvested with its insertion left intact. The superior medial geniculate artery is identified and protected. The MPFL along with the firm edge of the vastus medialis obliquus is repaired to its epicondylar origin while a medially displacing force is applied to the patella. The harvested adductor magnus tendon is then turned over the MPFL and sutured to it with absorbable stitches. The retinacular layer then is closed with a running stitch and the tenodesed adductor magnus is checked while ranging the knee from 0° to 90° to ensure easy gliding over the femoral epicondyle.

In some patients, particularly those with Patella Alta or trochlear dysplasia, the MPFL may be structurally incapable to restrain the patella. Even if it has normal strength, some authors [3, 17, 33, 38, 54] think that a lack of bony constraint can put the ligament at risk for repeated failure if additional measures are not taken to augment or support the native medial tether. Reconstruction of the MPFL in such cases may be necessary if sufficient collagen is not available to ensure a durable repair. Many different graft materials have been used including autograft, allograft, and synthetic polyesters [17, 38] Although the use of synthetic grafts for intra-articular ligament reconstruction has fallen out of favor in the United States, several authors have reported success using them for MPFL reconstruction [17, 38].

Ellera Gomes was the first to report a true MPFL reconstruction in 1992 [17]. He subsequently published a longer term follow-up study of the original patient cohort, which showed good long-term durability of the reconstruction [18]. In Japan, longstanding interest in patellar dislocation and the MPFL has resulted in several series on MPFL reconstruction [12, 13, 32, 33, 36, 38]. In the United States, Drez, Teitge, Burks, and Steensen have also published techniques [15, 45, 53, 54]. Erasmus of South Africa originally reported his technique for MPFL reconstruction in 1998, and has published good short-term clinical results [19, 20]. Several Australian centers have published techniques [11, 50], and there are many recent reports from Europe describing new techniques for MPFL reconstruction [8, 21, 46]. Clearly, MPFL reconstruction can be achieved in a variety of ways; and there is no shortage of new techniques for attaining the goal of restoring a functional ligament. There are also pitfalls of which the surgeon should be aware. The purpose of this chapter is to describe the technique the senior author has used since May 2001 using a consistent technique based on Muneta's [33] approach but using a semitendinosus tendon autograft instead of a synthetic graft. We clarify our indications and contraindications, and describe pitfalls and complications that must be avoided to have a rapid and successful return to sport without recurrent patellar instability or pain.

20.2 Indications for Medial Patellofemoral Ligament Reconstruction

MPFL reconstruction is used to treat episodic lateral patellar instability *due to* excessive laxity of medial retinacular patellar stabilizers, principally the MPFL. It is surprising how often a patient will present with a clear history of patellar dislocation, yet there is no sign on physical examination that there is abnormal patellofemoral laxity. The surgeon must take care when eliciting the history and in examining the patient that there is not some other occult injury masquerading as lateral instability. The surgeon must document MPFL laxity by physical examination [4], stress radiography [55], and/or arthrometry [24] before proceeding with the reconstruction. If the patient is too apprehensive to allow an adequate examination, an examination under anesthesia (EUA) should be performed to confirm the diagnosis. In any case, EUA and arthroscopy routinely precede the reconstruction, to document laxity objectively (without guarding or apprehension) and to stage cartilage lesions that may affect outcomes such as pain relief and arthrosis.

20.2.1 The Ideal Patient

The ideal patient has little pain between episodes of patellar instability. While pain may be present, it usually is not the primary complaint. The patient may report functional impairment when asked, but often he or she has made adjustments (reduced sports hours or changes in sports activities) in order to limit the disability. At this point, it is only the occasional dislocation or subluxation that precipitates the consultation. Please note that MPFL reconstruction should not be done for patellofemoral pain. There is little in the literature to support that approach, and on the contrary there is ample evidence that stabilization of the patella is unlikely to result in reduced pain even if done successfully [31,51]. In other words, patients should be counseled beforehand that stabilization of the patella will not reliably treat any pain that is not directly caused by their instability episodes. Preexisting arthritis is also a relative contraindication to MPFL reconstruction because the operation will increase patellar constraint and may actually increase loading on damaged patellofemoral surfaces. In such cases, realignment of the extensor mechanism and even lateral release may be combined with the stabilization in order to balance constraint and unload sensitive areas. Finally, the permanently dislocated or habitually dislocating patella, which dislocates with every knee flexion, is not due to lack of trochlear and ligamentous constraint. It is a complex entity that requires detailed analysis and surgical planning that is beyond the scope of this chapter.

20.2.2 Surgical Objectives

In performing MPFL reconstruction at our institution, we have two specific surgical objectives. First, we reestablish the natural check-rein against lateral patellar motion [4]. This check-rein, which is a palpable, firm stop when the patella is passively displaced in a lateral direction, represents the tethering of the patella by the intact MPFL. Our second objective is to reestablish normal limits of passive lateral patellar motion. In normal subjects and in controls, we have demonstrated that a 5-lb displacing force with the knee at 30° flexion results in 7–9 mm of lateral displacement [24, 27]. Therefore the goal of MPFL reconstruction is to restore passive stability to the patella so that the patella is free to glide laterally up to 9 mm, at which time the reconstructed medial ligamentous tether will engage in order to prevent further displacement.

20.3 Authors' Preferred Technique

20.3.1 Setup

This procedure typically requires 1 h of operative time. We use general anesthesia with a femoral nerve block, a tourniquet, and an adjustable knee support that can be used to adjust knee flexion during the procedure. The setup includes a fluoroscopy machine, standard arthroscopy tower and instruments, instruments for hamstring harvesting, a drill set (usually 4.5 or 3.2 mm drills are sufficient), and a curved suture passing device such as a doubled #18 or #20 gauge wire. One length of #5 braided polyester suture will be used as a pull-out suture, and several lengths of #0 absorbable suture material on a taper needle are used for whip-stitching the free graft ends and the looped end of the graft. The patient is positioned supine on the table. It is often helpful to use an image intensifier to confirm femoral tunnel placement and this should be taken into consideration when positioning the patient.

20.3.2 EUA

Patellar mobility is evaluated. If the patella cannot be dislocated, the diagnosis must be questioned. The diagnosis of patellar instability requires that there be a soft endpoint or no endpoint to lateral patellar displacement either at full knee extension or at 30° flexion, and that the patella be mobile enough to displace it more than 10 mm laterally from the centered position with the knee at 30° flexion.

20.3.3 Arthroscopy

Standard arthroscopy portals are made for the diagnostic arthroscopy. We use an anterolateral, anteromedial, and an accessory superolateral portal. The superolateral portal facilitates viewing of the patellar articular surface as well as passive patellar tracking and mobility. Concomitant injures to the articular cartilage should be inspected. Unstable cartilage flaps are removed, but other lesions are not addressed.

20.3.4 Semitendinosus Tendon Harvest

The skin incisions are shown in Fig. 20.1. Semitendinosus (semi-T) harvest follows the technique described by Brown et al. [5, 6]. Expose the sartorial

Fig. 20.1 Right knee. Incisions shown with the two patellar tunnels exposed. Medial femoral epicondyle and adductor tubercle are marked

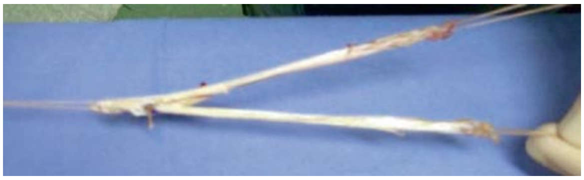

Fig. 20.2 A prepared graft consisting of a doubled semitendinosis autograft that is whip-stitched for 20 mm with #0 absorbable suture at the doubled end and on each individual limb

fascia 2 cm medial and distal to the medial border of tibial tuberosity. Incise the fascia with a light scalpel stroke in line with the palpable gracilis tendon, taking care to identify the bursal layer immediately deep to the sartorial fascia. Avoid making this incision too deeply in order to avoid injury to the underlying superficial medial collateral ligament (MCL). Identify both gracilis (proximal) and semi-T tendons from their deep aspect; i.e., from within the bursal layer. Apply tension to the isolated semi-T as you free it from crural fascia at the posteromedial corner with tissue scissors. Place stay stitches of #0 absorbable suture on a tapered needle, then divide tendon from its tibial insertion. We use absorbable suture for the baseball stitches on both free ends of the semitendinosus graft because these ends will be discarded after graft fixation. Harvest the tendon using closed (preferred) or open tendon stripper.

The graft is prepared and sized on the back table. The doubled, or looped, graft should be at least 120 mm after trimming (240 mm total graft length). Due to this length requirement, the gracilis is not sufficient for doubled graft with this technique. The graft is sized to 240–250 mm, and then folded in half and the excess is removed. A pullout suture of #5 polyester or similar material is placed through the loop to be used for pulling the doubled graft into the blind femoral tunnel. A baseball stitch 20 mm in length is placed in the looped end of the graft, similar to technique for ACL and other looped tendon graft applications. The two free ends are baseball-stitched with absorbable suture in preparation for their passage through the two patellar tunnels (Fig. 20.2). The looped end will be anchored in the blind femoral tunnel (Fig. 20.3a); while the two free ends will pass through individual tunnels in the medial patella (Fig. 20.3b). In this way the two ends "fan out" slightly on the patella to reproduce the normal insertion of the MPFL onto the patella (Fig. 20.4).

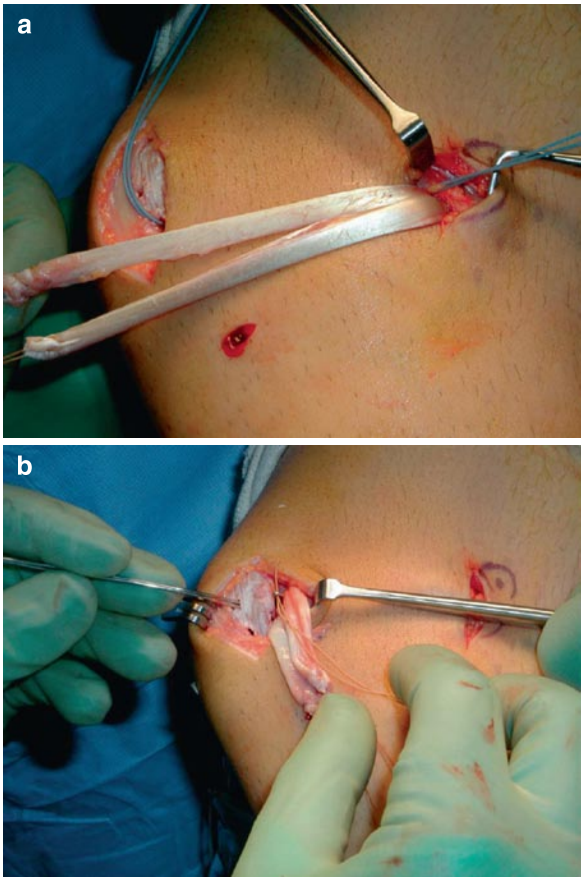

Fig. 20.3 (**a**) Graft fixed in femur, isometry stitch now used to pass the graft through retinaculum. (**b**) Passing graft arms through patellar tunnels

20.3.5 Patellar Exposure and Patellar Tunnels

Make an incision the length of the patella, centered over the junction of the medial and middle thirds of the patella (in line with the medial border of the expansion of the patellar tendon at the distal patellar pole). The medial quarter, or 8–10 mm, of the patella, is exposed by subperiosteal dissection with a scalpel. The dissection extends medially around the patella, through layers 1 and 2 (longitudinal retinaculum and MPFL), stopping after the transverse fibers of the native MPFL have been cut. At this level, only layer 3 (the capsular layer) remains intact. The graft may be placed in the interval between layers 1 and 2 or between layers 2 and 3. That is, it may lie superficial or deep to the native MPFL. Placing the graft between layers 2 and 3

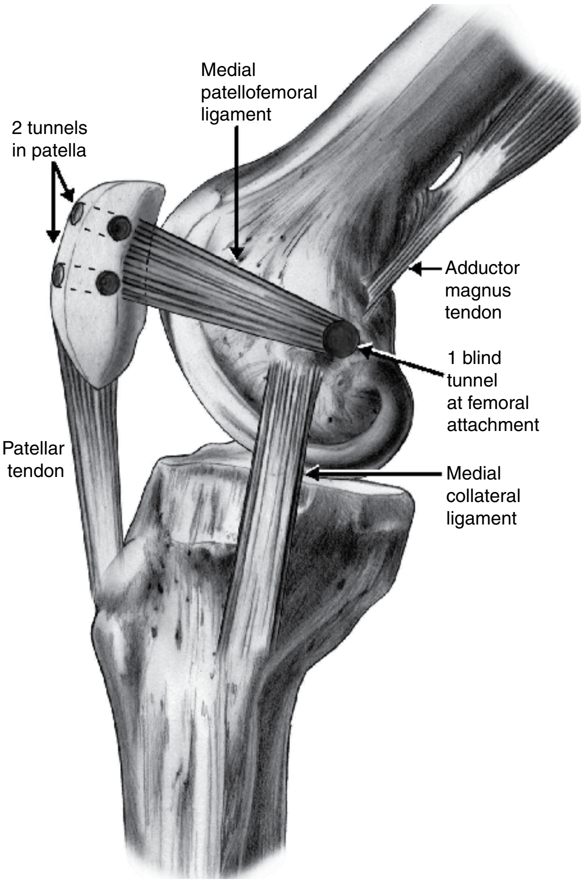

Fig. 20.4 Anteromedial schematic view of a right knee. The MPFL is shown, along with the MCL and adductor magnus tendon attachments to the medial femur. The MPFL originates from a ridge connecting the adductor tubercle and epicondyle. The MPFL fans out as it runs anteriorly and laterally, to insert on the proximal two thirds of the medial patellar border. The MPFL is reconstructed by making one blind tunnel at the femoral attachment, and two tunnels on the patella which enter at the medial articular margin and exit on the anterior (ventral) patellar surface

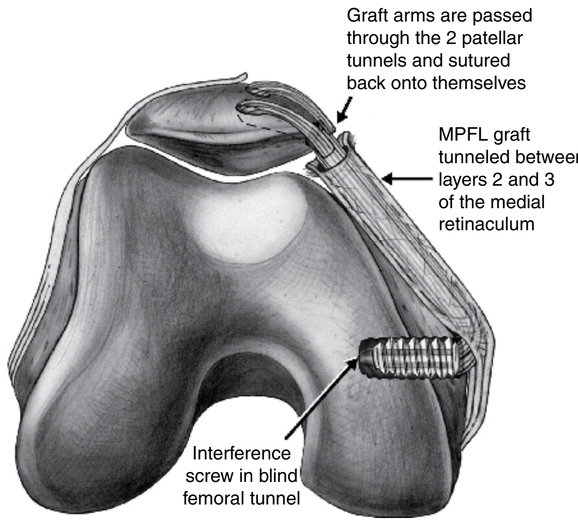

Fig. 20.5 Axial schematic view of a right knee, from below. The MPFL graft is shown, fixed in the blind femoral tunnel with an interference screw. The graft passes outside the capsular layer (layer 3) so that it remains extra-articular. The two free arms of the graft are passed into the patellar tunnels from the medial patellar border, exiting anteriorly, and the free ends are sewn back onto themselves with two figure-eight stitches of #2 nonabsorbable suture. All slack is removed from the graft before suturing, but the grafts should be under no tension when the patella is centered in the groove. Excess graft length is removed after tension and patellar mobility are confirmed to be satisfactory

is preferred for two reasons. First, the vastus medialis inserts superficially into the anterior 3 cm of the MPFL [57], so blind dissection superficial to the MPFL may cause unnecessary trauma to this insertion. Second, if the graft is placed deep to the MPFL, the native MPFL may be repaired to the graft during wound closure. The graft should not be deeper than layer 3 so that it remains extra-articular in order to avoid graft abrasion and to allow healing in the extra-articular environment. Using a long curved clamp, develop the selected soft tissue interval all the way to the medial femoral epicondyle.

Figure 20.5 shows an axial schematic view of the graft in place. The looped end is fixed in the femur with an absorbable screw. The graft passes between the capsular layer (layer 3) and the native MPFL (layer 2). Each free arm enters the medial border of the patella, exits anteriorly, and is sutured to itself with a #2 braided nonabsorbable suture.

Use a 4.5 mm drill to create the two tunnels in the proximal two thirds of patella (Fig. 20.4). Care should be taken to avoid inserting the graft distal to the native insertion of the MPFL, in order to avoid constraint of the distal patellar pole. Enter with the drill bit at the medial patellar border of the patella, adjacent to the articular margin, to a depth of 8–10 mm. Leave a distance between the two tunnels and keep them parallel to avoid fracturing the bone bridge between them. Then create exit holes on the anterior surface of the patella, at the lateral edge of the original retinacular dissection about 8 mm from the medial patellar border. A small angled curette is used to complete the connection between the anterior and medial holes to create the tunnels. Note that the semitendinosus is sometimes thicker than 4.5 mm diameter. If the grafts are too thick for 4.5 mm tunnel, enlarge the drill holes slightly as needed. The baseball stitches in the two free ends of the graft should not thicken the ends of the graft, and the sutures need not be stout: they should be just strong enough to pull the ends through the patellar tunnels. The excess length on the free ends will be discarded after final fixation, so permanent suture is not needed.

20.3.6 Femoral Exposure and Femoral Tunnel

Make an incision just anterior to the palpable ridge connecting the femoral epicondyle to the adductor tubercle (AT) (Fig. 20.1). If this landmark is difficult to palpate, flex the knee slightly. This maneuver shifts the medial hamstrings posteriorly away from the epicondyle so that the epicondyle is easier to locate. If obesity still makes exact localization of medial landmarks difficult, make a small incision and use digital palpation through the wound, and re-direct the incision as needed. When the epicondyle and adductor tubercle have been localized with confidence, reintroduce the long curved clamp into the retinacular interval from the patellar end of the medial retinaculum, and with the tip of the clamp overlying the ridge between the epicondyle and tubercle, incise layers 1 and 2 of the retinaculum using a scalpel blade. Place the tip of a Bieth guide pin at a point midway between the adductor tubercle and the epicondyle. Pass the pin towards the broad lateral (nonarticular) surface of femur. Pass a loop of #5 braided polyethylene suture around the Pin, through the dissected retinacular layers, then through the patellar tunnels. Hold the suture in place with a clamp on the superficial surface of the patella and range the knee to evaluate length change behavior (isometry). This suture is then left in the retinacular tunnel for later graft passing.

Placement of the femoral attachment is one of the most critical steps in the operation. It is often helpful to use fluoroscopy to confirm the placement of the Bieth pin just proximal to the junction of Blumensat's line and the posterior femoral cortex, along a line extending down from the posterior cortex of the femoral shaft [47]. The native MPFL originates on the ridge between the adductor tubercle and the medial femoral epicondyle (Fig. 20.4).

There is currently a good deal of discussion about the isometry of the native MPFL, and how the graft should behave during knee flexion [20, 39, 40, 45, 50, 52]. The normal MPFL sees greatest tension in full knee extension with the quadriceps contracted. The ideal length change behavior ("isometry") for an MPFL graft has not been established. The reader should understand two points with respect to the controversy over isometry in reconstruction of the MPFL. The first is that all published work is taken from normal cadaver knees, which may not represent the anatomy of a dysplastic trochlea or high patella, both of which are often present in patients with recurrent patellar dislocation. Therefore, it is impossible to predict from these studies exactly where you should attach the graft to the femur of your patient. The second point is that, whether or not the native MPFL in normal knees behaves isometrically, use of suture isometry allows the surgeon to understand how the graft will behave once it is fixed to the patella and femur in any given knee. Thus, it is wise to use suture to "model" graft behavior before committing to a given femoral attachment site. The principle of isometry in this setting is to ensure that the graft works in concert with the trochlea and to allow the patella to enter the trochlea smoothly in early flexion. Thaunat and Erasmus have recently pointed out that a graft that is too tight in extension may contribute to prolonged extensor lag postoperatively [56]. Adjust the pin site to minimize length change with knee flexion: if lengthening occurs in flexion, place a second pin more distally toward the epicondyle; if lengthening occurs in extension, place the second pin more proximally toward the adductor tubercle. Recheck isometry with the second pin. The graft should allow the patella to enter the trochlea from a slightly lateral position, which makes use of the more gradual proximal slope of the lateral trochlea facet. This also helps avoid an overtight MPFL in extension, which avoids the complication described by Thaunat and Erasmus [56].

Once the femoral pin site is accepted, ream a blind tunnel into the femur of the size needed to receive the doubled end of the graft; rarely more than 7 mm. Ream to a depth of at least 20 mm. If bone is of poor quality, ream small and dilate up to desired tunnel diameter. Alternatively, use EndoPearl™ to secure femoral fixation (Fig. 20.5 shows graft after femoral fixation). Fixation to femur may be achieved reliably with a 20 mm absorbable interference screw. The graft makes a turn of approximately 110° exiting the femoral tunnel (Fig. 20.5), and does not require extreme measures in order to be fixed securely. The looped isometry suture, which was removed from the Bieth needle prior to reaming but which was not removed from the retincaulum, can be used to lead the free graft ends through the space created within the retinaculum. After delivering the free ends through the retinaculum, pass the free graft arms individually through their respective patellar tunnels using doubled #18 or #20 gauge stainless steel wire or other curved suture passer such as a #5 Mayo needle. The graft arms enter the medial patellar border and exit anteriorly (Fig. 20.5). The surgeon takes all slack out of the graft, but there should be no tension on the graft with the patella centered in the groove. Each free end of the graft is doubled back and sutured to itself just medial to the patella using two figure-eight mattress sutures of #2 non-absorbable suture on a tapered needle (Fig. 20.5). Patellar mobility is checked after the first suture is placed. There should be a good endpoint, or check-rein, with the knee in full extension and at 30° knee flexion, knee range of motion should be full, and lateral patellar displacement from the centered position at 30° of flexion should be between 7 and 9 mm. Sharply remove excess graft, then close the retinaculum over the graft. Close wounds in standard fashion. No drains are used.

20.3.7 Pitfalls and Complications

During preparation of the two patellar tunnels, or during passage of an oversized tendon graft through a tight patellar tunnel, the bone bridge overlying the patellar tunnel may break. If this occurs, drill a second exit hole more laterally on the anterior patellar surface or drill the tunnel transversely across the entire patella, exiting at the lateral patellar margin. The graft can be secured by tying the sutures over a button or suturing the end of the graft to the soft tissues at the lateral patellar border.

Excessive medial constraint has been reported after MPFL reconstruction [33, 38, 39]. In the normal knee, the patella rests in a centered or slightly lateral position with respect to the femoral trochlea; it can be displaced laterally with gentle force but the normal MPFL tightens as the patella is displaced, limiting its displacement. The goal of MPFL reconstruction is to reproduce this relatively compliant system of patellar constraint. Overtightening of the graft so that the graft is under tension when the patella is in contact with the medial trochlea facet will result in an over-constrained patella that is painful, and could lead to arthrosis due to increased medial facet forces. After the graft is fixed in place, the patella should still enter the trochlea from the lateral side. At 30° knee flexion, the patella should be centered or in a slightly lateral position. When it is manually displaced, the graft should tighten in order to prevent excessive mobility. Sutures should be removed and graft re-tensioned if the patella enters the groove from a medial position or if there is less than 5 mm lateral patellar glide with gentle manual force at 30° knee flexion.

20.4 Postoperative Care

Perioperative pain management is generally easier than that for other knee reconstructive surgery, possibly because the synovium is not disturbed. Outpatient management is the norm, usually with a femoral nerve block placed intraoperatively and oral narcotics after discharge home. A drop-lock or knee extension brace is used for up to 6 weeks to prevent falls. Immediate full weight bearing is allowed and gait training may be progressed as soon as good muscular control has been reestablished. Physical therapy is used to restore quadriceps control and range of motion as quickly as possible. If the patient does not have at least 90° of flexion by 6 weeks, the intensity of the therapy program must be increased; manipulation under anesthesia (MUA) may be needed between 9 and 12 weeks postoperatively if stiffness does not resolve with therapy alone.

20.5 Results

In a review of the literature Smith et al. found eight articles that met their inclusion criteria which reported outcomes on a total of 186 MPFL reconstructions [51]. All of the articles were case series which used a variety of methods and indications. Of the 155 cases, from the six articles which it was reported, there were only six reports of dislocation or subluxation. One series in particular had four dislocations or subluxations postoperative of

46 reconstructions [13]. Of the five articles that reported post operative complications, totaling 109 cases, there were the following 20 complications: 1 arthrofibrosis, 1 hemarthrosis, 1 wound dehiscence, 1 post op hematoma, 1 patient with graft advancement, 2 minor wound infections, and 13 patients with painful hardware [51]. Eleven of the patients with painful hardware arose from one study where a staple was used for fixation this accounted for 41% of the patients in the study [38]. It appears from the literature, and in our hands, that MPFL reconstruction is an effective and safe procedure for the treatment of patellar instability. We have presented our indications, objectives and technique for MPFL reconstruction and the considerations behind them.

20.6 Summary

- The most important stabilizer of the patella in normal knees is the trochlear groove.
- When the groove is deficient, the retinacular ligaments take on a greater role.
- Stabilization of the patella should always include a reconstruction of the MPFL in order to restore passive patellar restraint.
- It is indicated for any patient with at least two documented patellar dislocations and excessive lateral patellar mobility.
- When the MPFL graft is properly positioned, it should remain lax throughout the range of motion if the patella is centered within the femoral groove, and should tighten only when the patella moves laterally. Early range of motion is important after MPFL reconstruction in order to overcome postoperative stiffness.
- MPFL reconstruction is a reliable technique for restoration of patellar stability.

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MPFL Reconstruction: The Adductor Sling Approach

21

Elizabeth A. Arendt

Surgical treatment of patella instability has two approaches. One is that anatomic alignment is the most important factor(s) and all elements of "malalignment" must be corrected. The other viewpoint is a "softer" approach that recognizes the importance of a soft tissue restraint to lateral patella translation: to stabilize or recreate this restraint can be sufficient in many cases with bony (mal)alignment left "uncorrected."

21.1 Indications for Medial Patellofemoral Ligament Reconstruction

- Laxity of the medial retinacular stabilizing structures of the patella due to recurrent lateral patellar dislocations.
- Medial patellofemoral ligament (MPFL) laxity with sufficient lateral excursion to be consistent with previous lateral patella dislocations. This should be documented by physical exam and/or stress radiographs and/or arthrometer testing.
- Recurrent lateral patella dislocations that have not responded to aggressive and appropriate nonoperative management.

An MPFL reconstruction is most often used alone without a bony procedure (distal realignment and/or trochleoplasty) when bony anatomy is normal or near normal. Its goal is to restore the loss of the medial soft tissue patella stabilizer, which is injured and/or chronically lax due to recurrent lateral patellar dislocations. An exam under anesthesia can be used to document laxity without guarding or apprehension. Arthroscopy is useful to stage articular cartilage lesions. Arthroscopy typically shows excessive lateral tilt and translation through a passive range of motion due to medial retinacular laxity with the joint distended. Thus, one should not judge lateral patella maltracking solely based on this arthroscopic view.

An ideal candidate for an isolated MPFL reconstruction might have the following profile of risk factors:

- Trochlear dysplasia, type A, or normal trochlea.
- A tubercle sulcus angle of 0°–5° valgus/or TTTG less than 20 mm.
- Patella Alta less than 1.2 (Insall-Salvati or Caton-Deschamps index).
- Patella tilt less than 20° utilizing axial image with posterior femoral condyles as a reference.
- Patella tilt on an axial radiograph that has no lateral tightness on physical exam after the patella is relocated.

(If the patella tilt is present on axial imaging without excessive tibial tuberosity offset, this is most likely due to lateral soft tissue tightness. Therefore, in this situation, an MPFL can be used with some form of lateral retinacular release or lengthening.)

21.2 Contraindications for MPFL Reconstruction

- Not indicated for isolated patellofemoral (PF) pain
- Not indicated for excessive lateral patellofemoral tilt and/or translation without history and

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physical exam evidence of recurrent lateral patella dislocations.

- Not indicated for PF arthritis.

21.3 MPFL Reconstruction Adductor Sling Approach: Surgical Technique

The procedure starts with an exam under anesthesia verifying lateral translation of the patella consistent with lateral patella dislocation. The degree of lateral translation of the patella is verified under anesthesia using the lateral glide test [2] which measures translation using a patella quadrant (one fourth the width of the patella) as the unit of measurement. For consistency this is measured at 0° of flexion but one should examine lateral translation in early flexion as well.

An arthroscopy is then performed using both anterolateral and superomedial arthroscopic visualization portals to view the entire patella surface, and observe passive patella tracking. The superomedial or superolateral position of the arthroscope provides the surgeon with the most accuracy in locating cartilage lesions of the patella and trochlear groove, as well as aids in observing passive patella tracking.

The arthroscopic instruments are removed from the knee; the rest of the procedure is performed with tourniquet control of hemostasis as needed.

A small incision (2–3 cm) is made along the medial border of the patella. Using fluoroscopy, the patella origin of the MPFL is identified. In a caudad – cephalad direction, this point is located at approximately one third of the longitudinal length of the patella measured from the superior patella tip (Fig. 21.1). Oftentimes, this is where the medial border of the patella becomes more vertical. Fluoroscopy helps to locate the position in the dorsal–ventral plane. One should avoid the articular cartilage surface as well as the anterior patella cortex, as the anterior cortex gives the patella its strength; violating the dorsal cortex increases fracture risk.

A K-wire is passed through the patella medial to lateral, exiting at the lateral border of the patella. If a lateral retinacular lengthening is to be performed concurrently, a separate lateral incision is made, and the K-wire exits within the lateral sided incision. When an islolated MPFL is being performed without any lateral sided soft tissue procedure, the K-wire exits a small stab wound in the skin. Once appropriate patella position is found, this K-wire is over drilled with a 4.0 or 4.5 mm cannulated reamer (depending on size of the graft). The length of the tunnel varies between 10 and 15 mm, 10 for a small patella (<35 mm in width) and 15 mm for most patellae.

Fig. 21.1 This lateral fluoroscopic image shows the approximate location of the patella insertion of the medial patellofemoral ligament (MPFL), located by this K-wire passing medial to lateral through the patella. Once an appropriate site is found, this K-wire is over drilled with a cannula; size and length of the tunnel is surgeon dependent

A looped passer is placed through the patella medial to lateral. This loop passer can be a #22 gauge wire looped on itself, or a Hewson suture passer, or the looped passer from a biotenodesis shoulder set. The looped passer is passed medial to lateral through the patella. A suture is threaded through the loop and passed lateral to medial through the patella. This looped suture will then pass the graft through the patella medial to lateral.

A semitendinosus or gracilis single strand is used as the graft. This can be either autograft or allograft. The suture is tied on both ends with leader sutures. Absorbable sutures are used so as not to have permanent sutures in the patella. One end of the graft, usually the more tubular distal end of the tendon, is marked according to the length of the tunnel.

The adductor magnus tendon is approached through a separate vertical incision. A 3 cm long incision is made superior and slightly posterior to the medial epicondyle, ending at the medial epicondyle. The incision is made in line with the medial intermuscular septum. Once through the fatty subcutaneous tissue you will reach the adductor fascia. This is a very thin fascia in most patients except the very young. One makes a small incision through this and typically finger dissects until the adductor magnus tendon is found. The adductor magnus tendon can often be palpated before it can be seen. Anatomically it sits flush to the posteromedial aspect of the femur, ending with its insertion on the adductor tubercle. Once this tendon is identified, one needs to dissect around it, freeing all interdigitations of the tendon down to its insertion assuring that the graft lays as distal on the tendon as possible. A looped suture is placed around the adductor tendon for aid in graft passage.

The MPFL graft is first passed into the patella tunnel medial to lateral, pulling the graft until the appropriate graft length is well seated in the patella tunnel. The graft is secured to the patella in two ways. On the lateral side, two sutures exit the lateral side of the patella. One arm of the suture is passed through the lateral retinaculum with a free needle and the two sutures are tied to themselves. The second point of fixation is on the medial side. The cuff of medial retinaculum is sewn to the graft as it exits the medial border of the patella. This can be secured with box stitch of an absorbable suture (Fig. 21.2).

The graft is then placed underneath the medial retinaculum, around the adductor tubercle tendon keeping the graft horizontal under the adductor tendon insertion (Fig. 21.3). It is important to keep this arm of the graft distal to the adductor tendon, as it better approximates the anatomic femoral insertion point of the MPFL. The graft is placed back underneath the medial retinaculum, and exits at the inferior medial aspect of the patella.

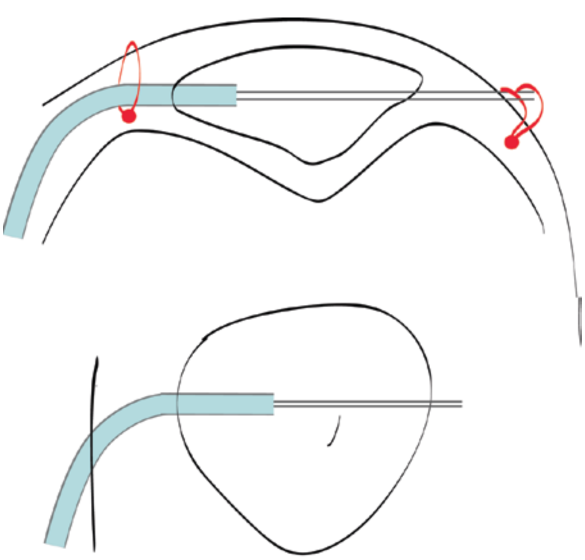

Fig. 21.2 The graft (depicted in blue) is passed into the medial sided patella tunnel, with its leader sutures exiting the lateral side of the patella. The graft is secured to the patella capsule at two sites. Medially the graft itself is sutured to the cuff of medial capsule just before it passes into the patella tunnel. Laterally the leader sutures are passes through the lateral retinaculum and tied to themselves

The knee is then bent to 40° of flexion, locating the patella in the groove. The graft is tightened only enough to reduce redundancy in the graft. Where the two arms of the graft cross over one another, just distal to the adductor insertion, a single #1 nonabsorbable stitch is placed across the two arms of the graft.

At this point in time, one can test a full range of motion and passive patella translation. If full motion knee flexion is not achieved, one can untie the knot in the graft, and place the knee at a slightly higher degree of flexion at the time of fixation of the two grafts arms. Forty degrees of knee flexion is based on laboratory reconstructions suggesting this angle to be the best compromise between allowing full knee flexion yet restraining the patella against excessive lateral patella translation. In early flexion, the patella should translate no more than 10 mm laterally.

The distal arm of the graft is secured to the distal medial border of the patella with a soft tissue technique. The rectus femoris fascia on the dorsal surface of the patella is undermined. The graft is looped underneath this fascia and secured with a #1 absorbable suture. Any excess length of the graft is excised.

21.4 Discussion

The surgical procedure of MPFL reconstruction for stabilization of lateral PF instability was begun at our institution in 2000, utilizing an approach for MPFL reconstruction that was not firmly fixed on the femur. At that time, knowledge of specific MPFL insertion sites on the femur was not well characterized. The increased strength and stiffness of the graft used to replace the MPFL was well known. It was felt that a strong and stiff graft with fixation points on the patella and femur that were not forgiving might be a recipe for disaster. Therefore, the technique of Gomes [1] was studied where the femoral insertion of the MPFL graft was slung around the adductor magnus tendon at the

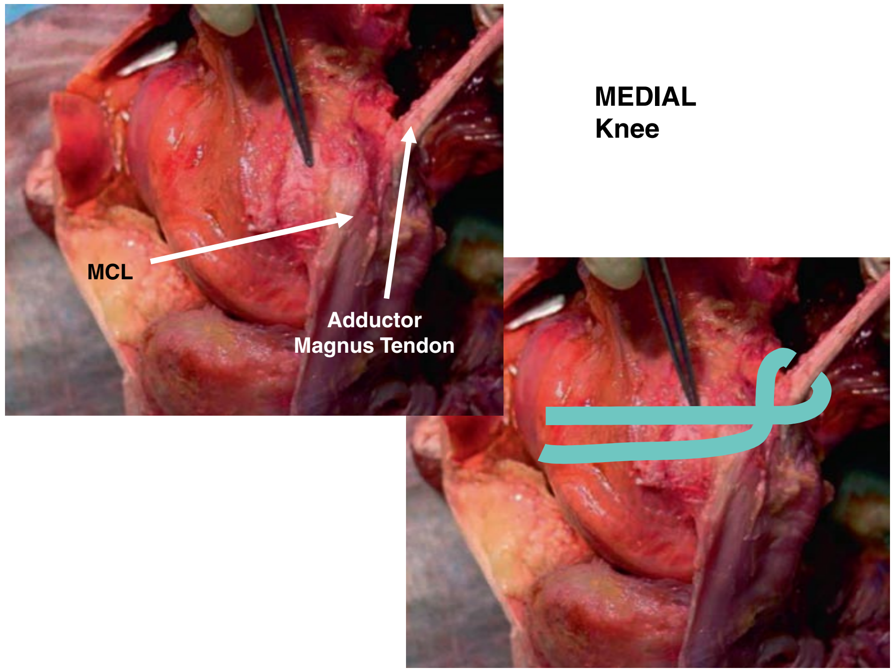

Fig. 21.3 This image is a cadaver representation of the medial patellofemoral ligament (MPFL) graft being "slung" around the insertion of the adductor magnus tendon, keeping one arm of the graft distal to the adductor magnus tendon insertion, passing the graft around the tendon, passing over itself just distal to the tendon insertion. It is at this site that a single nonabsorbable stitch is placed

adductor tubercle site. This technique has been modified from the original procedure by placing the horizontal arm of the graft distal to the adductor tendon. This places the graft within a few millimeters of the femoral anatomic insertion point of the MPFL.

This surgical method of MPFL reconstruction appeals to me for several reasons:

1. Most importantly, this is a technique that can be utilized safely with children as one does not violate the area at or near the distal femoral physis.
2. The fixation point on the femur is somewhat forgiving as it is not rigidly fixed. With forced lateral patella translation, the femoral fixation is able to "give" a bit before stretching of the graft tissue and / or disruption of the graft fixation (E. Arendt, personal observation, laboratory simulation).
3. The medial femoral condyle is a very unforgiving area in regards to metal fixation, hardware, and tunnels. Pain complaints are possible when this region is violated with either a tunnel and/or metal fixation.

The advantage of this procedure is its consistency. The anatomic location of the femoral insertion of the MPFL reconstruction is always at the same site as it utilizes the femoral insertion of the adductor magnus tendon. It can be used safely without the need for fluoroscopic verification of your femoral position.

21.5 The Minnesota Experience

This techniques has been used by the author since June 2003. One-hundred and sixty-five MPFL reconstructions have been performed. Within the subgroup of isolated MPFL with no bony procedure (80 patients), there has been one frank lateral patella dislocation (male, reinjured in a noncontact football injury), and two "subluxation" events (MPFL intact, recovered with nonoperative management).

Two patients reported recurrent giving way episodes without frank injury documented. Both improved when distal tibial tubercle transfer was added as a second stage surgery. Both have Patella Alta index >1.3 (Insall-Salvati index).

Two patients had painful flexion with limited motion. One had subsequent surgery with lengthening of the MPFL; motion was restored with persistent pain. Seven patients needed a manipulation within the first 8 weeks postsurgery; all recovered knee flexion >140°.

21.6 Conclusion

The adductor sling technique is a satisfactory surgical procedure for restoring the medial patella stabilizer and preventing lateral patella dislocations. It is a reproducible technique that can be used safely in all age groups, in particular those with open physis.

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22 Importance and Radiographic Identification of the Femoral Insertion in Medial Patellofemoral Ligament Reconstruction

Philip B. Schöttle

Since biomechanical studies have shown the MPFL as the main restraint against lateral patellar displacement [4, 6], MPFL reconstruction became a widely accepted technique to restore normal patellar tracking and stability [5, 9, 10]. Although the clinical outcome studies after MPFL reconstruction report promising results related to stability, there are some cases, reporting about increased pain or loss of function postoperatively [8, 11, 13, 15, 16]. Main reason therefore seems to be a nonanatomical reconstruction, since the importance of correct graft positioning for ligament reconstruction has been recognized already in 1938 by Palmer [12], and its influence on the clinical outcome is well known in ACL reconstruction [1]. While the patellar insertion, where the medial facet can be prepared completely, even with relatively small skin incisions, the femoral insertion, which is described to be close to the medial epicondyle and the adductor tubercle can be difficult to palpate, not only when covered by soft tissue, but also in skinny patients.

Since biomechanical studies [2, 7] have shown the consequence of a nonanatomical femoral insertion onto the patellofemoral pressure, this insertion became the key point in MPFL reconstruction.

The reason for this estimated increase of medial patellofemoral pressure is founded by the idea that a too proximal fixation point would lead to an increased distance to the patella, when the knee flexes, and vice versa for a too posterior attachment [2], a proper tunnel placement is necessary to restore physiological kinematics and pressure postoperatively.

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However, although numerous studies have focused the MPFL anatomy in preparation studies, guidelines for an intraoperative use for minimal invasive surgery is missing. Compared to ACL reconstruction, where radiographic guidelines for proper tunnel placement were given to improve clinical results [3], same guidelines are mandatory for an anatomical MPFL reconstruction, achieving not only stability, but also full range of motion / function without presence of patellofemoral pain due to increased retropatellar pressure [2, 7, 15].

In this work, a proper radiographic landmark is demonstrated to identify the anatomical femoral MPFL insertion intraoperatively or to use it as a postoperative control.

To initially verify this point, eight cadavers have been prepared and the center of the femoral MPFL insertion has been identified and marked with a radiodense ball with a small diameter. Then, a straight lateral view, with both posterior condyles projected in the same plane, were taken and the position of the ball was determined. When realizing that all points were situated in the same area, the following reference lines were determined as orientation: a first line in extension of the posterior femoral cortex towards distal to measure the anteroposterior position (line 1), a second line intersecting the contact of the posterior femoral condyle with the posterior cortex (line 2), and a third line intersecting the most posterior point of the Blumensaat line (line 3), both perpendicular to line 1, measuring the proximo-distal position (Figs. 22.1 and 22.2) [14].

Anterior-posterior position: The insertion marker was located anterior to the posterior cortical extension line in nearly all specimens, with a mean location of 1.3 ± 1.7mm anterior to line 1. Proximal-distal position: In all specimens the marker ball was midway

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between line 2 and line 3. The mean location was 2.5 ± 0.8 mm distal to line 2. However, since all points were within 5 mm of each other, it was possible to draw a 5 mm diameter circle containing all marker locations.

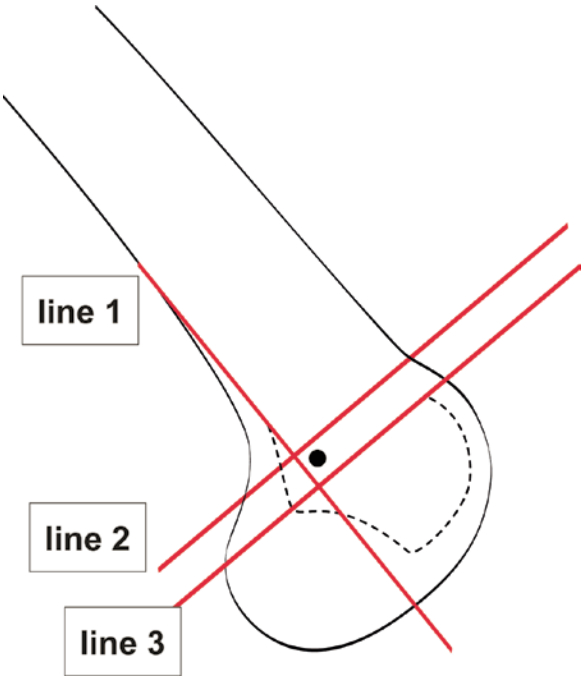

Fig. 22.1 Schematic drawing of a distal femur with the reference lines, seen in a straight lateral view. The circle is identifying the region, where an insertion would be anatomical

Although one can say that the mean position we determined is not valid for every knee as the distance of the single points is up to 5 mm in the proximal-distal direction, recent studies have shown [15] that a distance of 5 mm or less from the anatomical femoral MPFL insertion is not changing the MPFL isometry. Therefore, it is recommended to use this radiographic landmark intraoperatively due to the following benefits:

For intraoperative use, it is recommended to first prepare the laminar patellar insertion and to identify the anatomical MPFL layer, just in between the joint capsula and the vastus medialis obliquus muscle. A clamp is inserted into this layer down to the femur, where the tubercle and epicondyle is palpated. In this area, a little skin incision of 3 mm is performed and a guide wire is drilled into the medial distal femur, in the area of the bony landmarks, until it has a secure fixation. Afterwards, a cannulated drill (according to the graft diameter with a minimum of 5 mm) is inserted over the guide wire down to the bone, and the straight lateral view is taken with the use of a fluoroscope. The drilled insertion point is exactly there, where the cannulated drill attaches to the bone. As described before, this point should be anterior to the elongation of the posterior cortex, distal to the origin of the posterior medial condyle and proximal to the most posterior point of the Blumesaat line (Fig. 22.3). If this point is deviating obviously or the

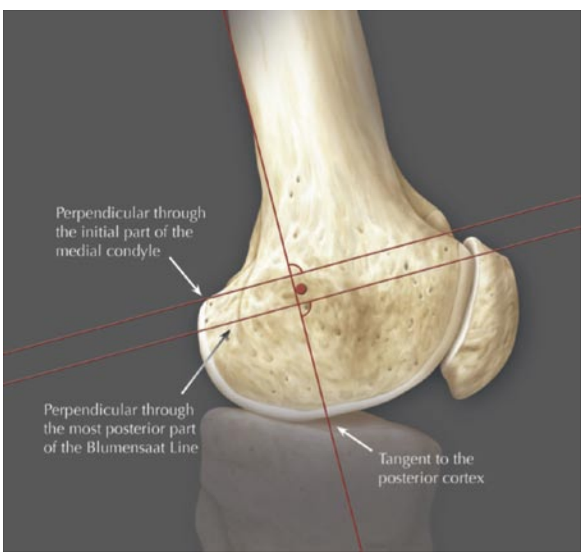

Fig. 22.2 Anatomical drawing with the same reference lines to show the relation to the gross anatomy, i.e., the medial epicondyle and the adductor tubercle

Fig. 22.3 Intraoperative view by fluoroscope at the correct position. The insertion point is identified at the point, where the cannulated drill is attaching the bone (anterior to the posterior condyle line, distal to the perpendicular through the insertion of the medial condyle and proximal to the most posterior point of the Blumensaat line)

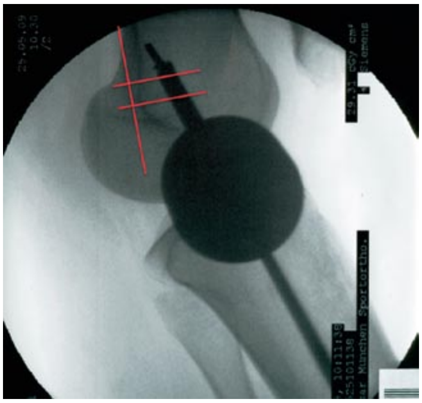

Fig. 22.4 Nonanatomical position: the cannulated drill attaches the bone too far anterior and proximal

cannulated drill is inside the anatomical insertion area only by 50% (Fig. 22.4), the guide wire has to be removed and reinserted towards the desired direction, until an anatomical positioning is achieved.

Besides the possibility of a very small skin incision at the femoral side with the maximal length of the screw diameter, used for the femoral fixation, the femoral insertion becomes reproducible and the risk of a nonanatomical reconstruction can be minimized drastically. Especially in patients, where the medial aspect of the distal femur is covered with soft tissue, a radiological identification of the insertion point is highly recommended and is simplifying the operation.

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MPTL (Medial Patellotibial Ligament) Reconstruction

23

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23.1 Background

The surgical treatment for patellar subluxation and related pathology described in this chapter is based on dynamic distal extensor mechanism reconstruction rather than a static correction of distal attachments.

It is extremely rare for us to proceed with surgical treatment if the patient has not undergone an intensive specific customized rehabilitation program. The rehabilitation period should finish with functional tests to verify the patient's ability to perform normal unrestricted sports activities. We believe that is not acceptable to adjust the performance to knee symptoms.

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Only in cases of failure of nonoperative program do we proceed with surgical treatment.

Indications for the following proposed surgical technique are:

- Continuous disability and symptoms of patellar dislocation
- Clinical history of more than one a-traumatic patellar dislocation
- Habitual patellar dislocation
- Generalized hyperlaxity with subjective symptoms of patellar subluxation

When the patient presents with only an extensor apparatus hyperlaxity or grade I medial patellofemoral ligament (MPFL) lesion we usually perform a medial patellotibial ligament (MPTL) reconstruction using the medial third of the patellar tendon.

When the patient presents with an extensor apparatus hyperlaxity or grade I MPFL lesion associated with Q-angle alterations and/or an abnormal tibial tuberosity/trochlear groove (TT-TG) defect we usually perform a modified Elmslie-Trillat procedure (a classic medial tibial tuberosity transfer procedure associated with an MPTL reconstruction).

As Arendt et al. [1] underline "a practical approach to surgery after patellar dislocation is the minimal amount of surgery necessary to reestablish objective constraints of the patella."

Hautamaa et al. [3] have found that "the MPFL was found to be the major medial ligamentous stabilizer of the patella. In addition, the patellotibial and patellomeniscal ligament complex played an important role in restraining lateral patellar displacement. Isolated repair of these ligaments restored balance to near normal levels."

Ideally repair of both structures, as suggested by Lind et al. [4], should be considered.

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The general and solid consensus is that the MPFL is the primary restraint to lateral patellar displacement. This has lead to increased popularity of this ligament reconstruction. The early results of this procedure are interesting [7]. However, proposed treatments are technically demanding, not completely reliable, quite invasive and subject to higher risk of severe complication (such as patellar and condyle fractures, and medial hypercorrection).

MPTL is the secondary restraint to lateral patellar displacement; for this reason its reconstruction could represent an effective solution for treatment of certain patellar instability. In fact the technique proposed can be less invasive with fewer complications, but permitting to improve patellar stability close to extension.

23.2 Anatomical Description

The MPTL is usually observed in 90% of the knees as a medial capsular reinforcement that goes from the inferior aspect of the medial patellar edge going medial on the tibia. This ligament has a variable angle direction in each patient, but usually inserts on the medial aspect of the tibia anteriorly to the medial collateral ligament close to the articular rim (Fig. 23.1).

23.3 Biomechanical Consideration

Patellar stability as we know it is obtained by dynamic, static and osseous restraints.

When the osseous components are anatomically normal the ligaments and muscles around the patella are responsible for its motion.

In patient with muscle imbalance and ligament hyperlaxity or mild ligament lesions the resultant force exerted on the patella can contribute to its lateral dislocation (Fig. 23.2a).

The MPTL reconstruction restores the medial static restraints in case of its complete rupture, but in the case of a mild disruption of the MPFL and especially in the case of severe hyperlaxity and muscle imbalance the reconstruction of the MPTL can act dynamically balancing the lateral force that cause the pathological patellar tracking (Fig. 23.2b).

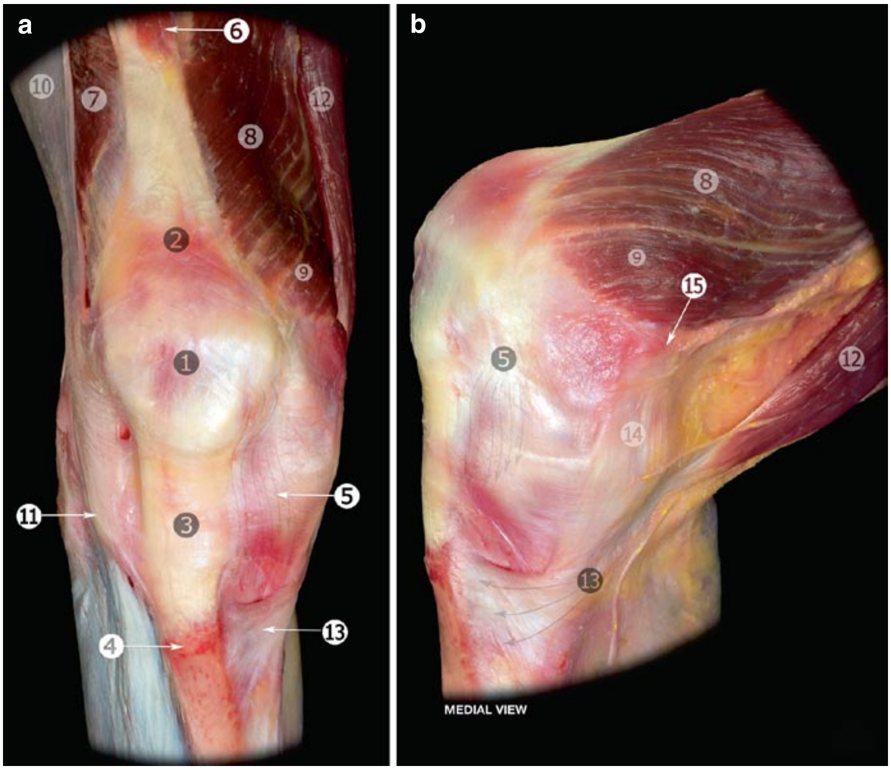

Fig. 23.1 Anatomical dissection of the right knee: (**a**) anterior view and (**b**) medial view. *1* Patella, *2* quadricipital tendon, *3* patellar tendon, *4* tibial tuberosity, *5* medial patellotibial ligament (MPTL), *6* rectus femoris muscle, *7* vastus lateralis muscle, *8* vastus medialis muscle, *9* vastus medialis oblique muscle, *10* iliotibial band, *11* gerdy's tubercle, *12* sartorius muscle, *13* pes anserinus, *14* medial collateral ligament, *15* medial epicondyle. The superficial nerves of this region have been removed (*yelow arrows*: Infrapatellar branch and saphenous nerve)

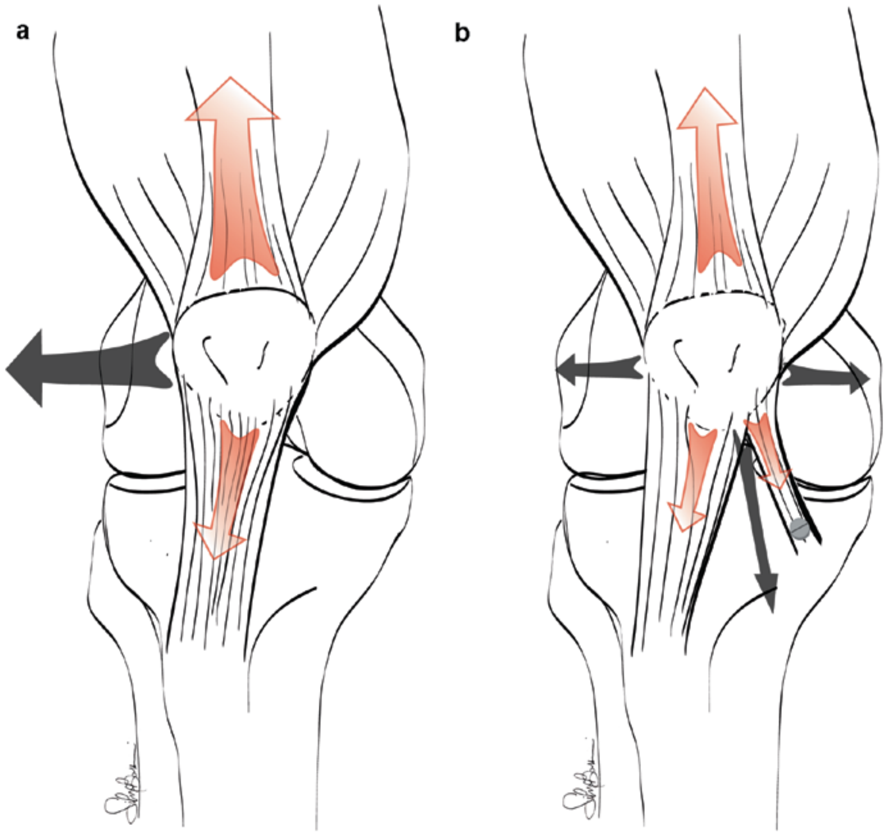

Fig. 23.2 (**a**) Patellar lateral dislocation and (**b**) patellar stability close to extension achieved by MPTL reconstruction

This reconstruction allows the patellar centration in the first degree of extension and in flexion is able to correct the patellar tilt reducing the cartilage stress on the lateral facet (Fig. 23.3a and b).

This surgical step must be dynamically checked through the full range of motion in order to obtain good patellar stability without over tightening of the medial structures (Fig. 23.3c).

23.4 Technique

The patient is positioned supine. After application of the tourniquet, the procedure is usually performed starting with the knee in 20° of flexion.

After preparation and draping of the leg, a midline incision is performed. This allows an easy approach to the medial and lateral side of the knee.

A lateral release can usually be performed when a tight lateral retinaculum is observed with abnormal patellar tilt.

Secondly, a dissection of the vastus medialis oblique muscle is performed in order to make a clearer evaluation of the patellar tracking in the trochlear groove and check the status of articular cartilage.

23.4.1 MPTL Reconstruction

The medial third of the patellar tendon is detached distally with a bone plug, maintaining its insertion on the inferior medial side of the patella. This ligament is then medialized and put under tension, trying to find a medial insertion location close to the anterior edge of medial collateral ligament. To perform this step, we normally release the tourniquet to avoid any influence on this functional evaluation of patella tracking.

The precise location where the bone plug must be fixed is determined by a repeated dynamic analysis of patella tracking that allow us to find a reinsertion point that leads to patellar stability especially near extension, without creating excessive tension on the ligament band when the knee is flexed. In this position the

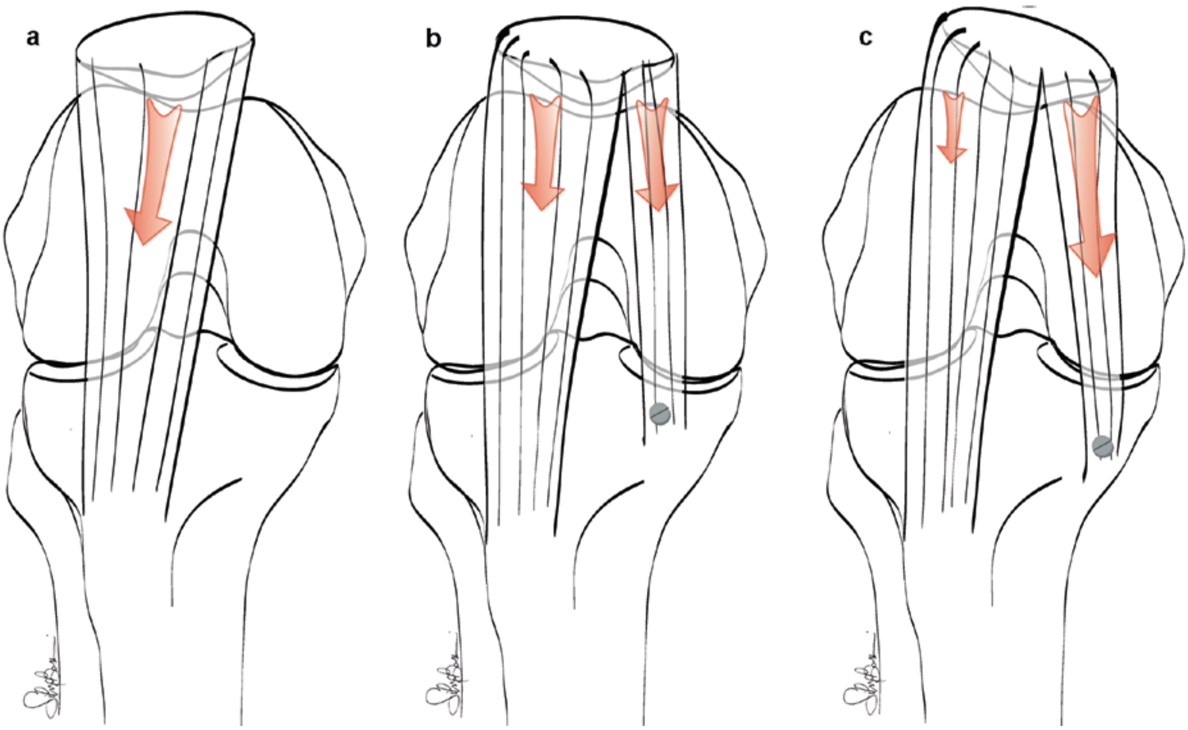

Fig. 23.3 (**a**) Lateral patellar tracking and (**b**) patellar tilt correction achieved by MPTL reconstruction, and (**c**) excessive medial tracking and cartilage hyperpressure after MPTL reconstruction

patella stability is tested using a finger that tries to pull the patella laterally in the first degrees of flexion. The patella must be stable throughout the full ROM without any joint limitation and avoiding any stretching of the ligament structure. After localization of this point, the periosteum is elevated, and a square is created in the cortical bone to obtain a groove in which to fix the bone plug of the medial third of the patellar tendon.

The bone plug is fixed to the tibia by a cancellous screw. This screw gives immediate stability to the implant. It is important to gently maintain the plug in place during screw insertion with a clamp to avoid malpositioning or breakage of the bone plug. If this occurs, it is possible to fix the ligament with metallic wire or nonabsorbable suture. To prevent this complication, it is possible to use small fragment screws, but the implant stability is probably lower. After fixation, the bone plug is inserted into the cortical bone without any protrusion of the plug (Fig. 23.4).

The vastus medialis is reinserted only when a frank insertion dysplasia of the vastus medialis is present to avoid excessive patellar medialization.

23.4.2 MPTL Reconstruction Plus Tibial Tuberosity Transfer

The tibial tubercle is isolated, and a 3 cm flat osteotomy is used to raise a 5–6-cm long osteoperiosteal flap that is at least 7 mm thick, tapered anteriorly and hinged distally with periosteum. The bone flap is then rotated medially (usually no more than 10 mm) and held in place with a K-wire, while the knee is put through a full passive range of motion.

At this time functional evaluation of patella tracking, especially in the first 30° of flexion, must be done to check patellar stability.

Secondly we fix the tibial tubercle with two cortical screws.

At the end we perform the MPTL reconstruction as previously described (Fig. 23.5).

Associated surgical steps (such as trochleoplasty) can be performed according to the degree of instability.

The combination of these procedures is performed when the anatomical abnormalities like trochlear

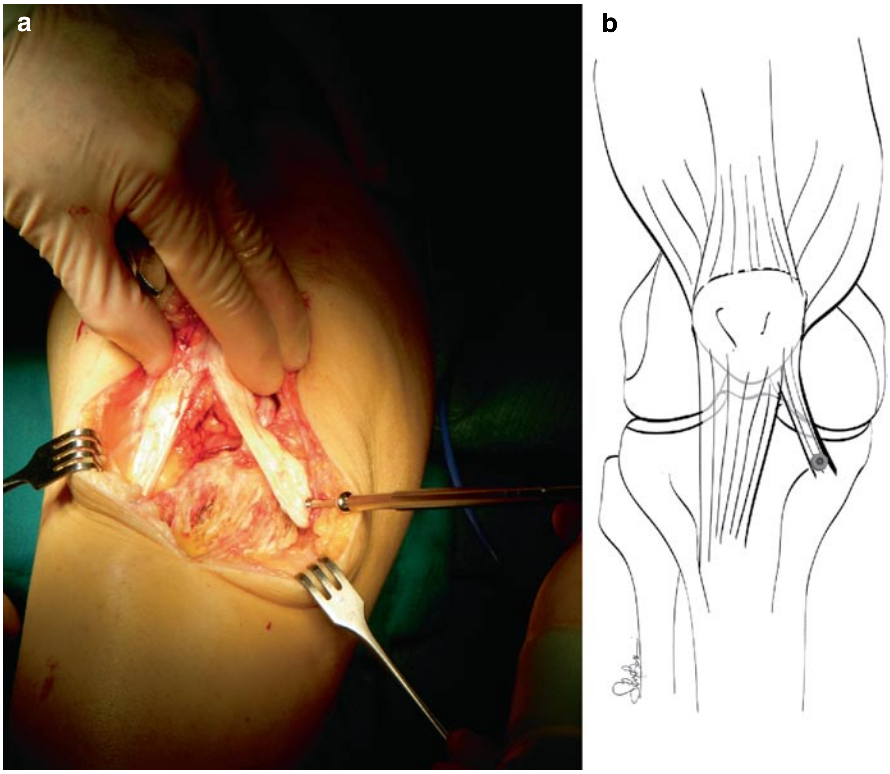

Fig. 23.4 (**a**) Intraoperative picture and (**b**) scheme of the completed *MPTL reconstruction* with achieved patellar stability. The screw is fixed in a cortical groove created after indication of the correct location

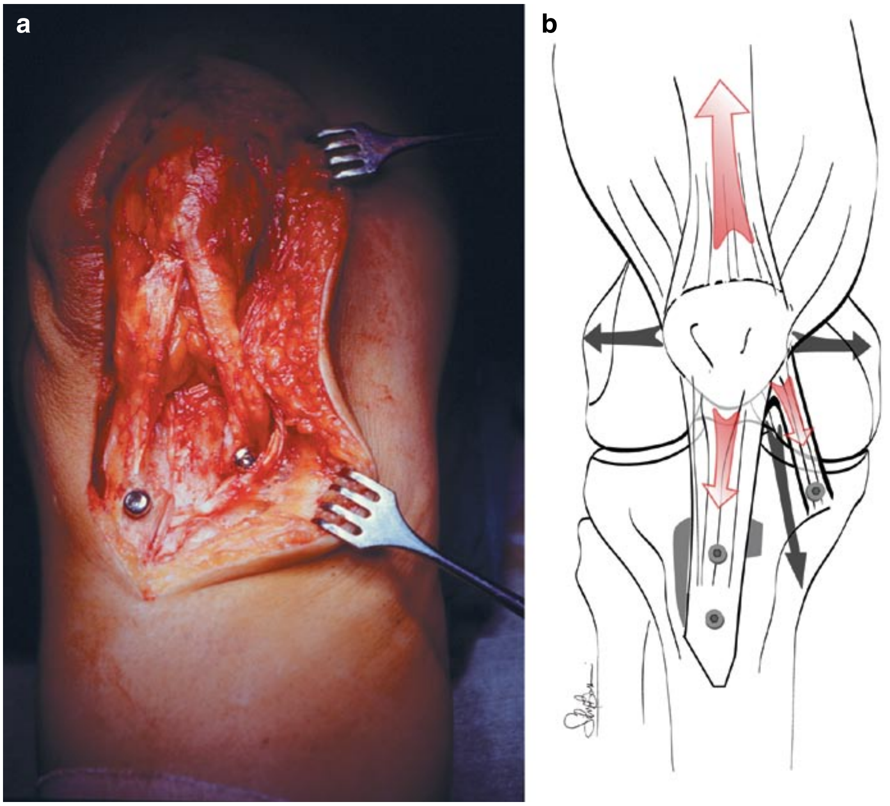

Fig. 23.5 (**a**) Intraoperative picture and (**b**) scheme of the completed *MPTL reconstruction plus tibial tuberosity transfer* with achieved patellar stability. The screw is fixed in a cortical groove created after indication of the correct location. In the represented case was also performed a lateral release because of a tight lateral retinaculum

dysplasia and excessive TT-TG are present in conjunction with hyperlaxity.

The wound is closed in layers, and the extremity is placed in a compressive dressing.

An x-ray control is performed.

A knee brace is applied and locked in full-extension immediately postoperatively.

23.5 Postoperative Rehabilitation Protocol

The leg is put in an extension brace. Weight bearing with the brace is allowed as tolerated after 3 days. Passive motion is started on the third day as well as isometric exercises. At 1 week after surgery, patients begin a closed kinetic chain strengthening program. The extensor and flexor muscles can be contracted in extension and at 30° of flexion, without any applied resistance.

At 1 month patients can begin a functional program which includes water exercises and progressive strengthening of muscles with a pain level control that allows a return to unrestricted activity, including sports, by 8–12 weeks postoperatively.

23.6 Results

A series of 18 patients treated for habitual and recurrent patellar dislocation with this combined procedure has been evaluated clinically and radiographically at 5 years follow-up [5].

At follow-up using the IKDC form, 11 knees were rated A (normal), four knees B (almost normal), two knees C (abnormal), and one knee D (severely abnormal).

The Kujala score showed excellent results in 16 knees, fair in one and poor in one.

The mean Tegner activity score rose from 2 preoperatively to 5 at follow-up.

No patient has reported an episode of patellar dislocation (medial or lateral) since the surgical procedures. All patients with satisfactory results had a full ROM with minimal symptoms caused by vigorous activity; no subjective instability was recorded.

Statistical analysis showed a significant correction of radiograph parameters (correction of the abnormal congruence angle) and significantly worse results in patients who underwent trochleoplasty. No progressive degenerative changes were observed at follow-up compared with the preoperative radiographs (Fig. 23.6). The correlation coefficient analysis has demonstrated that younger patients achieved better results than older ones.

23.7 Discussion

The technique described is one surgical step that can be added during surgery to other complex procedures, such as trochleoplasty, to achieve dynamic stability of the patella throughout the full ROM in cases of severe patellar instability.

The Kujala and IKDC scores have shown 88% satisfactory results with only two cases of minor discomfort. The only poor result was due to hypercorrection of the congruence angle (value of congruence angle -14°) [5].

Rillmann et al. [8] in 1998 described an isolated transfer of the medial third of the patellar tendon for the treatment of patellar dislocation or subluxation with highly satisfactory results. In this technique the lateral release and vastus medialization were avoided as well as the complete tibial tuberosity transposition. The results were good, with only 11% of patients with residual symptoms of instability, and good correction of the congruence angle reported. This isolated procedure can be efficacious in patients with patellar dislocation due to hyperlaxity with low morbidity for the patient. However, especially in chronic patellar dislocation, the surgery must foresee a global correction of anatomical abnormalities. Therefore, the medialization of the medial third of the patellar tendon with a bone plug is a single surgical step that can be added to medial tibial tuberosity transposition, with lateral release in case of a tight lateral retinaculum and/or with a trochleoplasty in cases with trochlear dysplasia.

The association of these procedures seems to lead to patellar stability and decrease patient discomfort, but the long-term effect of such a surgical approach is unknown.

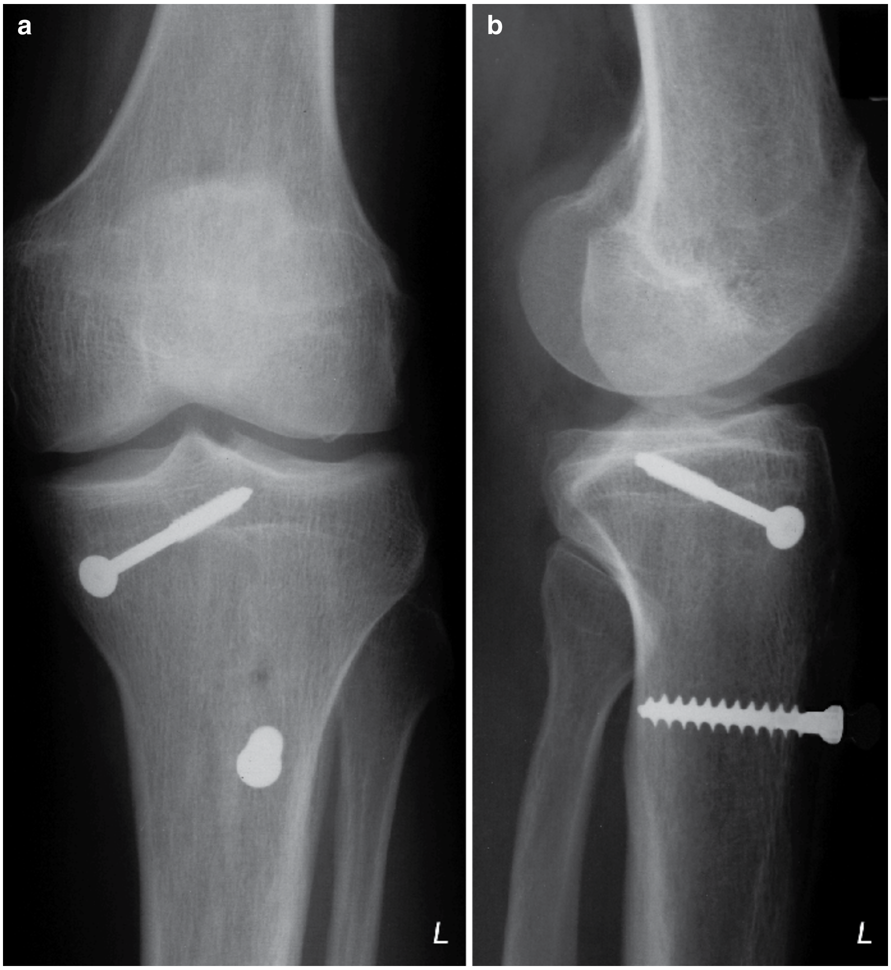

Fig. 23.6 X-ray control at 5 years follow-up after *MPTL reconstruction plus tibial tuberosity transfer* (*left knee*). (**a**) AP view and (**b**) lateral view showing good correction of the patella position with no sign of degenerative arthritis

In our technique, no special attention was applied to correct Patella Alta. This factor certainly plays a role in patellar instability. However, to avoid a deleterious complication such as Patella Baja, lowering of the tibial tuberosity was never performed. Caton et al. [2] and Mirroneau [6] have reported an automatic lowering of 3–5 mm with tibial tuberosity medialization. The procedure described has a supplementary effect on patella height.

It is interesting to observe that the younger patients had the better results. We want to underline the importance of the functional analysis performed during surgery to determine the exact location of fixation of the bone plug. The selected position should guarantee stability of the patella near extension, avoiding excessive tension during the rest of the ROM. The attempt to dislocate the patella with the finger is a fundamental dynamic test during surgery to achieve functional stability.

Moreover, it is important to avoid excessive medialization of the patella that will lead to patellar stability but a poor clinical outcome for the patient, especially regarding pain and functional capacity. In this procedure the medial side is closed without performing a medial capsulorraphy. According to Tomatsu et al. [9], avoidance of medial reefing reduces the incidence of saphenous nerve injury and improves the cosmetic appearance.

It is also important to underline that when the MPFL is torn, this structure should be reconstructed. The procedure described is not an alternative to MPFL reconstruction but can be used alone or in association with other surgical steps when hyperlaxity and small rotational defects of the femur or tibia are responsible for lateral patellar dislocation near extension.

23.8 Summary Statements

- MPTL is the second restraint against lateral patellar dislocation.
- MPTL is a capsular structure that goes from the medial-inferior edge of the patella to the medial tibial aspect close to the rim and MCL.
- MPTL reconstruction (dynamic) is not a substitute for MPFL reconstruction (static).
- MPTL reconstruction alone or combined for correction of other anatomical abnormalities is indicated when patella dislocation occurs for hyperlaxity or rotational defects even if the ligament structures are intact or reconstructed.
- MPTL reconstruction should allow dynamic control of patella stability close to extension.
- It is fundamental to not over tighten the structure to avoid medial hyperpressure.

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Distal Realignment: Medialization of Tibial Tuberosity: The Elmslie-Trillat Technique

24

Claudio Zorzi and Vincenzo Condello

24.1 Introduction

Patellofemoral problems are probably the most common knee complaints in adolescents and adults. The vague and general term "chondromalacia patellae" has been widely used in the past to describe retro-patellar pain and instability. The term patellofemoral malalignment (PFM) was introduced in 1979 by Insall [17] and since then, it indicates a wide range of pathological conditions from abnormal tracking of the patella on the trochlea with unbalanced transmitted loads on the cartilage, to acute and recurrent dislocation of the patella, which explains the anterior knee pain and patellar instability. This theory has influenced the development of several surgical procedures to correct the malalignment. At present only a small percentage of patients with patellofemoral pain are candidates for surgical correction of the malalignment [25].

According to Dejour et al. [11, 12], patellofemoral disorders can be classified into three major categories. *Objective patellar instability* is defined as true patellar dislocation or subluxation when trochlear dysplasia is present, *potential patellar instability* includes trochlear dysplasia when true patellar dislocation or subluxation has never occurred, and the third group covers *patellofemoral pain syndrome*.

More than 100 different surgical techniques for the treatment of PFM have been described during the past 100 years. The Elmslie-Trillat procedure aims to restore patellofemoral alignment and is one of the most commonly used operations for the treatment of patellofemoral dysfunction. It was originally described by Roux in 1888 [24] and later popularized by Elmslie in England and published by Trillat in France [29]. It involves a combination of soft tissue and bony procedures: namely lateral release and medial capsular reefing, as well as a tibial tubercle osteotomy and medial displacement over a distal periosteal pedicle.

Actually the indications for distal-medialization of tibial tuberosity (TT) with ET technique are restricted to patellar instability in young patients with no chondral lesions.

Instability of the patellofemoral joint is a multifactorial problem. It is generally defined as an abnormal movement of the patella with respect to the trochlear groove of the femur [13] and it occurs most often when the knee is between 0° and 30° of flexion and the patella is not fully engaged into the patellar groove [3]. Different factors have been recognized as responsible for patellar instability and divided into two main groups. Principle factors are tibial tuberosity – trochlear groove (TT-TG) offset, patellar height and patellar tilt. Secondary factors are genu valgum and genu recurvatum and femoral and tibial torsion (lower limb malalignment) or factors related locally to the actions of the muscles that act on the patella: insufficiency of the vastus medialis obliquus (VMO), a lax medial retinaculum, generalized ligamentous laxity.

The Elmslie-Trillat procedure for distal realignment modifying the main feature of PFM (TT-TG offset) is able to restore patellar stability, especially in the young population without degenerative changes and relieve anterior knee pain due to malalignment.

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24.2 Indications

The concept of patellar instability and extensor mechanism malalignment has undergone an evolution in treatment as well as in surgical indications. Cox [9] has outlined the indications for the Elmslie-Trillat procedure and which include: (1) recurrent subluxation or dislocation of the patella with an abnormal quadriceps angle or Patella Alta; (2) patellofemoral pain with malalignment of the extensor mechanism, and (3) acute patellar dislocation in adults with intra-articular pathology and malalignment of the extensor mechanism. Thanks to a better understanding of patellofemoral pathology and biomechanics, these wide indications have undergone changes. Brown [5] added an abnormal Q angle measured pre operatively and after surgical correction. In his study the correction of the Q angle to 10° was correlated with good or excellent results. However Naranja et al. [21] measured an abnormal Q angle in all patients in their series but it was not correlated to the results. Shelbourne et al. [28] has found the congruence angle a good and reliable measurement for assessing the need for surgical intervention.

In the 1990s some authors have restricted the indications to patellar instability with recurrent patellar dislocation or subluxation [8] sometimes with personal modification of the technique [19, 23]. Karataglis et al. [18] still has in his series patients with anterior knee pain with malalignment who had worse results compared to the instability group alone. Barber [4] has recently selected a group of patients with recurrent lateral dislocation (minimum three) or increasingly frequent subluxations with no patellofemoral pain or arthritis which could be seen radiographically.

In our practice we have restricted the use of this technique to young patients only (less than 30 years old) with symptomatic patellar instability, no anterior knee pain and with a TT-TG distance more than 20 mm measured on CT scan.

The CT is performed according to a dedicated protocol developed in Lyon [16] by superimposing CT coronal images of the summit of the trochlear groove and the tibial tubercle in full extension of the knee. The distance between the deepest point of the troclear groove and the middle point of the tibial tubercle is defined as the TT-TG. This measurement if superior to 20 mm is considered abnormal. A proper assessing of patellar tilt or subluxation preoperatively using CT images allows an accurate selection of surgical technique.

In case of severe instability, a VMO plasty is added. The medial patellofemoral ligament (MPFL) reconstruction can be indicated in the presence of a grade 3 trochlear dysplasia or in revision surgery. The goal of the TT transposition is reducing the TT-TG distance in a range going from 12 to 16 mm.

The exclusion criteria for medialization of TT with ET technique is an open proximal tibial growth plates and degenerative changes of the patellofemoral joint.

24.3 Surgical Technique

24.3.1 Historical Background

The original technique described by Trillat has been modified and personalized by different authors keeping intact the principal concepts of distal realignment. The operation involves a lateral retinacular release, medial capsular reefing and medial displacement of the anterior tibial tubercle hinged on a distal periosteal flap [29].

Skin incision In the original description it goes from the supero-lateral margin of the patella to the midportion of the patellar tendon then curves medially to the tibial tubercle, 4–5 cm below its inferior margin. Cox and Brown [5, 9] have used a full lateral incision which has become shorter [28], oblique [23] or centered on the tibial tubercle [4, 18, 19].

Medial Reefing Always performed in the 1980s [5, 9, 20], it has been gradually abandoned [19, 28] or performed in difficult cases sometimes with VMO muscle advancement [21]. Marcacci [19] has dissected the VMO to assess the medial facet of the patella and make a clearer evaluation of its tracking in the troclear groove. Barber [4] has used an intra-articular thermal shrinking of the medial retinaculum with a monopolar probe.

Lateral Release Every author has described an extensive lateral release from the tibial tubercle distally to the vastus lateralis tendon proximally, preserving the muscle fibers. At the beginning the release was made with a z plasty of superficial and deep fibers of the retinaculum [9, 29]. Later only the synovium has been preserved with open techniques. With artrhoscopic technique [4] the release starts from inside the joint under direct visualization.

Tibial Tubercle Osteotomy This part of the technique has been subjected to different evolutions. The osteotome is widely accepted as the main bone cutter, some authors begin with a microsagittal oscillating saw [18, 21]. The osteoperiosteal flap is from 4 to 7 cm long, from 0.7 to 1 cm thick and from 1.5 to 2 cm wide. The medialization on the periosteal hinge is 10 mm on average (from 0.7 to 15 mm maximum); this choice is always driven by accomodation of patellar tracking. Fixation of the medialized tubercle is achieved with one or two cancellous [9, 23, 28] or bicortical [18, 21] screws. Some authors have developed a personal modification of the technique: Marcacci [19] isolated the medial third of the patellar tendon with a corresponding bone plug that is attached near the medial collateral ligament under tension; a similar technique was used by Rillman [23] who has not described any proximal realignments.

24.3.2 Surgical Procedure

Patient Positioning and Sterile Field The patient is placed in a supine position and clinically evaluated under anesthesia. A pneumatic tourniquet is placed on the proximal third of the thigh and it is inflated just before the field preparation. A bloodless vision provides an accurate intra-articular inspection of the patellofemoral joint. The operative limb is placed on a leg holder as usual. After sterile drapping, an arthroscopy is performed using standard anteromedial and anterolateral portals. This last portal may be placed at a more distal level because it can be used as an instrument portal during the lateral release. A suprapatellar portal is not necessary, though some surgeons still use it as the standard portal for an inflow cannula or, sometimes, as an instrument portal to complete the lateral release.

An assessment of patellofemoral tracking is performed. The examination includes the lateral deviation of the patella (overhang sign) at varying degrees of knee flexion and incongruity of tracking in the intertrochlear sulcus. A proper assessment of patellar tracking should be conducted with the tourniquet deflated and the inflow turned off.

Meniscal and chondral abnormalities are treated first. Osteochondral damages may result from dislocation episodes or from chronic trauma secondary to the imposed stress of malalignment with osteochondral fragments visible from the medial patellar border or lateral femoral condyle. These fragments are removed as loose bodies or detached from the soft tissue.

Lateral Release The patellar tilt and the amount of medial mobilization after direct pressure on the lateral side are the two main indicators for a lateral release. The lateral release is patient specific and sometime not necessary.

Since the Elmslie-Trillat technique has been described, the lateral release has developed from an open technique to an all arthroscopic procedure. We now use only two standard arthroscopic approaches using a short skin incision just for the medialization of the tubercle.The arthroscope is placed into the anteromedial portal and the lateral retinaculum must be well visualized. The incision of the retinaculum starts at the middle third of the patella, 1–2 cm below its lateral border toward the distal end of the retinaculum. We usually prefer cutting with a bipolar surgical diathermy unit with a 90° hook. The first layer is the synovial covering, then the retinaculum to the level of the subcutaneous tissue. Proceeding upwards, the release must carefully avoid the distal fibers of the vastus lateralis: it may cause bleeding and a painful scar tissue. After the release, it is possible to control the bleeding using the same bipolar tool as an electrocauter. If the vascular stump are difficult to be visualized, deflating the tourniquet can help to identify and cauterize the vessels.

The release may not be complete at this stage because of some fibers left intact at the distal part of the ligament. During the tibial tuberosity transposition it will be completed with scissors.

After the lateral release, the patella should be visually better balanced in the trochlea and the tilt reduced or neutralized. An adequate release allows one to evert the articular surface 90° laterally.

Tibial Tuberosity Medial Displacement A longitudinal lateral incision of about 3–4 cm is made just lateral to the tibial tubercle to avoid the infrapatellar branch of the saphenous nerve (Fig. 24.1a and b). The soft tissue is carefully removed and the tibial tubercle is identified. The periosteum on the medial side is incised longitudinally for 5 cm with electrocautery along the planned osteotomy plane which should be tapered distally to allow a greenstick fracture (Fig. 24.2). On the lateral edge of the tibial tubercle, periostium and muscles are elevated with a blunt subperiosteal elevator for a depth of approximately 10 mm.

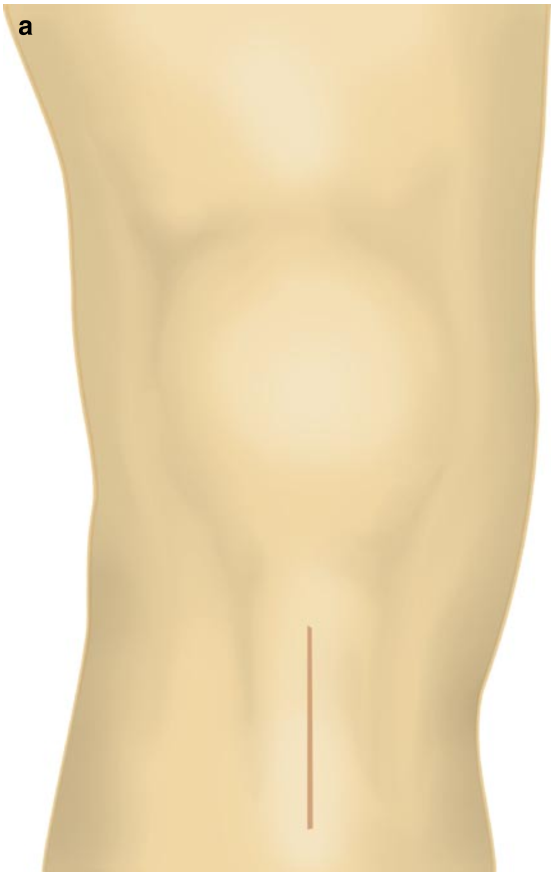

Fig. 24.1 (**a** and **b**) The surgical incision is about 3–4 cm long and it is lateral to the tibial tubercle to avoid the infrapatellar branch of the saphenous nerve

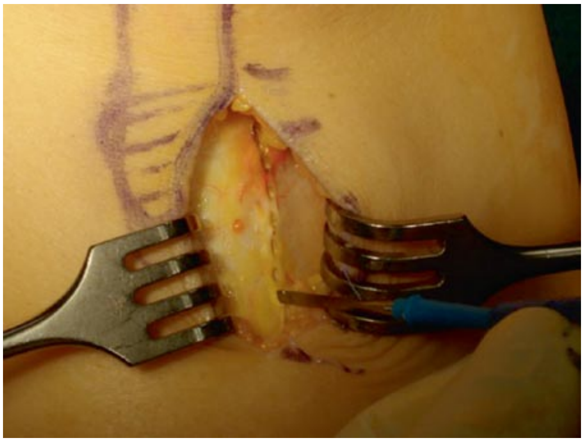

Fig. 24.2 Preparation of the osteotomy line cut with electrocautery

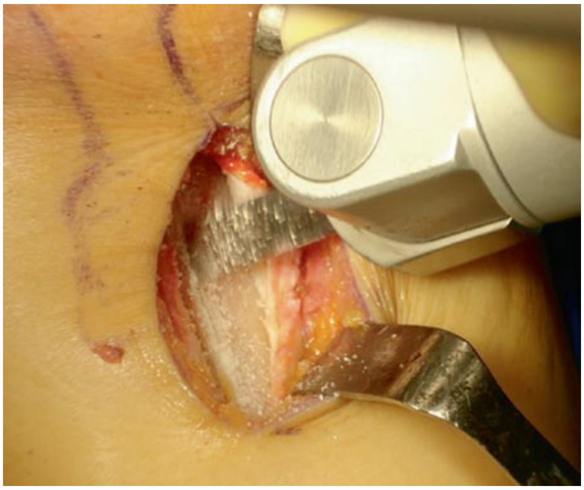

Fig. 24.3 Tibial tubercle osteotomy from the medial side with a micro sagittal saw "free hands." Same osteotomy is performed on the lateral side

The cut is started from the medial border of the tubercle, in its proximal portion. In our technique we first use an oscillating microsagittal saw "free hand" with an inclination of 45° to the tubercle with an oblique direction about 1 cm deep in the cancellous bone and about 5 cm distally near the distal extent of the tuberosity (Fig. 24.3). The same cut is performed on the lateral side at a slightly different angle then completed with an osteotome to release the pedicle, leaving a distal periosteal hinge. It results in a trapezoid bone fragment that, when medialized, raises the tubercle a few millimiters.

The direction of the osteotomy may be oblique, as suggested by Brown et al. [5] and by Fulkerson [14] from anteromedial toward postero-lateral so the medial transfer elevates the tuberosity, creating a "Maquet

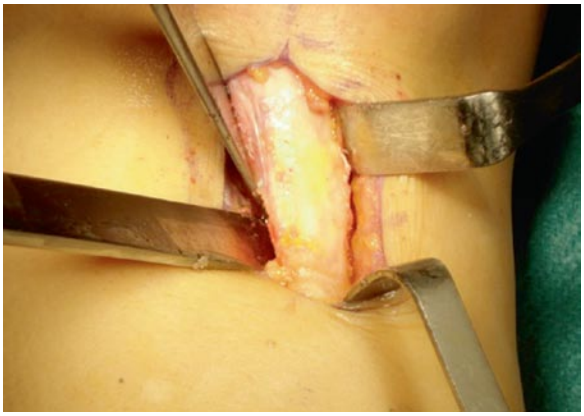

Fig. 24.4 An osteotome is used to release the pedicle with a light pressure on its proximal end, leaving a distal periosteal hinge

effect." Naraja and coworkers [21] suggest filling the space between the tubercle and the tibia with more cancellous bone in order to create an anteriorization of the tubercle of 1–1.5 cm minimum (Fig. 24.4).

Once the tuberosity is raised, the capsule is incised on the lateral side – to complete the lateral release – and on the medial side to release the patellar tendon. These releases are left open.

A small osteotome or a curette are used to remove the excess bone on the medial side and create a flat bed of cancellous bone. The pedicle is displaced medially about 1 cm (as measured on CT scan) and pierced temporarily with a drill bit in order to evaluate the patellar tracking in the selected position (Fig. 24.5). This inspection can be better carried out introducing the arthroscope into the joint without inflow. Finally the tibial tubercle is fixed with one or sometimes two bicortical screws (Fig. 24.6a and b)

Medial Reefing In the literature this procedure is no longer associated with TT transposition. In case of severe instability VMO plasty or MPFL reconstruction might be indicated; rarely a trochlear deepening.

24.4 Postoperative Treatment

The knee is placed in an hinge brace in full extension. Partial weight bearing with crutches is allowed after a few days as soon as pain decreases. The patient is instructed to move the knee through a nonpainful range of motion out of the brace as much as possible. Full weight bearing is usually allowed after 2 or 3 weeks when rehabilitation with closed chain kinetic strengthening program has started. The brace is discarded 6 weeks postoperatively and full motion should be reached within 8 weeks. Running is started after 12 weeks and return to unrestricted sport is allowed between 5 and 6 months postoperatively.

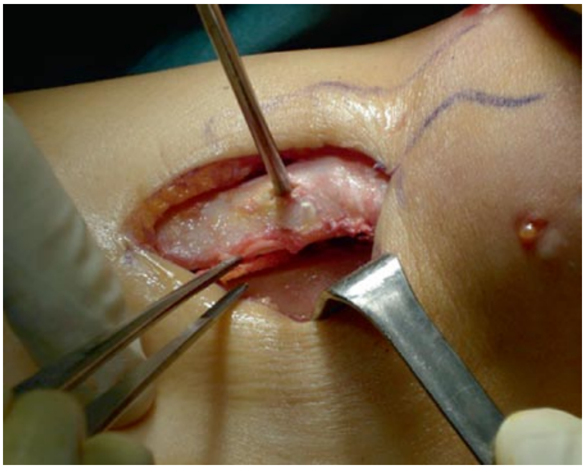

Fig. 24.5 The tibial tubercled in the new position is pierced temporarily with a drill bit in order to evaluate the patellar tracking. Cancellous bone may be added underneath to elevate the tuberosity

24.5 Discussion

Since Insall coined the term "Patellofemoral malalignment" [7], the concept of quadriceps malalignment has deeply changed. A better understanding of the biomechanics of the patellofemoral joint has given the surgeon the possibilities of differentiating the source of the anterior knee pain from that of patellar instability, leaving only a restricted area in common. Most patellofemoral problems are successfully treated with conservative therapy so that the surgeon deals with more selected cases than in the past.

The treatment for patellar instability always begins nonoperatively but, unfortunately the majority fail [15]. Therefore, surgical treatment is appropriate. Currently, there are actually three main types of treatment for patellar instability that can be performed alone or in combination: release of lateral structures such as the lateral retinaculum and vastus lateralis muscle; reinforcement, reconstruction or advancement

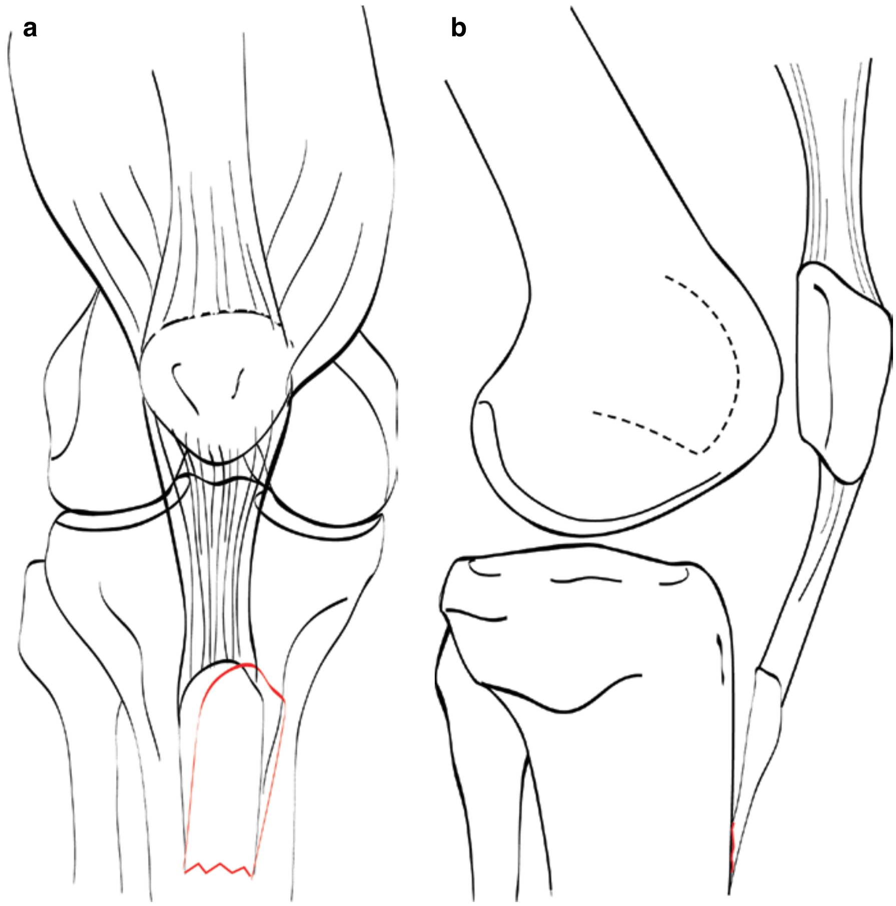

Fig. 24.6 (**a** and **b**) Final position of the tubercle medially displaced and still attached distally through a periosteal pedicle

of medial structures like the VMO, medial capsule and MPFL; improving joint congruity and decreasing PF contact force with distal realignment [27].

Proximal realignment has been widely used in the past with good results through the open technique. After 5 years, Abraham et al. [1] had a 78% of improvement in the unstable group while only 53% of improvement in patients suffered patellofemoral pain. This surgical procedure is able to restore a normal congruence angle [2, 26] but it cannot modify the TT-TG offset or the patellar height.

Isolated lateral releases are not effective in the long term because of the show of a decline of the good results [22].

Distal tibial tubercle realignment is considered an effective procedure for correcting the patellar tracking and for unloading the patellofemoral joint in a population with increased lateral offset of the TT-TG. Nowdays there are two main surgical techniques used by most surgeons for distal realignment: the Fulkerson osteotomy [14] and the Elmslie-Trillat procedure. The first combines medialization and anteriorization producing an added "Maquet effect."

The Elmslie-Trillat technique for distal realignment of the extensor mechanism of the knee has undergone readjustment and improvement though the principles of the technique are still efficient and supported by good mid and long-term results if referred to patellar instability. The medialization of the tibial tubercle allows one to correct abnormal patellar kinematics and to set a patellar lowering of about 5 mm [7]. Marcacci [19] has found a supplementary effect on patella height with a normalized Insall-Salvati index (1.19 from 1.49 preoperative value); Brown and Shelbourne [5, 28] report excellent results in patients with Patella Alta.

Cox [9] published a preliminary report on a group of 52 knees operated on for patellar instability. He found 88% good results but he has also recorded many associated problems like fractures of the patella or lateral femoral condyle, meniscus or MCL (medial collateral ligament) lesions. A few years later the same author [10] reviewed 116 patients: 104 for patellar dislocation and 12 for patellofemoral pain and malalignment, including the same group of patients in the first study. He found 7% recurrent dislocation and a worsening of results in the group controlled in the first study with 66% of satisfactory results at 1–7 years follow-up. However, the realignment reduced the anterior knee pain even in those who did not received any cartilage treatment. Carney et al. [6] from the same group of the Naval Medical Service, San Diego, CA USA, identified 18 patients from the group of 104 operated on for patellofemoral subluxation or dislocation between 1975 and 1979. The patients included in the study did not have any associated intra-articular or extra-articular pathology at the time of surgery nor any additional surgery or major trauma at the involved knee. Fourteen patients (15 knees) answered a questionnaire about recurrent episodes of patellar instability. One patient (7%) had recurrent instability, like the first study, 54% were rated as satisfactory results compared to 73% of the larger study group at 3 years FU. Carney's study is unique because it reports results of the E-T procedure at 26 years follow-up. There is of course a declined functional status of this subset group difficult to assess if compared with the original large study population but it is interesting to underline how this surgical procedure, applied in patients suffering just from patellar instability, may be effective even after 26 years.

Brown et al. [5] reviewed 27 knees at a mean follow-up of 45.9 months that were classified as dislocators (16 knees) or subluxator (11 knees). Though the authors do not give detailed information about anterior knee pain, they found 81% of patients rated as good or excellent. The Q angle measurement after surgery was correlated with results being 11° on average for those rated as excellent and good and 15° or greater for fair and poor results. They stated that 1 cm of medial displacement results in 1 mm of patellar lowering and a decrease of the Q angle from 20° to 10°. They also described an oblique osteotomy of the tibial tuberosity so that its medial transfer elevates the tubercle reducing the patellofemoral joint reaction force.

The measurement of the congruence angle as an objective assessment of patellar malalignment has been emphasized by Shelbourne et al. [28] who found a significant correlation between the congruence angle and the incidence of patellar instability and demonstrated that its correction to less than +15° resulted in a decreased incidence of postoperative patellar instability. The authors studied 40 athletically active patients who underwent 45 distal realignment procedures with a modified Elmslie-Trillat technique with a mean preoperative congruence angle of 21.5°. The authors identified a large congruence angle as the only reason for instability, in fact, their mean postoperative angle was 45° (range 26°–62°) and accomplished that the E-T distal realignment provides an average correction of 25° of congruence angle and more correction may be needed for patients with preoperative values highier than 40°.

Naraja et al. [21] reported the first long-term evaluation of E-T associated with Maquet procedure (a 1 cm thick bone block placed underneath the tibial tubercle) for PF disorders. They had an 84% subjective improvement of their status over a 74 months average follow-up period. Age > 31.5 years, less than two dislocations and degenerative changes from 2° at the medial and lateral tibiofemoral compartment were considered risk factors that worsened results. The redislocation rate at final follow-up was 11%. A decrease of results occurred between the third and fourth years post-op. Nakagawa et al. [20] analyzed the deterioration of clinical results after E-T procedure in 45 knees operated on for patellar instability. Subjectively the instability did not change with time while PF pain worsened in half the knees. The patients were divided into two groups: Good and Fair results. The Q angle difference was wide but not significant between the groups and increasing the grade of trochlear dysplasia affected the results in a negative way. Radiological changes and intervals between the first episode of dislocation and surgery longer than 1 year were associated with poorer results. The main cause of deterioration of clinical results was PF pain, not instability.

Rillman et al. [23] described a modified E-T technique; the medial third of the patellar tendon was detached together with a bone chip 2 cm long and 0.7 cm wide and fixed with a cancellous screw in a new groove placed 1 cm medially. This technique was used in a consecutive series of 41 patients with persistent patellar instability. The author reported good results with no redislocation and 11% had instability symptoms during vigorous sport. The x-rays showed no signs of osteoarthritis, one case of Patella Infera and significant correction of the patellar congruence angle.

Marcacci et al. [19] described a similar procedure. In their series of eighteen knees with severe instability, when the E-T procedure was non sufficient, he associated an extensive lateral release, dissection of vastus medialis obliqus and if the patella was still unstable, a medialisation of the medial third of the patellar tendon with correspondent bone block as described by Rillman [23]. In four patients with severe trochlear dysplasia a deepening trochleoplasty was performed too. At 5 years follow-up 88% showed satisfactory clinical results with no episodes of patellar dislocation. Significant improvement was recorded in the Tegner activity score, correction of the congruence angle and in the patellar height (without any distal advancement). The authors stated that a multifactorial problem like patellar instability cannot be treated with a single procedure, it is inadequate to address all the anatomical abnormalities. No special attention was applied to correct the Patella Alta but this procedure had a supplementary effect on patellar height with an automatic lowering to normal values according to the Insall-Salvati index. Henderson et al. in their series of 108 knees combined proximal and distal realignment with excellent and good results in 77.7% of patients after 19 months of follow-up. A second-look arthroscopy was performed in 60.2% of the patients together with screw removal and 29.2% of these had cartilage treatment on the patella: debridement/chondroplasty in 16 patients and autologous condrocyte implantation (ACI) in three patients. Barber and McGarry recently [4] confirmed the hypothesis of restricted indication of the E-T technique to a young population suffering only from patellar instability without chondral lesions although they were not able to link the results with trochlear dysplasia or any other radiographic measurement.

24.6 Conclusions

The Elmslie-Trillat procedure is effective in treating patellar instability in a young population with closed growth plates, a TT-TG offset more than 20 mm in absence of chondral lesions of grade 3 or 4. Unfortunately in the literature there are no prospective studies and none of them compare results with control groups. Neverthless, the explanation may be that PFM is a tremendous syndrome with a continuous development of its biomechanical etiology and both conservative and surgical treatments. In the surgical treatment of pure patellar instability the E-T technique compared with Fulkerson osteotomy is less aggressive on bone and soft tissues, allowing a faster postoperative recovery and a quicker rehabilitation program.

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Bony Surgery Distal Realignment Surgery for Episodic Patellar Dislocations

25

E. Servien, S. Lustig, and P. Neyret

25.1 Introduction

A patellar dislocation is most likely a result of a number of anatomic and physiologic factors causing a failure of the extensor mechanism to deliver the patella into the femoral sulcus. The Lyon group has reported this experience in several articles [5,7,9,17–20]. In the episodic patellar dislocation (EPD) patient population, several morphological anomalies have been identified that facilitate or allow patellar dislocation [18]. The radiographic examination will detect, in more than 96% of cases, at least one of the four following features in EPD group: (1) trochlear dysplasia, (2) Patella Alta, (3) tibial tubercle-trochlear groove distance (TT-TG) >20 mm, and (4) patellar tilt >20°. The aim of the distal realignment is to correct one or two identifiable "main factors" for EPD, while the "fundamental factor," i.e., trochlear dysplasia, itself may not be corrected. In order to lower or medialize the distal extensor mechanism, different surgical techniques have been proposed and described. They all have in common that these techniques transfer the distal insertion of the patellar tendon [3,15,16].

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25.2 Indication

25.2.1 Distal Realignment

25.2.1.1 Patella Alta

The patellar height is called a "main factor" for several reasons; it is very often present in the EPD group and absent in a control group (patient without any history of patellar dislocation). This factor has been measured and a threshold has been defined [18].

Distalization of the tibial tubercle correct the patellar height and therefore increase the patellofemoral stability. Under normal circumstances, the patella engages early on in flexion in the trochlear groove. The adapted configuration of the trochlear groove and patella ensures the stability of the extensor apparatus. In the case of a Patella Alta, the engagement will be delayed and this results in an increased risk for dislocation.

Furthermore, in some patients, the length of the patellar tendon is increased while the level of the distal insertion on the tibial tubercle was within normal limits [10].

25.2.1.2 Height Measurement

There are several indices that can be used to measure patellar height. The Insall-Salvati [14] index which measures the length of the patellar tendon and the length of the patella, will not change in case of a distal

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tibial tubercle transfer (TTT). The Caton-Deschamps index [21], on the contrary, which uses the anterior tibial plateau as a reference (distance from anterior tibial plateau to lower border of articular surface of patella and length of the articular surface of the patella) will normalize after a distal TTT. For this reason, tibial referencing is the standard method.

Measured in MRI, it may be more specific and sensitive than patellar height index measured in profile radiographis for the study of patellar instability [10]. In some cases, the patellar tendon is excessively long (generally greater than 52 mm) in patients with patellar instability.

25.3 Surgical Technique: The Anterior Tibial Tubercle Osteotomy

Whatever the procedure, an arthroscopy should be done at the beginning of the procedure to evaluate associated lesions, chondral lesions and patellar tracking, which can be done using an accessory superolateral portal.

The orientation of the osteotomy plane will allow correction in the three dimensions.

25.3.1 *Anterior Tibial Tuberosity Distalization*

This technique is indicated to correct Patella Alta [4,20]. The objective is to bring the anterior tibial tubercle (ATT) to a more distal position in order to obtain a Caton-Deschamps index of 1. For example, in a patient with a Caton-Deschamps index of 1.3, with AT distance of 39 mm and an AP distance of 30 mm, the distalization necessary is 9 mm to reach an index of 1. A Patella Alta (Caton-Deschamps ratio measured on the strict lateral x-ray) greater than 1.2 is corrected to between 0.8 and 1.0 by distal transfer of the tibial tubercle.

The approach is antero-medial and extended from the lower third of patella to 6 cm above the patellar tendon's insertion.

Prior to carrying out the osteotomy, the first step is to prepare the fixation. Usually, the anterior cortex is drilled with a 4.5 mm drill.

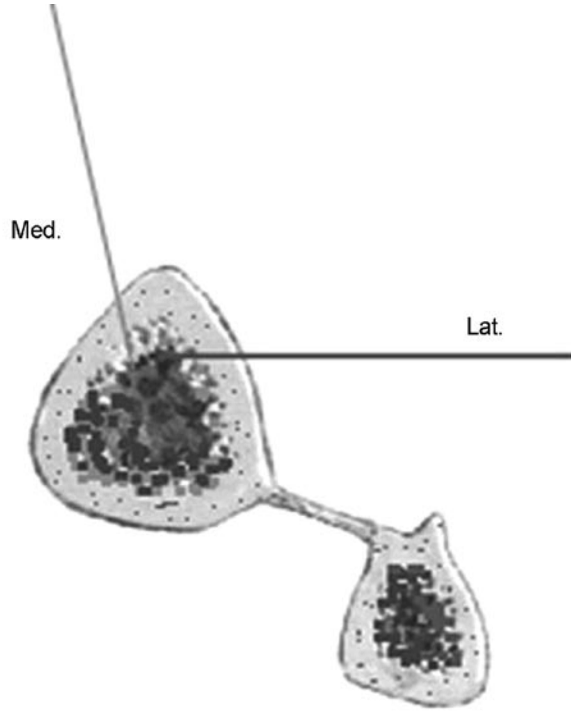

Fig. 25.1 Medial anterior tibial tubercle (ATT) osteotomy with the horizontal cut

The osteotomy is done with an oscillating saw and completed with an osteotome. The lateral cut is done first, in a horizontal direction, followed by the medial cut, in an almost vertical direction (Fig. 25.1), followed by the distal cut. The bone block should be 6–8 cm in length and of sufficiently thick, i.e., in cancellous bone (Fig. 25.2). Two 3.5-mm orifices are done through the posterior cortex perpendicular to tibial shaft and fixation of the osteotomy bone block is in those cases assured by two screws. The osteotomy is fixed with a 4.5 mm cortical screw, 2 mm longer than the measured orifice.

In case of large lowering, the medial and the lateral retinaculum must be released.

The ATT is then moved to the planned more distal position as calculated before surgery (Fig. 25.3).

25.3.2 *Patellar Tendon Tenodesis*

This patellar tendon tenodesis may be done in association with an ATT's distal transfer. A patellar tendon tenodesis [10] may be an adjuvant procedure to ATT distalization surgeries. In case of excessively long

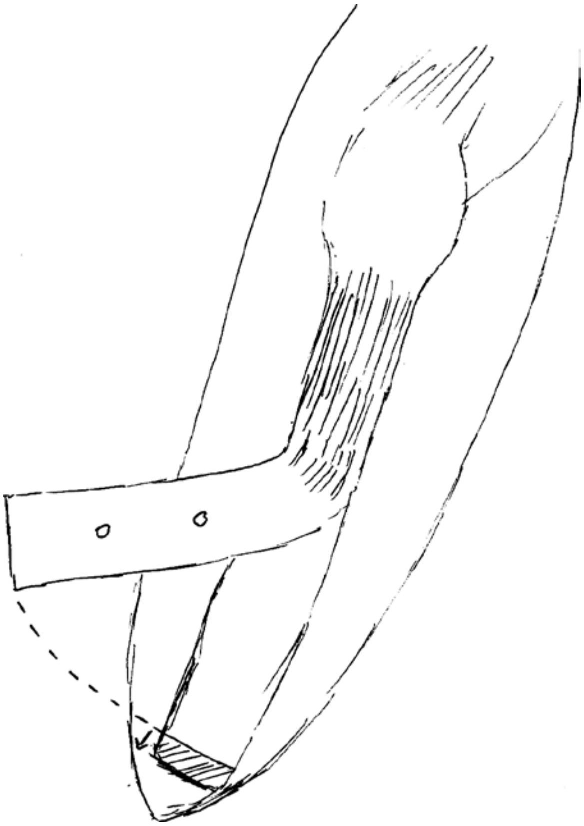

Fig. 25.2 The osteotomy is entirely detached to perform the lowering

Fig. 25.3 Post surgical lateral radiography of anterior tibial tubercle (ATT) distalization

patellar tendon, distal TTT does not correct the length of the patellar tendon and does not avoid a windshield wiper effect. Thus it might be considered when the patient has a patellar tendon length superior to 52 mm.

The patellar tendon is opened following the direction of fibers two times to prepare the site of fixation. After the ATT osteotomy for distalization, as described above, two anchors with sutures are fixed at both sides of patellar tendon, about 29 mm distal to tibial plateau level, at the "original level" of ATT and the ATT was fixed by two screws. After ATT fixation, the tenodesis is carried out with two knots that are tied (Fig. 25.4).

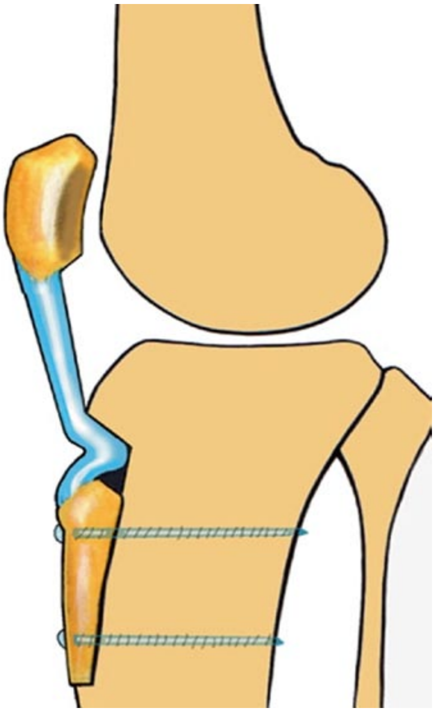

Fig. 25.4 Patellar tenodesis

25.3.3 Complications

Most frequently, the complications after distal realignment are of an iatrogenic nature and can thus be avoided. "Over"medialization is a commonly observed error.

A recent study performed at our institution indicated that a distal TTT induces a medialization of 3–4 mm because of tibial torsion [7]. This phenomenon should be included in the calculations for the desired correction as they could contribute to "over"medialization.

Fractures of the tibial shaft are rare and most likely iatrogenic. The last cut during the surgical procedure must be done with an osteotome instead a saw. Furthermore, a too thick or/and too large osteotomy may lead to a further fracture.

25.4 Discussion

Clinically, patellofemoral pain is frequently associated with malalignment of the patellofemoral joint and lateral tracking. From a surgical viewpoint, the objectives are to provide extensor mechanism stability with normal patellar tracking that results in an unloading of damaged articular cartilage.

In the literature, distal tibial tubercle realignment is described as an efficient procedure to correct abnormal patellar kinematics as correct the patellar height a nd restore the patellofemoral stability. Laboratory studies have confirmed the clinical observations [12]. Regarding to the patellar tendon tenodesis, Upadhyay et al. [2] showed that the contact surfaces increased from 15% to 18% at 15° flexion after a 10% shortening of the patellar tendon without augmentation of patellar forces.

In cadaveric model, Ramappa et al. [8] studied the changes in medial and lateral contact measures of the dynamic patellofemoral joint contact pressure and kinematic data after two types of tibial tubercle osteotomies. The authors concluded that both medialization and anteromedialization of the tibial tubercle osteotomies are equivalent to reestablish normal patella tracking and kinematics. However, it should be underscored that this experimental design did not evaluate changes in proximal and distal patellar mechanics.

Wang et al. [1] evaluated 48 patients with 53 knees were submitted to distal realignment for patellofemoral disorders after failure of at least 6 months of conservative treatments for pain and patellofemoral instability. In this series of patients, the results were considered satisfactory in 47 knees (88.7%) and unsatisfactory in six knees (11.3%) with 25–96 months follow-up. However, the authors emphasized that error in patient selection and inadequate surgical technique was attributable to poor outcomes.

In a prospective study, Koëter et al. [3] analyzed two groups of 30 patients classified as painful lateral tracking of the patella and objective patellar instability, respectively. In all cases, a subtle transfer of the tibial tubercle was performed according preoperative CT-scan information. A TT-TG superior to 15 mm in symptomatic patients was considered as a surgical indication. The clinical results showed marked improvement in pain and functional score in both study groups. Although, it can be judged as simple procedure, there are some pitfalls. The authors conclude that hematomas, local infection, and also tibial fracture were complications that could be avoided by an improved surgical technique.

In our experience, the Elmslie-Trillat procedure remains the primary intervention to address EPD in the presence of Patella Alta and/or excessive TT-TG. We analyzed the functional outcome of 174 knees operated on between 1988 and 1999 for patellofemoral instability [6,7]. The average follow-up was 5 years (range 24–152 months). The subjective International Knee Documentation Committee (IKDC) evaluation chart was used. The IKDC score averaged 77.2 (45.9–95.4) and 94.5% of the patients were satisfied or very satisfied at the final follow-up. In case of isolated distal transfer, the lowering averaged 7 mm (Fig. 25.5). Nevertheless, in 37.6% of these cases climate-related pain or discomfort was noted. This discomfort was often related to the material and was resolved by screw removal. However, comparative data on soft tissue surgery versus TTT for the treatment of EPD is nonexistent in the literature.

Levigne [11] reviewed the causes of failure after surgical treatment for EPD and the results of re-intervention in 83 knees (71 patients). In its study, correction of mechanical problems caused by the original surgical intervention constituted one of two main goals of the re-intervention [11] and Patella Alta was associated with failed primary intervention in 45%, making it the second most frequent finding among EPD patients undergoing revision stabilization.

Whenever, the pathoanathomical factors are not constant and every EPD cannot be corrected just by a bony distal realignment [5] as well as by a soft tissue procedure. As pointed by Henri Dejour, the surgical treatment for patellar instability must be considered as a "menu à la carte," where, the criteria of surgical

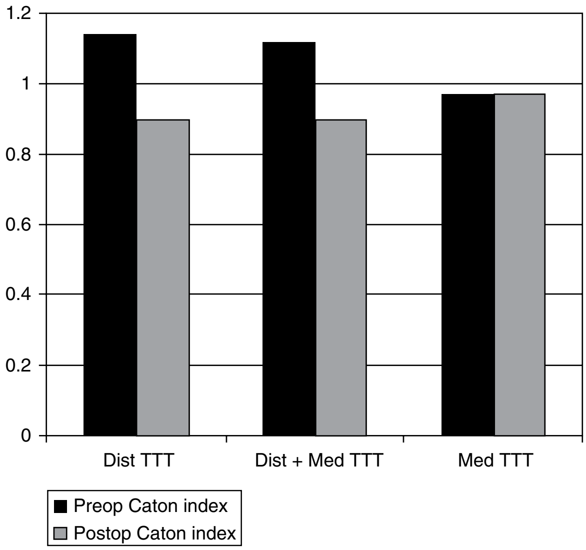

Fig. 25.5 Preoperative and postoperative Caton-Deschamps index: results of a distal transfer (with or without medial transfer)

intervention for patellofemoral problems must be planned carefully and take into account clinical and radiological patient anatomy particularities. The soft tissue procedure and bony procedure are both of them a part of the treatment and their association should be discussed [17]. Thus, in case of Caton-Deschamps index greater than 1.2, the correction of Patella Alta should be discussed. To our knowledgment, no biomechanical data is available on the negative effect of a Patella Alta in association with a trochlear dysplasia. Nevertheless, a distal TTT should result in a more normal and timely engagement of the patella into the trochlear groove and distal realignment procedures should be considered in all cases of patellofemoral instability with a Patella Alta and excessive TT-TG.

25.5 Summary

- Distal realignment is indicated in cases of Patella Alta; one of the main factor associated with EPD.
- It is usually performed in association with other procedures.
- Excessive patellar tendon length may be the cause of a patella instability and should be addressed.
- In case of Caton-Deschamps index greater than 1.2, the correction of Patella Alta should be discussed.
- No biomechanical data is available on the negative effect of a Patella Alta in association with a trochlear dysplasia.
- A distal TTT should result in a more normal and timely engagement of the patella into the trochlear groove and distal realignment procedures should be considered in all cases of patellofemoral instability with a Patella Alta and excessive TT-TG.

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Trochlear Lengthening Osteotomy with or Without Elevation of the Lateral Trochlear Facet

26

Roland M. Biedert

26.1 Introduction

The femoral trochlea is important for controlling the patellofemoral gliding mechanism [4,19]. The normal articular shape of the trochlea and patella allow for undisturbed patellar tracking. The normal cartilaginous surface of the trochlea consists of the lateral and medial facets of the femoral sulcus and is defined by different criteria in the proximal-distal, medio-lateral, and antero-posterior direction [9, 10, 27]. The normal trochlea deepens from proximal to distal [9, 27]. In the proximal-distal direction, it is longest laterally and shortest on the medial side (Fig. 26.1). The deepened trochlear groove separates the lateral facet from the medial part. In the antero-posterior measurements, the most anterior aspect of the lateral condyle is normally higher than the medial condyle and the deepest point is represented by the center of the trochlear groove [10].

Trochlear dysplasia is an abnormality of shape and depth of the trochlear groove, mainly in its proximal extent [17,28]. It represents an important pathologic articular morphology that is a strong risk factor for permanent patellar instability [3, 4, 9, 12–15, 17, 18, 22, 23, 25, 29, 30]. Dejour et al. [15] described several types of trochlear dysplasia with increasing severity. The trochlear depth may be decreased, the trochlea may be flat, or a trochlear bump is present. According to this, different classifications are described in the literature [12, 16].

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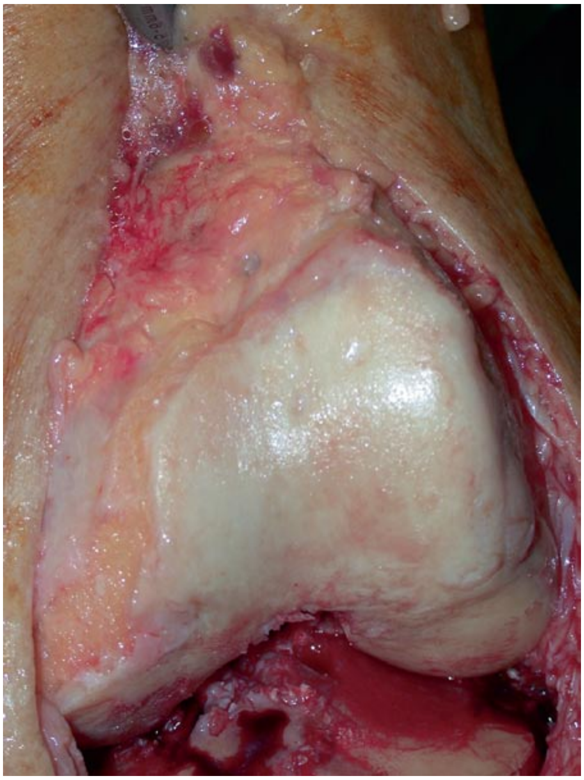

Fig. 26.1 Normal shape and length of the lateral articular trochlea (anterior view, left knee, patient with degenerative joint disease)

Additionally we have noticed that there exists a wide spread variability of combinations of trochlear dysplasia [9]. Seen from this angle we documented a different and unknown type of trochlear dysplasia, which to our present knowledge not described before: the too short lateral articular trochlea (Fig. 26.2) [5,6]. We believe that this short lateral trochlea is another relevant factor for lateral patellar instability. Accordingly, surgical treatment should aim to correct this specific type of dysplastic trochlea.

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26.2 Physical Examination

The patients with a too short lateral trochlea facet suffer from patellar instability. The patella is well centred in the trochlea under relaxed conditions. But when the patient contracts the quadriceps muscle with the leg in extension, the patella is pulled to proximal out of the short trochlea because it is not sufficiently guided and stabilized by the too short lateral facet of the trochlea. In most cases, the contraction also causes subluxation to the lateral side (Fig. 26.3a and b). We call this abnormal gliding mechanism *dynamic supero-lateral patellar subluxation*. This clinical finding is often only mild, but significant. In severe cases, this can also cause complete dynamic lateral patellar dislocation. In contrast to the lateral *pull sign* described by Kolowich et al. [21], this type of patellofemoral instability is primarily due not to soft tissue abnormalities (atrophy of the vastus medialis obliquus and hypertrophy of the vastus lateralis and lateral structures), but caused by a pathologic proximal patellar tracking due to the missing osteochondral opposing force of the lateral trochlea facet. This type of patella instability can also be depicted by manual examination in complete extension of the knee. Only minimal manual pressure laterally causes subluxation and discomfort to the patient. In most cases the patient feels pain and tries to resist this manoeuvre. This test in full extension must be differentiated from the *patellar apprehension test* which is performed in 20°–30° of knee flexion [4, 24]. With increasing knee flexion, the patella enters into the more distal and normal part of the trochlear groove and becomes more and more stable. This confirms the clinical suspicion of proximal patellar instability to the lateral side.

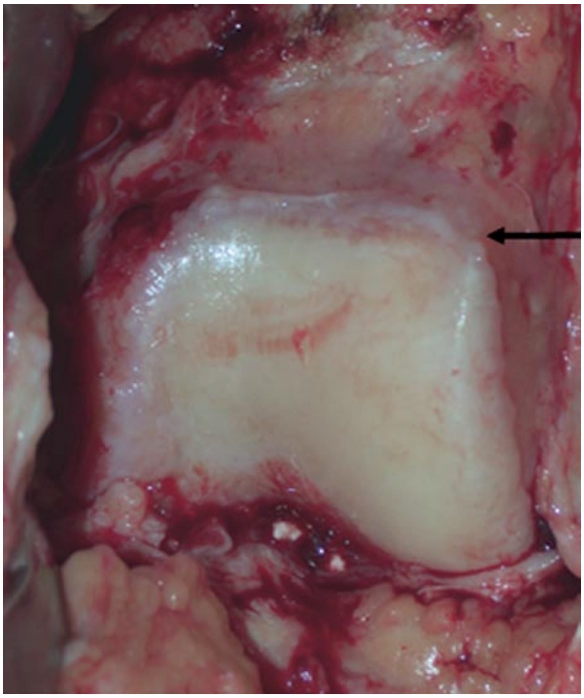

Fig. 26.2 Too short lateral articular trochlea (end marked by *arrow*) compared to the medial facet and the normal trochlea groove and shape (anterior view, left knee, patient with degenerative joint disease)

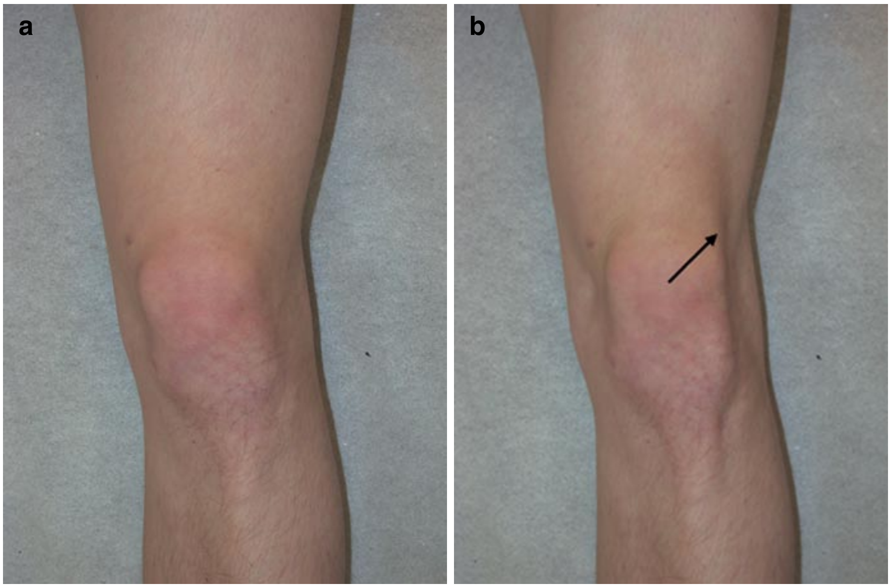

Fig. 26.3 (**a**) Well-centred patella without muscle contraction. (**b**) Dynamic supero-lateral patellar subluxation caused by quadriceps contraction

26.3 Imaging

26.3.1 Radiographs

The radiologic examination of patients with a too short lateral facet of the trochlea do not normally show the typical findings of trochlear dysplasia in the true lateral view such as the crossing sign, supratrochlear spur, double contour [12, 14, 15, 17] or lateral trochlear sign [20]. Radiographs can only show signs of dysplasia in combined trochlear abnormalities. The different indices used for patellar height measurements are normal.

26.3.2 MR Measurements

MR images allow complete and precise visualization of the patellofemoral joint by clearly delineating the proximal portion of the trochlea and for assessing femoral trochlear dysplasia [12, 26]. MR imaging is therefore the best modality to assess the proximal part of the trochlea in patients with suspected too short lateral facet of the trochlea.

MR measurements are performed with the knee in 0° of flexion, the foot in 15° external rotation, and the quadriceps muscle consciously relaxed. Measurements on sagittal images include different parameters (Fig. 26.4) [5, 6, 11]. The parameters are measured on the most lateral section of the lateral condyle with visible articular cartilage in the trochlea (Fig. 26.5). The length of the anterior articular cartilage of the lateral trochlea (a) is calculated using as a reference the length of the posterior articular cartilage of the lateral condyle (p). For each individual subject *p* is always considered to be 100%. The variable length of *a* is calculated in percentages with regard to *p*. The *lateral condyle index* compares the length *a* with the length *p* and is expressed in percentages.

The values of the lateral condyle index found in a normal control population without any patellofemoral complaints were on average 93% [11]. Therefore we consider an anterior length of the lateral articular facet of the trochlea with index values of 93% or more of the length of the posterior articular cartilage as normal (Fig. 26.5). Lateral condyle index values of 84% (on average) were found in patients with chronic lateral patellar subluxation and instability documenting a too short lateral articular facet of the trochlea (Fig. 26.6). Index values of less than 93% must therefore be considered as pathologic and values of 86% or less confirm the presence of a too short lateral facet. Index values between 86% and 93% need additional assessment such as the patellotrochlear index or radiologic patellar height measurements (Insall-Salvati, Blackburne-Peel,Caton-Dechamps ratios) to document or exclude Patella Alta [7]. In cases with normal patellar height measurements, lengthening of the anterior lateral articular facet of the trochlea is recommended. In cases with Patella Alta, other surgical interventions, such as distalization of the tibial tubercle or shortening of the patellar tendon, may be needed.

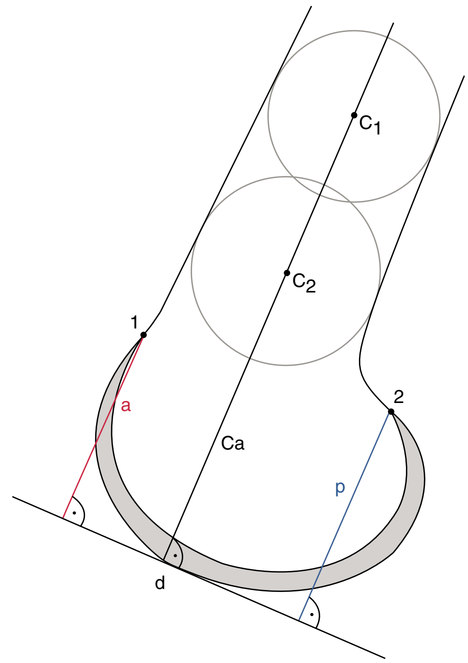

Fig. 26.4 MR measurements (31).
C1 Proximal circle in the femoral shaft.
C2 Distal circle in the femoral shaft.
Ca Central axis.
d Baseline distal condyle (perpendicular to Ca).
1 Superior most aspect of anterior cartilage of the lateral condyle.
2 Superior most aspect of posterior cartilage of the lateral condyle.
a Length of the anterior articular cartilage of the lateral condyle (red line).
p Length of the posterior articular cartilage of the lateral condyle (blue line)

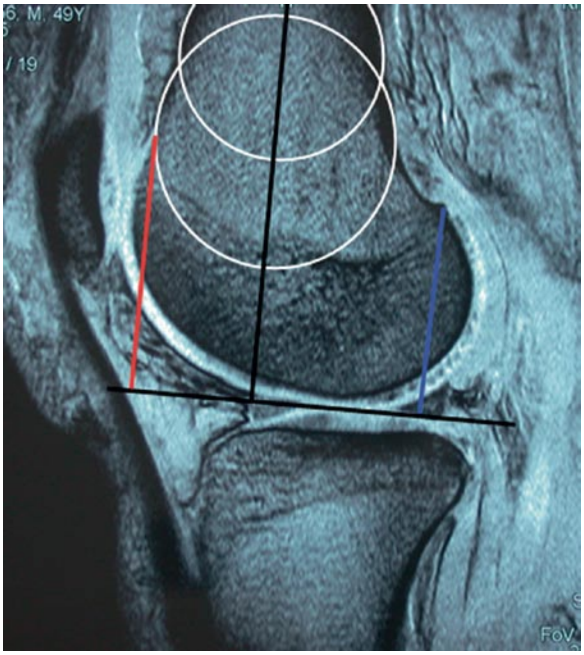

Fig. 26.5 MR measurement with normal length of the anterior articular cartilage of the lateral facet of the trochlea

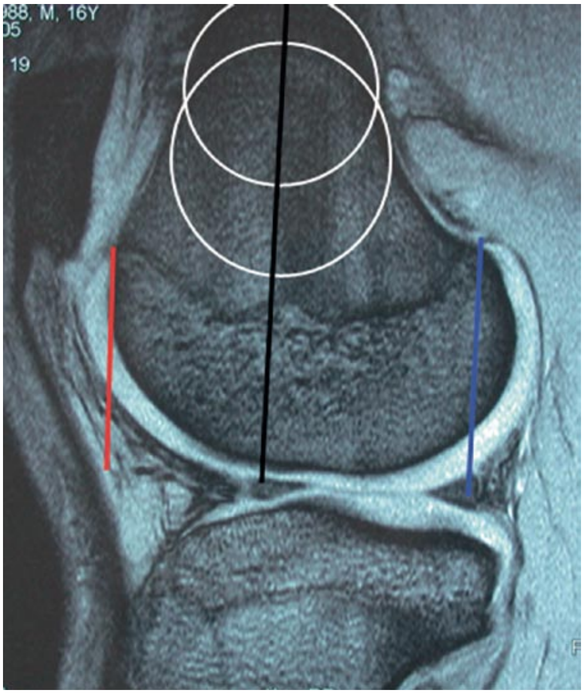

Fig. 26.6 MR measurement with too short anterior articular cartilage of the lateral facet of the trochlea (same patient as Figs. 26.9, 26.10, and 26.11)

26.4 Surgery

Surgical techniques have been developed to correct the pathologic morphology, though they differ in the site of surgical correction [1–3, 13–15, 17, 22, 25, 29, 30]. The therapeutic procedure which aims at correcting the abnormalities is selected according to the documented type of trochlear dysplasia [9,17]. Elevation of the lateral trochlea facet of a flat dysplastic trochlea, lowering the floor of the sulcus, and removing a prominent trochlear bump are described in numerous variations as reasonable well known surgical procedures to treat patellar instability [1, 3, 4, 9, 12–15, 17, 23, 29, 30].

26.4.1 Lengthening

Lengthening of the lateral facet is another, mostly unknown technique of trochleoplasty. It is indicated when a too short lateral trochlea is documented (clinically and with MRI) and the patient remains symptomatic after conservative therapy. A clear indication is given when the lateral condyle index is 86% or less. Lengthening is designed to create a longer proximal part of the lateral trochlear sulcus to improve the contact within the patellofemoral joint and to optimize the patellofemoral gliding mechanism. A longer lateral trochlea facet is the feature that must “capture” the patella in extension before the knee starts to flex, to ensure that it is guided into the more distal trochlear groove. Normally, the contact between the articular surface of the trochlea and the articular cartilage behind the patella is about one third of the length of the patellar cartilage (measured using the patellotrochlear index) [7]. This value is very helpful both in planning (using MRI) and during surgery to determine how much lengthening to the proximal should be performed.

Through a short parapatellar lateral incision (maximum 5 cm), the superficial retinaculum is localized. About 1 cm from the border of the patella it is longitudinally incised and carefully separated from the oblique part of the retinaculum in the posterior direction to allow lengthening of the lateral retinaculum at the end of surgery if needed [4]. The oblique part is cut, together with the synovial membrane. The patellofemoral joint is opened and the intraarticular inspection possible. Other pathologies can be identified and treated if necessary.

The proximal shape of the lateral facet of the trochlea and the length of the articular cartilage are assessed with regards to the length of the sulcus and the medial facet of the trochlea (Fig. 26.7). The presence of a too short lateral articular facet is reconfirmed. In such a case, the patellotrochlear overlap is less than one third. The overlap present allows one to determine the amount of lengthening of the lateral facet and should be about one third at the end, measured in extension (0° of flexion) [4,7]. The incomplete lateral osteotomy is made at least 5 mm from the cartilage of the sulcus to prevent necrosis of the trochlea or breaking of the lateral facet. The osteotomy starts at the end of the cartilage (arrow) and is continued approximately 1–1.5cm distal into the femoral condyle and proximal into the femoral shaft, always according to the aimed patellofemoral overlapping (Fig. 26.10). The osteotomy is opened carefully with the use of a chisel. Fracture of the distal cartilage may occur and has no consequences; sharp edges must be smoothed. Cancellous bone (obtained through a small cortical opening of the lateral condyle more posterior) is inserted and impacted (Fig. 26.8). Additional fixation is possible using resorbable sutures. To finish, the lateral retinaculum is reconstructed in about 60° of knee flexion.

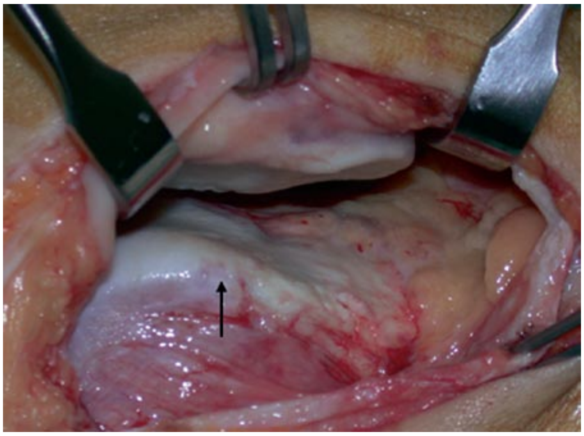

Fig. 26.7 Intraarticular inspection shows the too short articular cartilage of the lateral facet (*arrow*) with destruction caused by subluxation

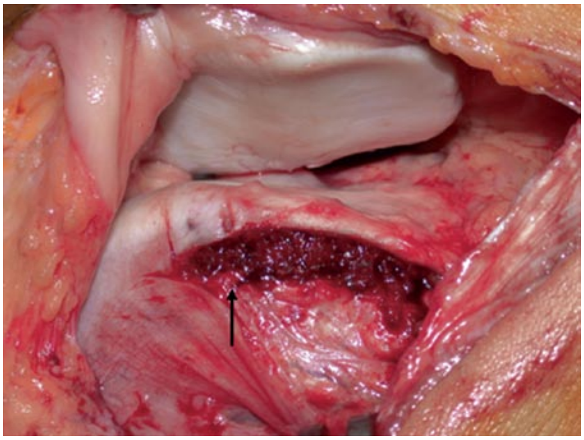

Fig. 26.8 Completed lengthening osteotomy with inserted cancellous bone (*arrow* indicates former end of articular cartilage). The patellotrochlear overlap is increased now

26.4.2 Elevation

Combined pathologies with a too short, but also a flat lateral facet of the trochlea can occur (Fig. 26.9). The surgical steps consist then of a lengthening osteotomy with additional elevation of the lateral facet. The approach is the same. The osteotomy is opened carefully and the lateral facet lifted up to the desired height (Fig. 26.10). The amount of elevation depends on the present pathomorphology. The lateral facet of the sulcus should be higher than the medial facet (Fig. 26.11). The anterior cortex of the femoral shaft serves as an orientation of the necessary elevation. In most cases 5–6 mm elevation are sufficient. Overcorrection (with hypercompression) must be strictly avoided. It also has to be considered that in five out of six cases the lateral condyle is not too flat, but the floor of the trochlea too high (8, 10). This would be visible on preoperative axial MR images.

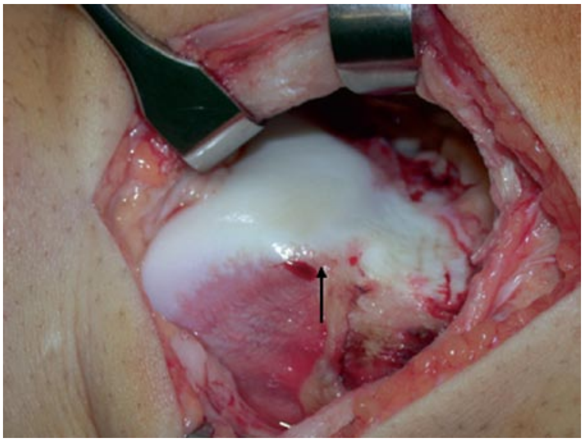

Fig. 26.9 Too short and flat lateral articular trochlea (*arrow*) (same patient as Fig. 26.6)

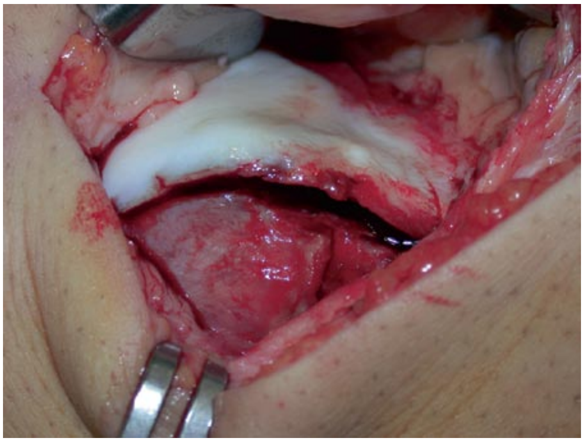

Fig. 26.10 Location and amount of the incomplete lateral osteotomy

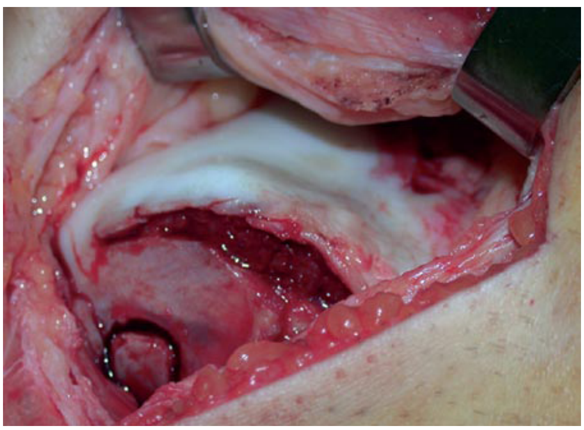

Fig. 26.11 Intraoperative view after combined osteotomy with lengthening and raising. The reconstructed proximal trochlea represents normal shape and length. The osteotomy gap is filled with cancellous bone, the access to the lateral condyle to the take cancellous bone is closed

26.5 Postoperative Care

Partial weight bearing (10–20kg) is recommended for 3–4 weeks to avoid hypercompression of the osteotomy. Range of motion is limited (0°–90°) in the very beginning for some days to decrease swelling and pain. Continuous passive motion starts immediately to optimize the patellofemoral gliding mechanism and to form the reconstructed trochlea. Bicycling and swimming are the first sport activities allowed after 2–3 weeks. Sports activities without any restriction are permitted after 3 months.

26.6 Conclusions

The described too short lateral articular facet of the trochlea represents another type of trochlear dysplasia causing lateral patellar instability. Physical examination and MRI help to document this type of pathomorphology. The lateral condyle index is the most reliable measurement for the diagnosis. Index values 93% or more are normal, values of 86% or less pathologic and confirm the presence of a too short lateral facet. Surgical correction must address also in such cases the underlying abnormality. Lengthening is the surgical treatment of choice to improve the patellotrochlear overlapping and with this the stability. In cases with additional flat lateral facet, moderate elevation of the lateral trochlea may be necessary.

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27 Proximal Open Trochleoplasty (Grooveplasty)

Lars Peterson and Haris S. Vasiliadis

27.1 Introduction (Stability of the Patellofemoral Joint: Passive and Active Stability)

The total functional stability is dependent on optimal synergic collaboration of the skeletal, ligamentous and muscular stabilizers, all working together (Fig. 31.5).

The skeletal geometry by its own creates a passive stability during knee motion. The geometry of the trochlear groove is of high importance during 0°–30° of flexion (30°–0° of extension) where most of the dislocations occur. The skeletal stability can be affected by patellofemoral dysplasia, where the geometric configuration of the trochlea is primarily not developed. The patella shape usually plays a secondary role even if it is found dysplastic [6].

The stability of the patellofemoral joint is also maintained by the attached ligaments (retinacula). The shape of the trochlea surface affecting the skeletal stability and the ligaments of patellofemoral joint, preserve the passive stability which cannot be affected by training or any voluntary activity. The active stability is maintained by the attached muscle tendons of the quadriceps acting over the joint during contraction. The active stability of the patellofemoral joint can be improved by training.

Ligamentous stability works by stabilizing the joint throughout the whole range of motion. The patellar ligament (tendon) mainly acts as a passive stabilizer by limiting the proximal movement of the patella. Secondarily, it acts as a tendon of the quadriceps muscle, thus acting as an active stabilizer.

The longitudinal medial and lateral retinaculum act also through passive support to the patellar ligament. However, they are also active stabilizers acting as tendon-like aponeuroses of the vastus medialis obliquus (VMO) and vastus lateralis muscles (VL).

The medial patellofemoral ligament and the lateral patellofemoral ligament (transverse retinaculum) are also passive stabilizers medially and laterally of the patella. They work synergetically with the VMO and VL muscles [1].

27.2 Trochlear Dysplasia

Trochlear dysplasia can be classified into 3 grades depending on the shape of the articular surface. In grade 1, trochlea is flat or shallow while in grade 2 it is convex shaped and extends more proximal. In grade 3, the lateral trochlea is flat with the lateral patella facet articulating on its lateral surface and not to the dysplastic medial trochlea (Figs. 27.1 and 27.2).

Patients with dysplasia of the trochlea are subject to lateral tracking and tilting of the patella, especially during muscle contraction. Depending on the grade of the dysplasia, the patella may be slightly tracked or tilted laterally, recurrently subluxating or dislocating [4].

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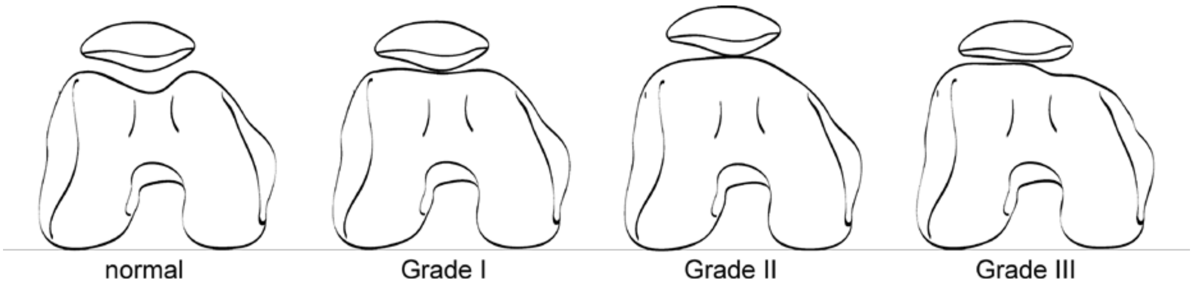

Fig. 27.1 Schematic drawings of trochlear dysplasia. Grade I: flat or shallow trochlea. Grade II: convex shaped trochlea-extends more proximal. Grade III: lateral trochlea is flat with patella articulating on the lateral trochlear surface, medial trochlea dysplastic [3]

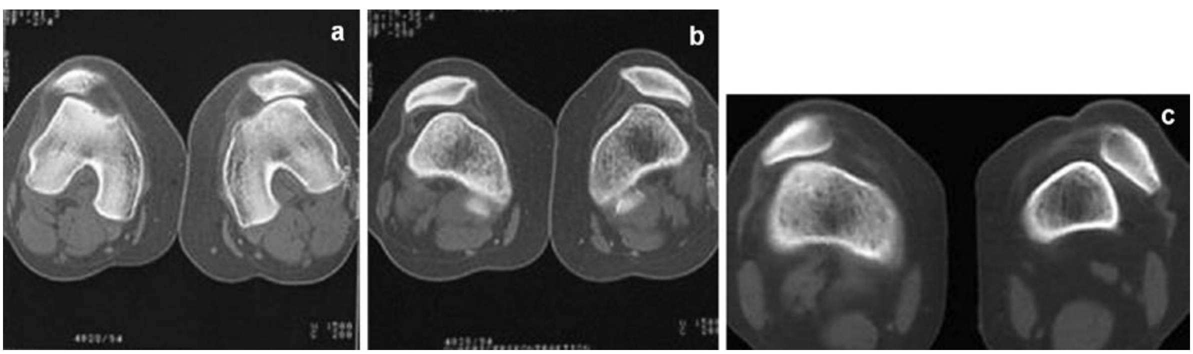

Fig. 27.2 Computerized tomography with the knees in extension. (**a**) Patient with grade III trochlear dysplasia showing flat lateral trochlear articular surface articulating with lateral patella facet, with slight subluxation on the right knee. (**b**) Patient with extended knees and quadriceps contraction showing subluxation of both patellas. (**c**) Patient with extended knees during quadriceps contraction showing right knee with subluxation and left knee with dislocation. Both (b) and (c) show flat trochlear grooves

In any case, there is an alert of the contact areas and the normally applied forces on the trochlea and patella. The forces are applied in different areas than in normal patellofemoral joints (Fig. 27.3). Besides, those areas are subject to shearing forces on the medial-lateral axis, because of the tilting or subluxation or dislocation of the patella. Lateral tracking will cause a stress concentration in a small contact area of the patellofemoral joint. As a result, the so-called kissing lesions on lateral trochlear surface and lateral patellar facet are eventually caused, either due to repeated abnormal forces or as an acute traumatic lesion.

Especially given the young age of the patients, the cartilage lesions should be treated along with the trochlear dysplasia or any other background factors leading to the patellar instability or malalignment (Table 31.3).

27.3 Proximal Open Trochleoplasty

The proximal open trochleoplasty was first presented in 1988 [6]. It is indicated in cases with symptomatic patellofemoral instability with trochlear dysplasia. The aim of this technique is to reconstruct the trochlear groove and to stabilize the patella during the initial 0°–30° of flexion (extension 30-0), without too much interfering with the patellar trochlea congruity.

The philosophy of the procedure is based on that patella dislocations initiate during the first 30° of knee flexion. A quadriceps' contraction at that point, in case of trochlear dysplasia, is usually the cause of dislocation or subluxation of the patella. If the patella is not subluxated at about 30 degrees, then in further flexion it will remain stable by the passive and active stabilizers (and especially the medial and lateral retinaculum) which

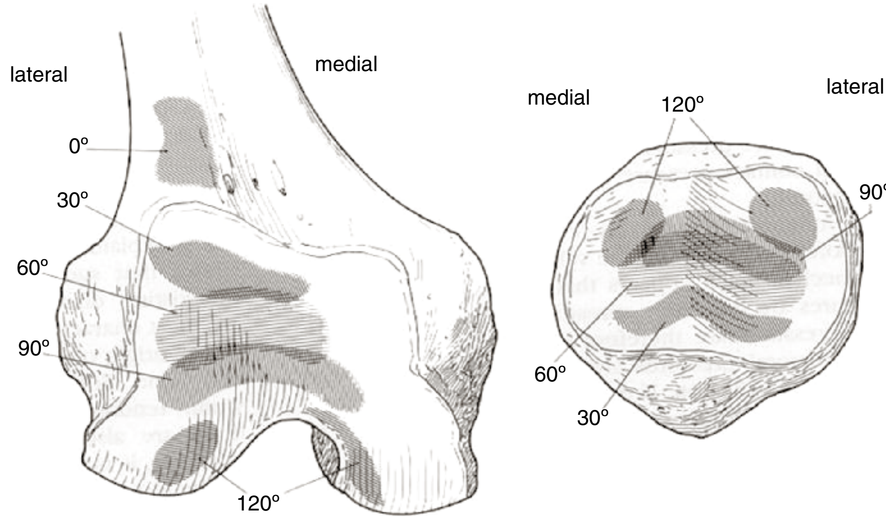

Fig. 27.3 The different contact areas of normal trochlea and patella in different angles of knee flexion

effectively stabilize the patellofemoral joint at flexion angles exceeding the 30°. According to that, only the proximal part of the trochlea, which is in contact with the patella during the first 30°, needs to be deepened in order to achieve the desired patellofemoral joint stability leaving the congruity of the patella-trochlea intact distally.

Other trochlear grooveplasties have also been used, such as lateral trochlear open wedge osteotomy and subchondral trochlear burring [2,5]. Such techniques restore the proximal skeletal stability, but interfere with the patella-trochlea congruity. The alteration of the congruity of the patellofemoral joint may lead to an increase of the applying forces on the cartilage and also to eccentric loading of the joint. That finally contributes to several iatrogenic problems including aggravation of cartilage lesions, and primary osteoarthritis.

In almost all the cases, the proximal open trochleoplasty should be performed as a part of more extended surgery, aiming to total restoration of the patellofemoral alignment. The whole surgical protocol is described later on, in this chapter (Chap. 27.4). The grooveplasty alone is described in Chap. 27.3.2 and in Fig. 27.4.

27.3.1 Preoperative Planning

The preoperative planning is important for any patient with the suspicion of patellar instability. The aim should be to identify any background factor that may contribute to the malalignment and instability of the patella. Based on the findings, the surgery will be planned, including the corrections needed to be performed. The therapeutic approach should be individualized upon the findings, for any single patient.

Clinical examination is of high importance and should be definitely done carefully before proceeding to the laboratory exams if necessary. In grade I instability, the patella will not dislocate but track laterally before moving proximally on slow quadriceps' contraction with the knee in extension; slow VMO activation delays proximal traction. Apprehension test is negative. In grade II and III, the apprehension test is positive. Patellar lateral subluxation and patellar tilt is found. Quadriceps contraction on an extended knee may dislocate the patella in grade II. A persisting instability with recurrent subluxation is present in 0°–30° of flexion, in grade III instability.

Long plain x-rays on AP plane should be performed in order to measure the Q-angle and identify a potentially valgus knee. CT scan of the patellofemoral joint in extension is used with and without quadriceps contraction in order to reveal lateral tracking or instability and trochlea dysplasia.

Skyline views of the patella are usually suggested as an easily performed method of evaluating the patellofemoral stability, congruity and trochlear sulcus. However, it gives only a static and no functional image of the joint. It lacks the ability of the active evaluation of the joint in full extension or 20° of flexion and fails

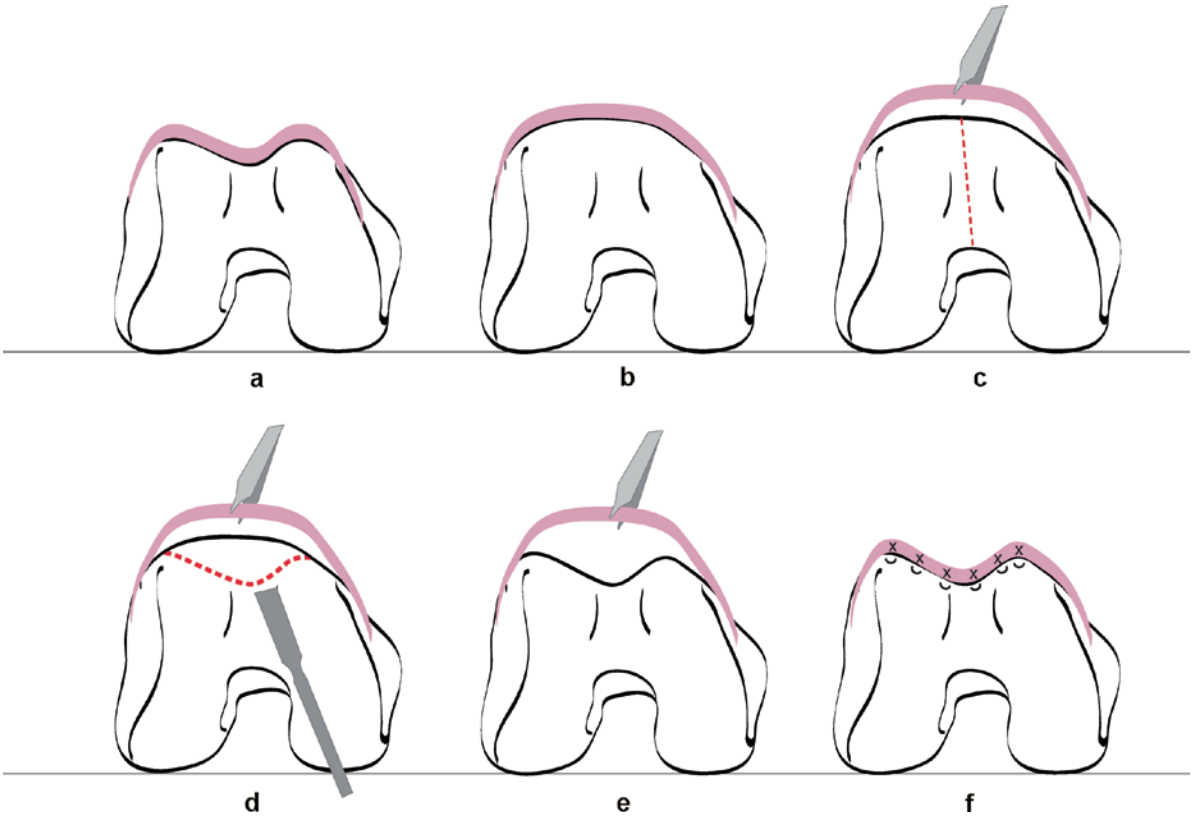

Fig. 27.4 Proximal trochlear grooveplasty. (**a**) normal configuration of the trochlea groove, (**b**) flat trochlear dysplasia, (**c**) synovial lining released from the trochlea articular border, (**d**) with a curved osteotome perform distal resection of about 10–12 mm of the cartilage and bone, aiming to the top of the intercondylar notch. Then complete the trochleoplasty by about 15 mm medial and lateral enlargement of the groove, (**e**) restoration of the trochlea groove after completed resection, (**f**) resuturing of the synovial lining to the cartilage border of the trochlea using mattress sutures

to demonstrate the tendency of subluxation under the traction of quadriceps.

MRI can be added to the CT scan, also demonstrating the integrity of the ligamentous as well as muscular stabilizers of the patella. Dynamic MRI will be used in the future for a more functional assessment of the patellofemoral joint in general and cartilage pathology.

27.3.2 Operative Technique

The trochlea is exposed, preferably after central skin incision and medial or lateral arthrotomy, as described below.

After the exploration of the patellofemoral joint, the surgeon should first identify or confirm the type of dysplasia and the extent of the articular cartilage injuries (Figs. 27.4b and 27.5a).

Then, he has to release the synovial lining (posterior wall of the suprapatellar bursa) from the articular border of the trochlea in proximal direction (Fig. 27.4c).

Then aim for the top of the intercondylar notch. Draw an imaginary line from the top or the notch to the top of the articular surface (Fig. 27.4c). Use a curved osteotome to remove articular cartilage and bone from the center of the trochlea, about 10 mm distal and 15 mm medial and lateral, into a maximum depth of about 5 mm. The aim is to create a concavity on the most proximal part of the trochlea (Figs. 27.4d, e and 27.5b). If the bone is also flat or convex proximal to the trochlea, remove it with the osteotome or a burr and create a continuous concavity. Check the patella sliding through the groove and adjust the Q-angle to centralize the patella.

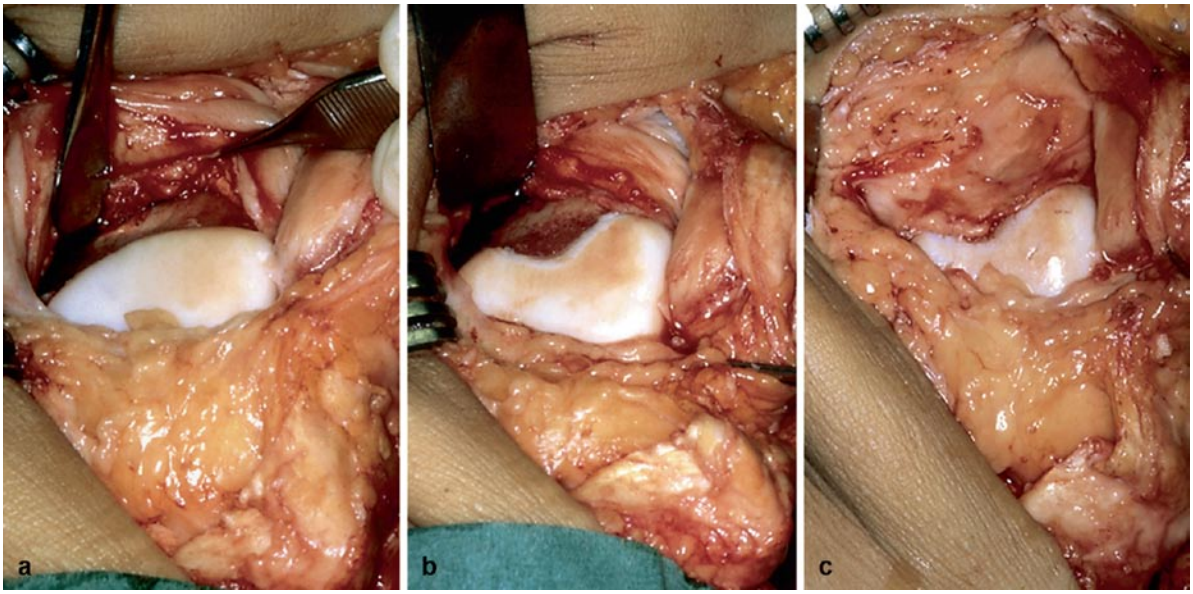

Fig. 27.5 Surgical pictures of different stages of proximal open trochleoplasty. (**a**) dysplasia of the trochlea with a convex groove, (**b**) after creating the desired concavity with the curved osteotome, (**c**) after suturing the of the synovial lining to the proximal cartilage border

Then resuture the synovial lining back to the cartilage border using mattress reabsorbable 3-0 sutures, to cover the raw bone surface of the distal femur (Figs. 27.4f and 27.5c). Inject fibrin glue to fix the synovial lining to the roughened bone (Fig. 27.5).

27.3.3 Pearls and Pitfalls

Always evaluate the trochlea dysplasia in the patellofemoral instability. Consider trochlea dysplasia an important part of the instability and correct it. However, isolated dysplasia of the trochlea is rare, and other background factors are equally important to correct.

It is important that the proximal location of the concavity created is aiming and directed to the top of the intercondylar notch. Then, when deciding the degree of medialization of the tibial tuberosity, adjust it so that the extensor mechanism with the patella is entering the trochleoplasty area without angulation, not to compress laterally either to subluxate medially.

Avoid a step from the bone to the cartilage border; make the cartilage borders oblique with the use of a knife.

When reattaching the synovial lining to the cartilage border start through the synovial lining, continue deep into the cartilage penetrating 10 mm to the surface, start the return 3 mm aside, then go through the cartilage back to the border and catch the synovial lining 2–3 mm apart from the initial entrance. Then tighten the suture so that the synovial lining adapts to the cartilage border. Place as many sutures as needed to adapt the synovial lining to the whole border with about 6–8 mm intervals.

Sometimes it is hard to cover the bony defect with the synovium. Then make a transverse incision to the synovium proximally and release it, to allow distal reattachment.

When injecting the fibrin glue, compress the synovium to the bone with a dry sponge for 2 min to adhere the synovium to the bone surface and avoid bleeding.

27.4 Other Surgeries

In the cases of trochlear dysplasia, the trochleoplasty cannot address alone the complex problem of the patellar instability and cartilage lesions of the patellofemoral joint. Other background factors leading to patellar instability usually coexist, some of them as a result of the recurrent subluxations or dislocations of the patella. The ligamentous stability is disrupted due to the subsequent elongation of the medial elements (medial retinaculum, medial patellofemoral ligament) and there is also a shrinkage of the lateral retinaculum. Besides that, there is usually a disruption of the whole musculoskeletal arrangement of the knee joint; that dictates the need for transformation of the tibial tuberosity for the medialization of the forces and unloading of the patellofemoral joint. The restoration of the trochlear dysplasia by the grooveplasty should be accompanied by the correction of all the concomitant background factors, along with the treatment of the potential cartilage lesions, preferably with autologous chondrocyte implantation (ACI) (see Chap. 31).

So, the whole surgery is described in the following text, keeping the order that all the stages should be performed. In the absence of trochlear dysplasia, depending of the underlying background factors, some of those stages can be enough, to restore the patellar alignment. Whenever trochlear dysplasia is present, it should be corrected.

The operation is performed with the patient supine in bloodless field. Starting from the skin incision, a midline incision starting 1–2 cm proximal to the base of the patella down and distal to the tibial tuberosity should be performed; then a medial parapatellar arthrotomy starting 1 cm proximal to the patella, between the rectus femoris and the VMO, running 5–7 mm medial to the patellar insertion of the VMO and patellofemoral ligament. Continue down to the tibial condyle and incise the joint capsule, inspect the joint, especially the patella and trochlear groove. Evaluate the articular cartilage lesions along with the patellofemoral joint incongruity or any other malfunctions and address the surgical plan for their treatment. Include a meticulous assessment of the Q-angle and the patellar tracking in the groove or if it is dysplastic.

27.4.1 Lateral Release

The lateral release (release of the lateral transverse retinaculum and distal VL insertion) and the medial arthrotomy incising the medial retinaculum and VMO should be performed first (Fig. 27.6b and c). However, the suturing (plication) of the medial retinaculum should be preserved as the last stage of the surgery (Fig. 27.6e).

27.4.2 Tibial Tuberosity Transfer: Unloading Procedures

In case of an increased Q-angle, think of performing a tibial tuberosity transfer, in order to correct it. A straight medial transfer should be undertaken in order to correct the Q-angle, an anteromedial transfer to correct the Q-angle along with unloading the patellofemoral joint and an additional distal transfer in the case of Patella Alta.

Simultaneous anteriorization is achieved by using an oblique osteotomy starting from posterior laterally aiming to anterior-medially. Increased angle of the osteotomy increases the anteriorization.

For both medial and anteromedial transfer, a distalization can be added by an oblique distal osteotomy angulating by 10° for every mm of distal transfer needed.

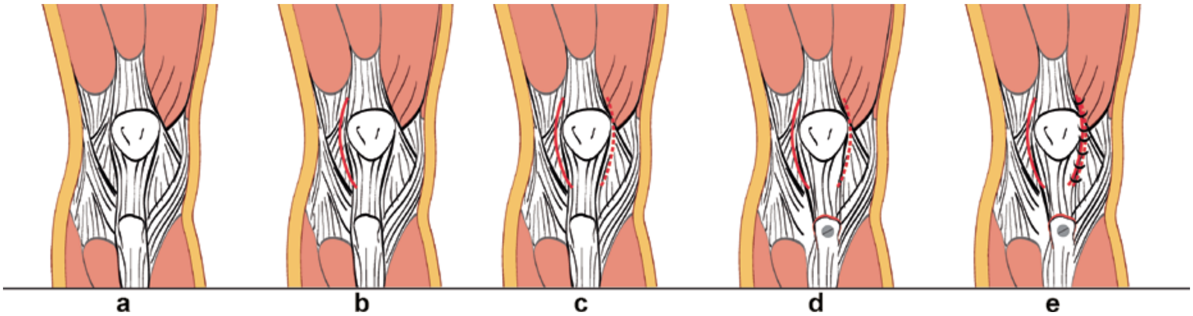

Fig. 27.6 Reconstruction of the extensor mechanism (realignment procedure). (**a**) important structures to address, (**b**) release of the lateral transverse retinaculum and distal VL insertion, (**c**) anteromedial incision staring 1 cm proximal to basis patella between the VMO and rectus femoris down through the VMO and MPFL and capsule 5–7 mm medial to the insertion in the patella down to the tibial tuberosity, (**d**) osteotomy and medial-distal transfer of the tibial tuberosity and screw fixation. Trochleoplasty or ACI should be performed at that stage, before the screw fixation, (**e**) plication of the VMO and MPFL en-block. Details of the plication technique see Fig. 27.9

Isolated tibial tuberosity anteriorization (ventralization) is used to unload the patellofemoral joint in kissing patella-trochlea lesions or large uncontained patella and trochlea lesions. A straight proximal osteotomy of the tibial tuberosity, keeping the attachment to the bone distally, is elevated about 10 mm and a 10 mm wedge of bone is taken from the lateral tibial plateau and pressed into the osteotomy and fixed with a screw.

Open the infrapatellar bursa, medial and lateral, and dissect free the tibial condyle if you need an anteriorization. Use a saw or an osteotome and go from posterior-lateral to anterior-medial through the tibial tuberosity and then perform an oblique osteotomy 3–5 cm distal to the patellar tendon insertion after predrilling for later screw fixation. Check the degree of medialization needed for correcting the Q-angle and maltracking; usually 10–14 mm of medial transfer is needed. When a distal transfer is needed to correct a Patella Alta, an oblique distal osteotomy is used. (Fig. 27.6)

The fixation of the transferred tubercle in its new place should be performed at the end of surgery, after the trochleoplasty or ACI (if performed), just before the medial plication (Fig. 27.6d and e).

27.4.3 Trochlea Grooveplasty

Next step is to perform the trochlear grooveplasty, as described before, if dysplasia is present.

27.4.4 Autologous Chondrocyte Implantation

Now proceed to the ACI for the treatment of cartilage lesions, as described in Chap. 31. In that case of course, a cartilage biopsy and chondrocyte culturing should have been preceded. When a trochlea grooveplasty is scheduled, the cartilage biopsy can be retrieved from the proximal central part of the dysplastic trochlea; this area will anyway be removed during the grooveplasty.

27.4.5 Medial Plication

Now, as the last stage of the surgery, prepare for the shortening of the medial patellofemoral ligament and VMO (medial retinaculum), which should be done en-block (Figs. 27.6e and 27.7). Roughen the bone between the soft tissue insertion to the medial side of the patella and the articular cartilage. Pass sutures through the soft tissue flap close to the patellar bone from outside to inside. Then suture through the medial end of the soft tissue block, including the medial patellofemoral ligament and the VMO-tendon, from anterior to posterior. Finally return the suture from inside-out through the soft tissue close to the patella. Use three to four of these sutures; tighten them and check the stability of the patella. Than overlap the lateral flap by interrupted sutures. Continue with the suturing of the medial arthrotomy. Close the skin and bandage the knee.

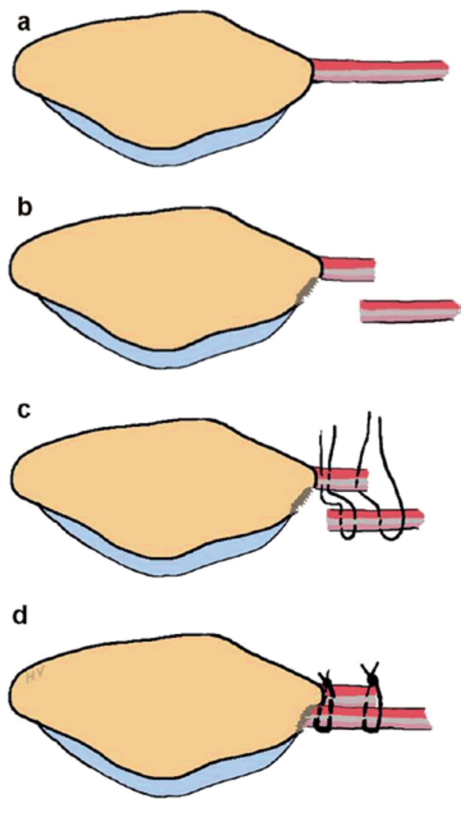

Fig. 27.7 Medial soft tissue plication including VMO (red color), MPFL (gray color) and synovial capsule (violet color) (**a**) medial structures (VMO, MPFL, synovial capsule), (**b**) transaction of soft tissue en-block and roughening the area between the soft tissue insertion ant the articular cartilage border for better ingrowth, (**c**) technique of reinsertion and fixation of the soft tissue plication to the roughened surface of the patella using mattress sutures, (**d**) tightening and knotting of the sutures

The row of the above described interventions is of high importance. The lateral release should be performed first and then the incision to the medial retinaculum (not the suturing); then the trochleoplasty and the ACI (if they are also performed), preserving for the end the plication of the medial retinaculum and VMO (Fig. 27.6).

27.5 Rehabilitation

The proximal open grooveplasty does not interfere with any bone to bone healing as in other trochleoplasty procedures. The integrity of the trochleoplasty is not jeopardized by any accelerated postoperative rehabilitation. Thus, rehabilitation is mainly dependent on the concomitant surgeries, such as the transfer of tibial tuberosity or the ACI (if performed for cartilage lesions). As a result, the rehabilitation is the same as if the grooveplasty was not performed.

27.6 Complications

Complications like medial subluxation or remaining lateral instability may occur if you do not plan or execute the procedure according to the surgical instructions and rehabilitation protocol. The medial subluxation may occur if the Q-angle is overcorrected by excessive medialization of the tibial tuberosity or overtensioning of the medial plication.

Athrofibrosis due to adhesions may be the result of persisting bleeding from the bone. Could be prevented by adequate fixation of the synovium with sutures and fibrin glue. Arthofibrosis may also be due to concomitant procedures and subsequent bleeding especially in the tibial tuberosity area. Sometimes fibrin glue can be added to the bony surfaces or a drainage could be left for 24 h. Early mobilization is a key to avoid arthrofibrosis and the progress of range of motion should be followed closely in the early postoperative period.

27.7 Summary Statement

- The open trochlear grooveplasty is an effective treatment option for the trochlear dysplasia.
- Its aims is the reconstruction of a close to normal trochlear concavity, stabilizing the patella in the critical first 30° of knee flexion.
- The technique appears to not extensively interfere with the patellar trochlea congruity, thus avoiding complications connected to an excessive and eccentric loading.
- The open groove plasty should almost never be performed alone.
- Other background factors contributing to the patellofemoral malalignment should also be addressed.

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Deepening Trochleoplasty for Patellar Instability

28

David Dejour, Peter Byn, and Paulo R. Saggin

28.1 Introduction

The patellofemoral joint has a low degree of congruency by nature; therefore it is susceptible to dislocation. There are active and passive restraints that prevent the patella from being subluxated or dislocated. The passive stability depends on static anatomical restraints and the congruence between the trochlea and patella, which is low, as mentioned above. The active stability is provided by the dynamic restraints: the muscles and the balance between the ligaments: both bony and soft tissues structures provide an active and passive stability which allows the patella to function during knee movements.

Patellar dislocation has a low rate of recurrence. Some predisposing factors, mostly congenital, lead to chronic patellar instability; those factors have a high genetic incidence.

Henri Dejour [4,5] established in 1987 a classification of patellofemoral instability and described four major factors for instability with statistical threshold. The four instability factors were: trochlear dysplasia, Patella Alta, excessive distance between tibial tubercle and trochlear groove (TT-TG > 20 mm) and excessive patellar tilt (>20°).

Trochlear dysplasia is the main determinant; it is present in 96% of the objective patellar dislocation (OPD) population (at least one patellar dislocation). Sometimes it is obligatory to correct the sulcus angle if there is a high grade trochlear dysplasia (type B and D) to achieve normal patellar tracking. The trochlear shape can be modified by two types of trochleoplasties [1,3,4], either lifting the lateral facet or deepening the trochlea creating a new trochlear groove. It is the deepening trochleoplasty that will be described in this chapter.

28.2 Indications

The indication for such surgery is a combination between the clinical analysis and the radiological analysis. On the clinical field, the deepening trochleoplasty is a very rare indication, recommended only in severe instability, including patient with permanent or habitual dislocation or dislocation in their daily activities and patients with an abnormal patellar tracking during flexion and extension with passive and or active motion. Looking to the radiographic analysis the trochleoplasty is indicated in patients with high grade trochlear dysplasia. A trochlea is defined as dysplastic if it has little or no congruence with the patella. These trochleas are flat or even convex.

In contrast to the lateral lifting trochleoplasty, the sulcus deepening trochleoplasty corrects the etiology of the deformation. It is indicated in severe dysplasia (types B and D) (Fig. 28.1), in which the trochlea is prominent and convex and the patella impinges on the trochlear bump during knee flexion. An abnormal patellar tracking sign reflect these types (Fig. 28.2).

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Other instability factors are analyzed to decide if the procedure has to be combined or done isolated. One of these factors is the TT-TG distance. When a deepening trochleoplasty is performed a new groove is created in a more anatomic position, thereby performing a type of proximal realignment. This will effectively decrease the TT-TG distance. Therefore one should be cautious when adding a distal realignment, as this will often be unnecessary.

Frequently there are other anatomical abnormalities associated in this patient population that the surgeon has to address. Consequently the trochleoplasty is seldom performed as an isolated procedure. It can be associated with a tibial tubercle distalization to correct a high patella, or a medialization [8] to correct an excessive TT-TG (> 20 mm). At present, a medial soft tissue procedure is always added (Fig. 28.3). Previously this used to be a vastus medialis plasty, but the efficacy of that procedure is now doubtful. At present, the best combination is a medial patellofemoral ligament reconstruction using a gracilis tendon autograft with two patellar tunnels and one blind tunnel at the isometric point in the femoral insertion's area, close to the medial epicondyle [7].

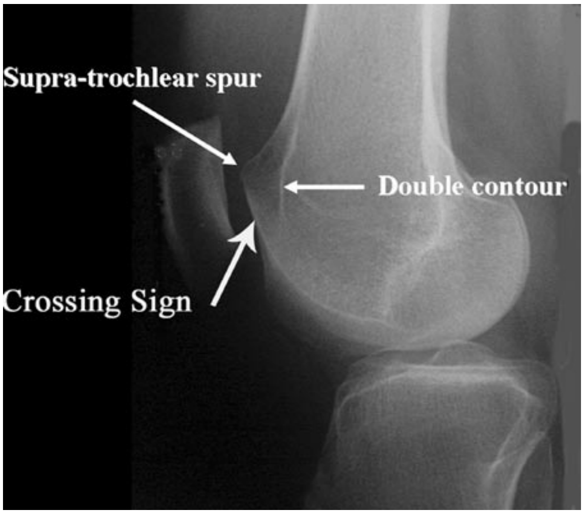

Fig. 28.1 Trochlear dysplasia type D combining the crossing sign, the supratrochlear spur which represents the prominence of the trochlea, and the double contour (projection on the lateral view of the subchondraol bone of the hypoplasic medial facet)

28.3 Contraindications

- High grade trochlear dysplasia with instability associated with patellofemoral pre-arthritis or arthritis;
- Anterior knee pain without instability;
- Absence of the trochlear bump (supratrochlear spur);

28.4 Techniques

28.4.1 Trochleoplasty

The procedure is performed under regional anesthesia, complemented by patient sedation. The patient is positioned supine. The entire extremity is prepared and draped, and the incision is performed with the extremity flexed to 90°.

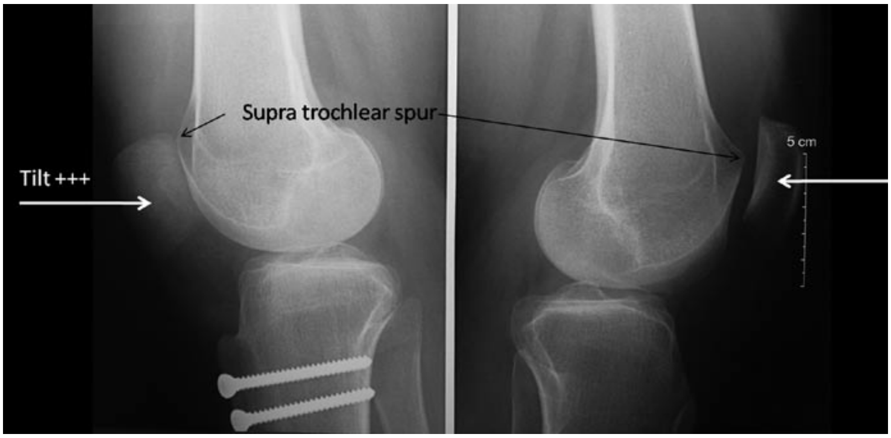

Fig. 28.2 Bilateral type D trochlear dysplasia. On the operated knee (isolated TT transfer) the patellar tilt is still pathological

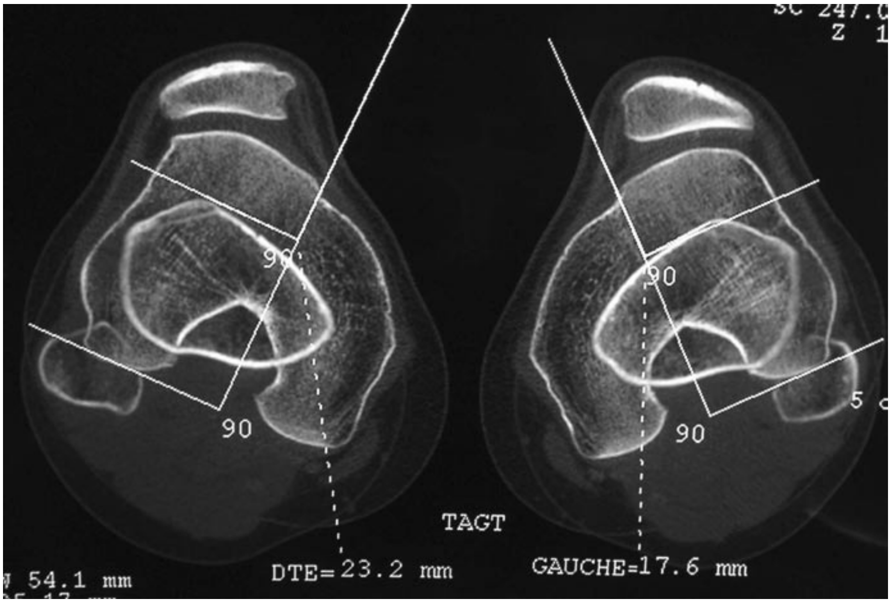

Fig. 28.3 CT scan shows on the reference cut the convex trochlea, abnormal TT-TG (right knee) and abnormal patellar tilt (not measured)

A straight midline skin incision is carried out 4 cm from the superior patellar margin to the lower part of the patella. The extremity is then positioned in extension and a medial full thickness skin flap including the three medial layers is developed. The arthrotomy is performed through a mid-vastus adapted approach: medial retinaculum sharp dissection starting over the 1–2 cm medial border of the patella, and blunt dissection of VMO fibers starting distally, at the patellar supero-medial pole, extending approximately 4 cm into the muscle.

The patella is not everted but a careful inspection of the chondral status is done, the lesions are rated using the ICRS classification. The trochlea is exposed and peritrochlear synovium and periosteum are incised along their osteochondral junction, and reflected from the field using a periosteal elevator. The anterior femoral cortex should be visible to define the amount of bone to be removed. The prominence of the superior part of the trochlea has to be removed. Changing the knee degree of flexion-extension allows a better view of the complete operatory field and avoids extending the incision.

Once the trochlea is fully exposed, the new one is planned and drawn with a sterile pen. The new trochlear groove is drawn (Fig. 28.4) using as starting point the top of the intercondylar notch. From there, a straight line representing the new sulcus is directed proximally and 3°–6° laterally. The superior limit is the osteochondral edge. Two divergent lines are also drawn, starting at the notch and going proximally, representing lateral and medial facet's limits. The superior limits are the medial and lateral condylo-trochlear sulcus.

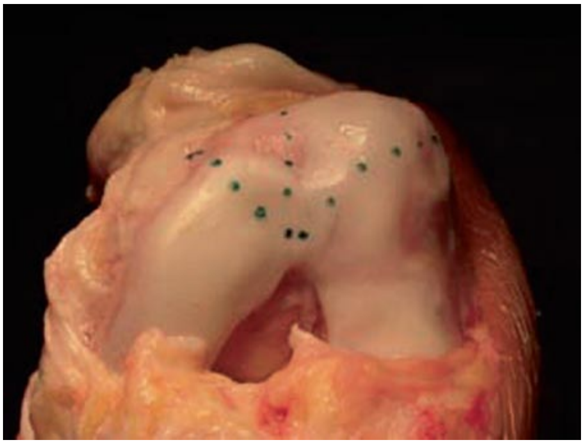

Fig. 28.4 Drawing of the new trochlea limits, the medial facet is nearly inexistent

The next step is accessing the under surface of the femoral trochlea. For this purpose, a thin strip of cortical bone is removed from the osteochondral edge. The width of the strip is similar to the prominence of the trochlea from the anterior femoral cortex, the bump formed. A sharp osteotome is used and gently tapped. A rongeur is used next, to remove the bone.

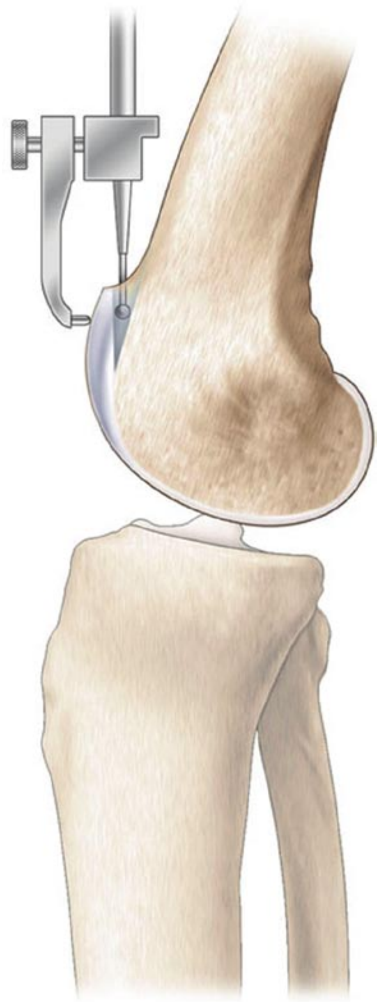

Fig. 28.5 Cancellous bone removal with powered burr. The probe is set at 5 mm to prevent any cartilage damage

Subsequently, cancellous bone must be removed from the under surface of the trochlea. A drill with a depth guide of 5 mm (Figs. 28.5 and 28.6) is used to ensure uniform thickness of the osteochondral flap, thus maintaining an adequate amount of bone attached to the cartilage. The probe of the guide also avoids injuring the cartilage or getting too close to it, otherwise thermal injury could be produced. The shell produced must be sufficiently compliant to allow modeling without being fractured.

Cancellous bone removal is extended to the notch. More bone is removed from the central portion where the new sulcus will rest.

Light pressure should be able to model the flap to the underlying cancellous bone bed in the distal femur.

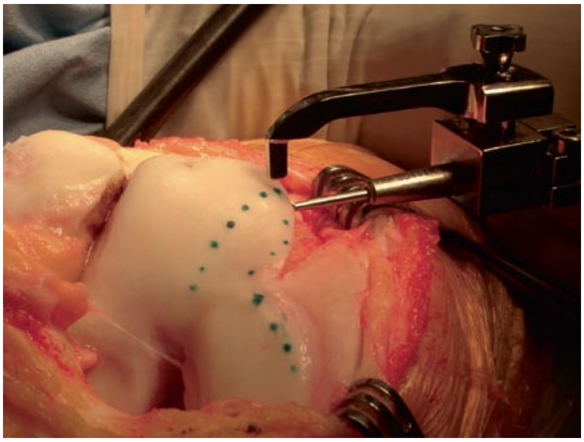

Fig. 28.6 Operating view of the burr, see the very hypoplasic medial facet

The bottom of the groove and sometimes the lateral and the medial facet external margin should be slightly osteotomized to allow further modeling, which is done by gently tapping over a scalpel. If the correction obtained is satisfactory, the new trochlea is fixed with two staples (hand made with a 1 mm K-wire), one in each side of the groove (Fig. 28.7). The staples are fixed with one arm in the cartilaginous upper part of each facet, and the other arm in the anterior femoral cortex. The staple is sunk into the cartilage to prevent any impingement with the patella. Patellar tracking is tested and measures may be obtained. Periosteum and synovial tissue are sutured to the osteochondral edge and anchored to the staples.

28.4.2 MPFL Reconstruction

MPFL reconstruction is performed through the same incision, and a medial 1 cm incision over the medial epicondyle is performed to allow femoral tunnel perforation. Gracilis harvesting also requires a 2 cm incision (Fig. 28.8).

The procedure starts by harvesting the graft. It is our choice to harvest a gracilis graft. Two convergent tunnels are perforated in an anteroposterior direction, starting 1 cm from the medial border of the patella and approximately in the middle of the patella's long axis. They should be apart 1 cm from each other, and must converge before reaching the articular surface of the patella.

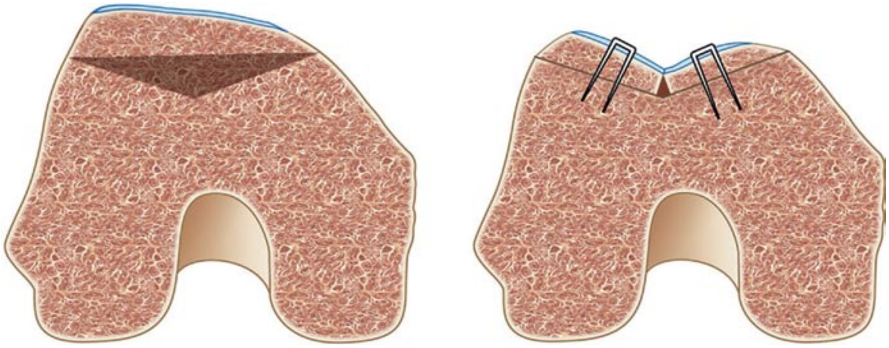

Fig. 28.7 The two facets are fixed with two staple made with 1 mm K-wires

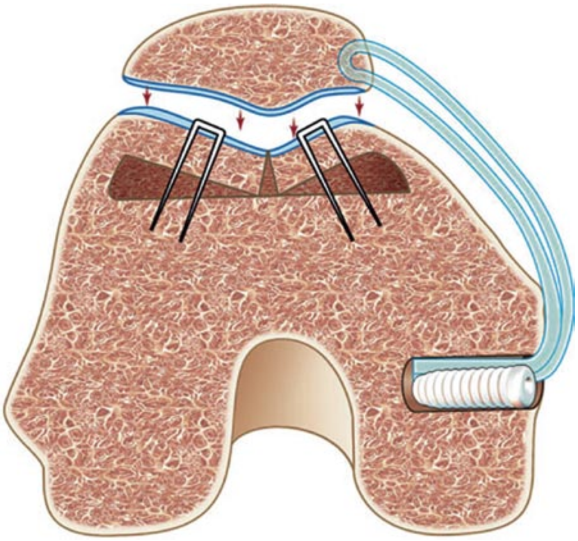

Fig. 28.8 The deepening trochleoplasty is combined to a MPFL reconstruction using the gracilis tendon and fixed in a blind tunnel with an interference screw

After patellar tunnels are done, graft passage is performed. No fixation there is needed, since its extremities will be fixed in the femoral tunnel. A 1 cm window is created in the medial retinaculum, 2 cm away from its free border. The graft will then pass through it from the profound plane to continue in the subcutaneous tissue, and lately enter the femoral tunnel.

The femoral tunnel for graft fixation is perforated slightly superior and posterior to the medial femoral epicondyle using a 1 cm direct stab incision. It should be deep enough to accommodate the graft's extremities after tensioning. Before perforation, however, the graft is tied over the guide pin in the tunnel position to allow tunnel placement and isometricity testing.

The graft is then passed in the femoral tunnel. Proper tensioning is effectuated in 60° of knee flexion after cycling, and should allow further flexion without overconstraining the knee, but should also avoid patellar dislocation in extension. Finally, fixation is achieved with a bioabsorbable interference screw.

28.5 Results

28.5.1 Postoperative Care

The postoperative care will need to take into account the associated procedures, since the trochleoplasty or another procedure is rarely carried out as an isolated procedure. Therefore the following rehabilitation protocol is only a guide. The rehabilitation is divided in three phases with at least three sessions in each week.

Phase 1 starts the day after the surgery and ends at the 45th day. Immediate weight-bearing is allowed, the patient has to walk with crutches and an extension brace for 4 weeks. Walking without a brace is allowed after 1 month, only if the quadriceps are efficient. Lateral and longitudinal quadriceps mobilizations are performed; the posterior muscular chains are stretched. Active ascension of the patella is performed, seated with the leg stretched and the knee unlocked, by static quadriceps contractions. Range of motion is gradually regained (avoiding passive, forced or painful postures) until 100° of flexion and 0° of extension during the first 6 weeks. Frequent knee movement is encouraged, to improve the nutrition of the cartilage and to allow further molding of the trochlea by patellar tracking after trochleoplasty. Resting position with the knee in 20° of flexion without a brace is allowed and encouraged. Dynamic and isometric quadriceps strengthening with weights on the feet or tibial tubercle is prohibited.

Phase 2 goes from the 46th day until the 90th day. The articular running-in is continued and cycling is possible with weak resistance initially. Those resistances can be gradually intensified. Active exercises are added: static co-contractions of the hamstrings and the quadriceps between 30° and 90°, static and dynamic strengthening of the hamstrings against resistance between 60° and 90°, in neutral position static strengthening of the internal and external rotators with the knees 90° flexed and strengthening of the biceps and fascia lata with the knee unlocked. Dynamic and isometric quadriceps strengthening with weights on the feet or tibial tubercle is still forbidden. The anterior and posterior muscular chains are stretched, and the patient is encouraged to continue the rehabilitation on his own. Weight-bearing proprioception exercises are started when full extension is complete, first in bipodal stance and later in monopodal stance when there is no pain. Closed chain muscular strengthening weakly charged between 0° and 60° can also be initiated.

If possible an isokinetic test of the hamstrings (after a medical consultation) is performed after 3 months in order to restart running. This test provides objective data of the muscular balance and recovery. With satisfactory values the patient can restart running without risk. If there is an insufficient recovery or a muscular imbalance the rehabilitation is adjusted and running is delayed.

Phase 3 is passed from the 4th until the 6th month, this is the sports phase. Closed kinetic chain muscular reinforcement, leg press and charged squatting between 0° and 60° with minor loads but long series are allowed, so are Kabat and mono- and bipodal proprioception exercises. A global muscular work-out is started, which addresses the opposite leg, the spinal and abdominal muscles. Weight-bearing and monopodal proprioception exercises are started when there is no pain. Also work-out machines are implemented: leg behind (hamstring training), vertical or horizontal press between 0° and 60°, charged squatting between 0° and 60°, cycling and elliptical cycling, rowing machine, steps, adductor and abductor machines. Leg before is forbidden. Dynamic and isometric quadriceps strengthening with weights on the feet or tibial tubercle is still prohibited. Stretching of the anterior and posterior muscular chains is continued. The patient is encouraged to proceed with the rehabilitation on his own.

After 6 months sports on a recreational or competitive level can be resumed.

Six weeks postoperatively control radiographs, including AP and lateral views and an axial view in 30° of flexion, are taken. After 6 months a control CT scan is performed in order to document the obtained correction (Figs. 28.9a, b and 28.10a, b).

28.5.2 Results

Two series were published in the "Journée lyonnaise de chirurgie du genou" 2002.

28.5.3 Group I

The first group included 18 patients, who had failed patellar surgery for instability. The mean age at surgery was 24 years, there were no patients lost to follow-up. The mean follow-up was 6 years (2–8 years). The new surgery was 6 times indicated for pain, 12 times for recurrence of instability. The average number of surgeries before the trochleoplasty was 2 (medialization, arthroscopy, distalization, lateral release, etc.)

The deepening trochleoplasty was 8 times associated with a tibial tubercle medialization, 6 times with a distalization and 18 times with a medial vastus plasty.

Preoperatively there were 8 grade B trochlear dysplasias, 4 grade C and 6 grade D. The mean TT-TG was 18 mm (14–24), the mean Caton-Deschamps Index was 1.1 (0.8–1.3). The mean Patellar tilt was 35° (18–48).

28.5.3.1 Clinical Results

All patients were revisited clinically and radiographicaly with the IKDC form.

65% were satisfied or very satisfied, the knee stability was rated 13 times type A and 5 times type B. Twenty-eight percent of the patients had residual pain, this was correlated to the cartilage status at surgery. Two patients had patellofemoral arthritis.

28.5.3.2 Radiological Results

The mean patellar index was 1 (0.8–1.1) and the mean TG-TT was 12 (6–17). The mean patellar tilt with the quadriceps relaxed was 21° (11°–28°), the mean patellar tilt with the quadriceps contracted was 24° (16°–32°).

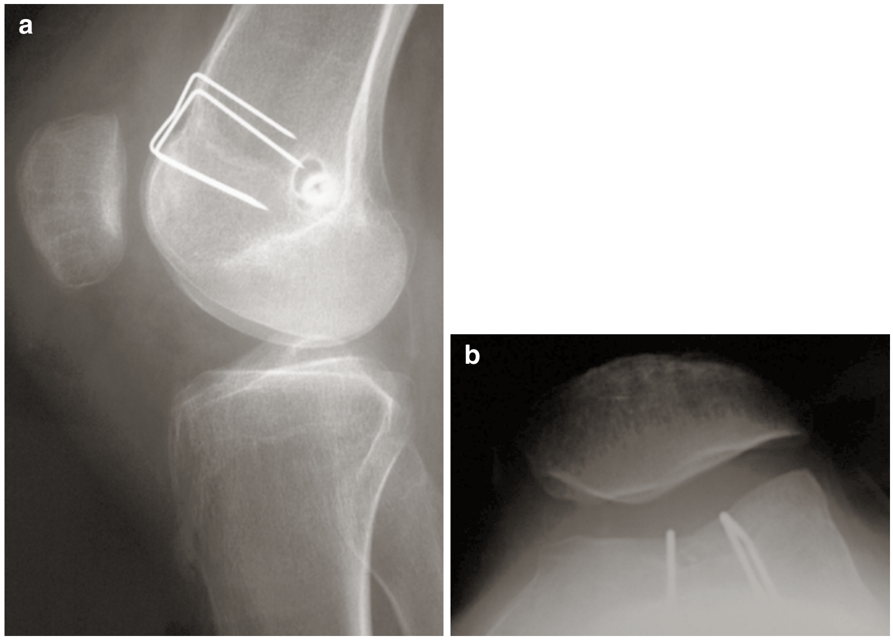

Fig. 28.9 (**a**) True profile after a deepening trochleoplasty. (**b**) Axial view after a trochleoplasty, the sulcus angle is inferior to 145°

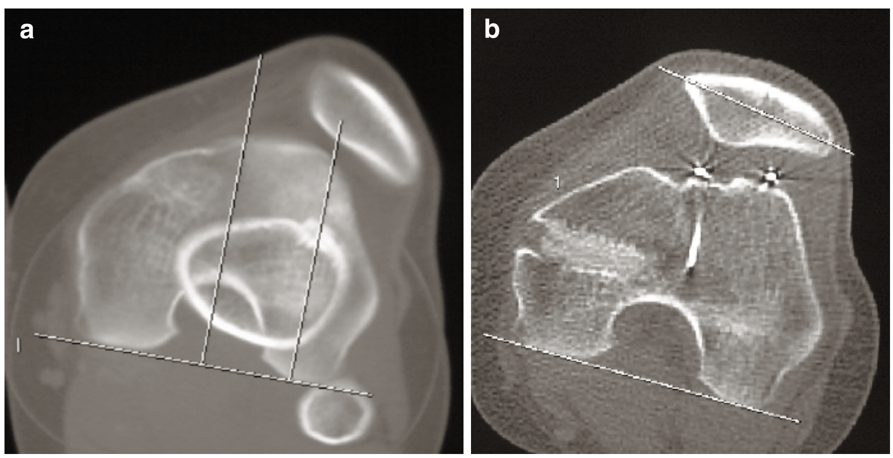

Fig. 28.10 (**a**) Pre-operative CT scan shows excessive TT-TG and pathological patellar tilt. (**b**) CT scan of the same patient after trochleoplasty shows the correction of the patellar tilt, the two staples, and the blind tunnel

28.5.4 Group II

In the second group there were 44 patients. They all had no surgical antecedents. The mean age at surgery was 23 years, two patients were lost to follow-up. The mean follow-up was 7 years (2–9 years). Twenty-two tibial tubercle medializations, 26 distalizations and 32 medial vastus plasties were associated.

Preoperatively there were 21 grade B trochlear dysplasias, 12 grade C, and 11 grade D. The mean TT-TG was 24 mm (15–32), the mean Caton-Deschamps index was 1.3 (1–1.4). The mean patellar tilt was 33° (24–52).

The patients were revisited clinically and radiographicaly with the IKDC form.

Eighty-five percent were satisfied or very satisfied, the knee stability was rated 31 times type A and 13 times type B. Five percent had residual pain, this was not correlated to the cartilage status at surgery. No patellofemoral arthritis was noted.

28.5.4.1 Radiologic Results

The mean patellar index was 1 (1–1.1), the mean TT-TG was 16 (14–21), the mean patellar tilt with the quadriceps relaxed was 18°(9°–30°) and the mean patellar tilt with the quadriceps contracted was 22° (14°–34°).

28.6 Discussion

The conclusion of these two short series shows that in the first group the arthritis risk is high [10].

Other studies [2,6,9,10] also reported this slightly higher incidence of degenerative changes (35% of patients) in patients requiring late surgery for recurrent instability than in patients treated nonoperatively (11–22% of patients at 6–26 years after injury). Some report that degenerative changes are uncommon and require more than 5 years to develop, although it is possible that this may simply reflect a greater severity of disease among patients receiving surgical treatment. Other studies have also shown an increased incidence of osteoarthritis in the surgical group, possibly because of overcorrection or failure to recognize and thus treat the underlying abnormality. The longest published results [10] for trochleoplasty are a mean of 8.3 years. All patients in this series said they would undergo the surgery again, despite evidence of greater than grade 2 radiographic patellofemoral changes in 30% of patients.

The residual pain is still there in cases of previous surgery, therefore the indication should be very careful in those patients. The guarded optimism about the ability to treat isolated patellofemoral arthritis, especially when it is associated with malalignment, and create high performance to patellofemoral joint function, as advocated by Arendt et al. might be dangerous.

The trochleoplasty is indicated in case of instability recurrence but not in cases of residual pain. In the second group (without surgical antecedents) the deepening trochleoplasty is a good option regarding stability and residual pain. The anatomical abnormalities are very well corrected especially the patellar tilt correction.

Outcomes for this patient population need to be reviewed on the long term and on an ongoing basis.

28.7 Conclusion

The patellofemoral pathologies are difficult to treat. They have to be separated into two groups: the clinical patellar instabilities with history of a true dislocation and anatomical anomalies and the patellofemoral pains without anatomical anomalies. A radiographic work-up, including an AP-view, a true profile at 30° of flexion (alignment of the two posterior condyles) and an axial view of 30° of flexion to appreciate systematically the trochlear dysplasia with the crossing sign and to measure the patellar height, has always to be performed. Only when there is a discrepancy between the clinical and radiological data does a CT scan need to be performed to quantify the anatomical anomalies.

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29 Arthroscopic Deepening Trochleoplasty for Patella Instability

Lars Blønd and Philip Schöttle

29.1 Background

Chronic patellofemoral instability is a disabling condition and the surgical solutions for this condition have improved due to an increased understanding of the anatomy and pathomorphology of the unstable patellofemoral joint. Since it was demonstrated in 1994 that trochlear dysplasia was present in 85% of the cases with patellofemoral instability [3], trochleoplasty became an accepted surgical procedure to treat some of these patients. With this procedure, the instability causing factor of missing bony guidance can be addressed by creating a sufficient trochlear grove [4,7–9]. With this procedure, rather than performing indirect procedures such as transfer of the tuberosity, stability can be provided in more then 20° of flexion without increasing the patellofemoral pressure. However, open trochleoplasty is a major operation and the surgical trauma, the retinacular scar as well as the subcutaneous scar and the postoperative pain seems to be more pronounced compared to other stabilizing methods, leaving the joint intact. Furthermore, compared to arthroscopic procedures open procedures are commonly related to an increased risk of infection and arthrofibrosis [8]. Additionally, patients undergoing the open trochleoplasty need several days of hospitalization to manage the postoperative pain and to initialize the mobilization, as well as a long time to get back to work, all factors that make the procedure relatively expensive. Despite the good clinical results of trochleoplasty, applied in cases with severe trochlear dysplasia and recurrent patellar dislocations, and despite the documentation of normal postoperative cartilage status [5], a mixture of these above-mentioned circumstances have until now been reluctant factors for surgeons to commence to this operation. Since arthroscopic techniques have continuously improved in orthopedic surgery, and due to the obvious advantages of this minimally invasive surgery such as less pain, faster rehabilitation, shorter hospitalization and less scar formation, these techniques has become more and more favored. Due to the above-mentioned postoperative effects after open trochleoplasty, a need for developing an arthroscopic technique in this situation has also been requested. This, in order to avoid the above-mentioned risks and deficiencies, and therefore provides an accelerated and less painful postoperative phase. With improvement of arthroscopic instruments and devices, this newly developed technique was tested and specified in a series of cadavers before instituting its clinical use in the beginning of 2008. The results have been encouraging with the above-mentioned advantages regarding less pain, faster rehabilitation, shorter hospitalization and less scar formation and at least it has been documented that the technique is possible. We would like to emphasize that it is a technical demanding procedure and there is a need for a longer follow-up. Indication for the arthroscopic trochleoplasty are two or more patellar dislocations with a persistent Fairbank's apprehension sign from 0° to 50° of flexion and trochlear dysplasia grade B to C and eventually also grade D, as defined by Dejour et al. and regraded by Tecklenburg et al. [2,6]. Exclusion criteria are a cartilage defect in the trochlea ICRS grade 3 or 4 with a diameter of 2 mm or more.

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29.2 Surgical Technique

A tourniquet is mounted to the thigh, in case bleeding occurs and reduces visualization. Initially, an arthroscopy is performed via a standard lateral arthroscopic portal to determine the trochlear shape and to inspect the cartilaginous situation. If the indication for trochleoplasty is verified, the procedure is continued placing further arthroscopic portals.

29.2.1 Special Arthroscopic Portals and Preparation of the Cartilaginous Flake

To achieve an optimal view to the bony border of the proximal trochlea, still with the arthroscope in the lateral portal and with the knee extended, one medial and one lateral superior arthroscopic portal is set in the proximal part of the suprapatellar bursa close to the quadriceps tendon, using a needle as a guide. In the superolateral portal a working cannula is introduced and the arthroscope is switched to the superomedial portal and also an additional lateral working portal is placed at the level just proximal to the lateral trochlea, where a further working cannula is introduced. Through this lateral working portal the synovial tissue proximal to the trochlea is ablated with a radiofrequency energy device (RF) in a first step until the cortical bone is exposed to a length of at least 10 mm. In a next step, the cartilaginous trochlea has to be detached from the underlying bone. Therefore, the trochlear flake is released using a 4 mm round burr (bone cutter) shaver. With the view from the superomedial portal, this flake is mobilized beginning at the proximal-lateral corner of the trochlea. Care has to be taken at the beginning, until the cleavage between bone and cartilage is identified. Then, the cartilaginous flake can be easily separated from the underlying bone without harming the cartilage. Working with the shaver blade from side to side, switching between the two different lateral working portals, the cartilage flake is released until the curve of the trochlea gets to bend. In case some bone is left on the cartilage flake; this has to be removed with the shaver, in order to have a plastic cartilage flake. Instead of using the burr for the detachment at the most lateral trochlea, the cartilage in this area can also be released using an osteotome thin enough to be introduced through the superolateral cannula

29.2.2 Preparation of the Trochlea Groove

If present, a supratrochlear bump or spur is removed before deepening the dysplastic groove. Using the same 4 mm round burr shaver blade, the trochlea groove is then modeled giving it a deeper and more lateralized shape via the superolateral portal, starting distally, where the original trochlea can be identified In order to evaluate the shape and depth of the new-modeled groove, the cartilage flake is pressed down into the new groove, using the numb side of the bone cutter. If the newly created trochlear groove is not yet deep enough according to normal anatomy, more bone is removed in the above-described way.

29.2.3 Refixation of the Cartilage Flake

The cartilage flake is refixated using four knotless suture anchors: The first anchor is loaded with one 3 mm resorbable tape and one resorbable 1-0 suture. By working through a standard medial portal on the level of the joint line, the hole for this anchor is predrilled just distal to the hinge of the cartilage flake in the grove center, and the preloaded anchor is then introduced into the hole, so the loop of the tape and the suture are each kept fixated inside the bone and the four free ends can be used for further intra-articular placement. To apply the further anchors perpendicular to the bone, an additional stab incision is placed just medial to the proximal edge of the patella, after testing a possible perpendicular placement with a needle. With a suture grasper, the distally fixated sutures and one free tape end are shuttled through this portal, while one free tape end is shuttled through the lateral working portal. A second knotless anchor is loaded with the two free suture ends, and is placed just proximal to the newly created trochlear groove into the bone.

Then the tape ends are loaded in one anchor each and the anchors are placed at the proximal-medial and the proximal-lateral trochlear end, holding down the flake by this spider like configuration of tapes and sutures

(Fig. 29.1). After testing the stability of the refixated flake with a probe, the suture and tape ends are cut with an arthroscopic scissor and the arthroscope is removed.

Since the trochlea groove is providing patellofemoral stability mainly in flexion of more than 20°, when the patella starts to engage in the trochlear groove, an additional procedure has to be added to also achieve stability close to knee extension, when there is no bony guidance of the patella. Therefore, it is recommended to combine the above-described procedure with a reconstruction of the medial patellofemoral ligament.

29.2.4 Postoperative Regime

For postoperative pain management, a few additional doses of morphine (p.o.) can be prescribed besides normal analgesics (i.e., paracetamol). Full weight bearing is allowed immediately after surgery, while a knee immobilizer with limited extension of 30° and free flexion is prescribed for 2 weeks. The patients can safely leave the hospital the day after the surgery.

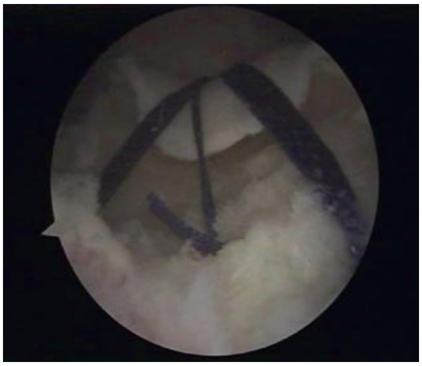

Fig. 29.1 Examples of refixation of the cartilage flake, after the flake is pressed down into the new-formed trochlea by the tapes and sutures

Postoperatively all patients receive physiotherapist guided knee mobilizing and stabilizing training for a period of at least 12 weeks. Sports activities such as running, bike riding and swimming is allowed after 6 weeks, while contact sports should not be started before 4 months postoperatively.

For all the patients operated on so far, the apprehension sign disappeared completely at the 12 months follow-up and the Kujala as well as the Tegner activity score were increasing significantly in comparison to the preoperative status. MRI at 3 months postoperatively showed no cartilage degeneration and a physiological cartilaginous trochlea. In two patients, where a second look arthroscopy was performed, macroscopic normal cartilage was found and only in the area where the first anchor was placed could small differences be observed (Fig. 29.2).

29.3 Discussion

Even though the above-described technique is a technical demanding procedure, the arthroscopically performed trochleoplasty shows several advantages in comparison to the open procedure. These advantages seem to be reduced pain, a faster mobilization, less risk for development of arthrofibrosis and reduced scar formation. The removal of the trochlear spur seems to be

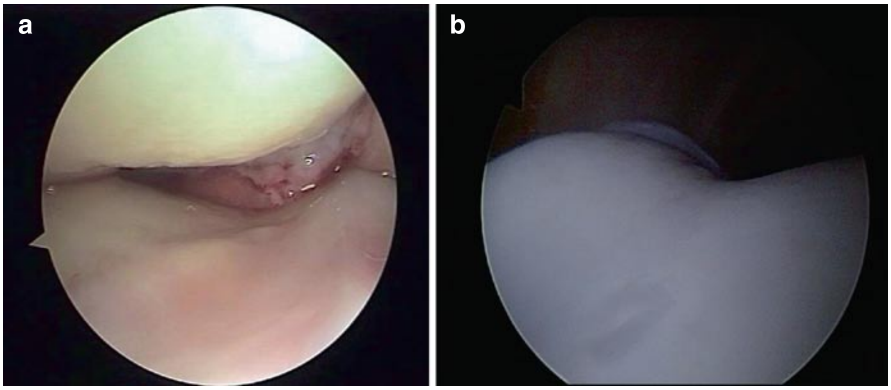

Fig. 29.2 Arthroscopic view of two different knees, 6 months postoperatively, looking from proximal (**a**) and from distal (**b**). The new-formed trochlea is visible, the reattached cartilage is healed and the sutures are absorbed in both examples

an especially easy and helpful procedure. We consider the operation feasible for 1-day surgery.

The disadvantage of the arthroscopic trochleoplasty is the difficulties in the technique and especially how to estimate the correct shaping of the new trochlea.

Regarding the lost of apprehension it is difficult to estimate, if that occurred due to the trochleoplasty or the additional treatment of the MPFL. However, since it has been proven biomechanically that patellofemoral stability in flexion of more than 30° is mainly from the presence of a trochlear grove, while the MPFL is the passive structure to stabilize the joint in extension, the disappearance of apprehension in all degrees of flexion indicates the trochleoplasty provides stability in early flexion degrees. Since it is estimated that the MPFL is insufficient, absent or chronically torn in cases of trochlear dysplasia, we advise reconstructing the MPFL instead of reinserting it in all cases, where a trochleoplasty is performed.

Although the isolated MPFL reconstruction can provide good results in cases with a low grade trochlear dysplasia, the combination of both interventions is demanding in cases with a higher grade deformity, since the decrease of the tilt and shift, achieved by the MPFL reconstruction leads to an increase of patellofemoral pressure and eventually leads to arthrosis. As it has been shown that the cartilage viability is given after open trochleoplasty, no reason has been detected so far that cartilage degeneration should occur using the arthroscopic technique [5]. A further advantage of the arthroscopic treatment is the integrity of the lateral patellofemoral soft tissue complex, since all recent biomechanical studies have shown that a weakening of the lateral structures leads to an increase of patellofemoral instability [1]. Since the arthroscopic technique shows promising results without arthrofibrosis and fast wound healing as well as minimal pain, we want to encourage proceeding with this combination procedure with the above explained indications. However we would also emphasize that the follow-up period is short and too few procedures have been completed to estimate the risk of technical errors and the risk of complications.

29.4 Summary

- The arthroscopic deepening trochleoplasty is a new promising alternative to the open trochleoplasty.
- The procedure has the well known advantages of the arthroscopic techniques compared to the open techniques.
- It less painful and has a shorter hospitalization, and a faster rehabilitation.
- It is a technical difficult procedure with only a short follow-up.

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The Role of Limb Rotational Osteotomy in the Treatment of Patellofemoral Dysfunction

30

Robert A. Teitge

30.1 Importance

The shape of the skeleton is a major determinant of the force which is applied to the patellofemoral joint. Osteotomy to change limb alignment may be critical to change these forces.

Rotational osteotomy should be considered for that patient with anterior knee pain or patellar instability where there is a significant torsional deformity in limb.

30.2 Intrinsic and Extrinsic Limb Factors

It is the author's opinion that PF symptoms should be considered as those which arise from the joint itself and are considered intrinsic factors and those which are caused by forces external to the joint itself are considered extrinsic factors.

The intrinsic factors are largely the recipients of the applied force and include ligaments, the patella and trochlea, both articular surfaces and subchondral bone and the tendons. Instability due to ligament injury, tendinosis and arthrosis or chondral damage are examples of intrinsic failure. These intrinsic factors also include such PF variations from normal as a high-riding or low patella, a dysplastic patella, and dysplasia of the trochlea. These factors may alter the ability of the PF joint to accept load but the forces which are causing the tissue failure are all extrinsic. To address the failed tissue with procedures such as cartilage surgery without addressing the excess load which caused the failure is inviting further failure.

Extrinsic factors are largely the source of load to which the knee joint is subjected. These include the body mass, the distance from the center of mass to the knee joint and to the ground (i.e., the length of the lever arms), the total force of muscles which is required to control acceleration, deceleration, resistance to gravitational pull of the body mass (balance). The shape of the skeleton largely determines the location and orientation of the knee joint between the body mass and the ground. The skeletal shape also determines the direction of muscle pull on the patella and the consequent location of the weight bearing vector. Osteotomy to correct the skeletal alignment to unload the PF joint is analogous to correcting a varus deformity to unload the medial compartment.

PF dysfunction includes: (a) PF instability, (b) anterior knee pain, and (c) patellofemoral arthrosis and chondromalacia.

PF instability is a result of (a) inadequate bony and ligament resistance to a displacing force, (b) an excess of displacement forces, or (c) a combination of both. To consider only the restraints to patellar displacement is to ignore the force which causes the displacement.

Brattström [2] in 1968 demonstrated the high correlation between recurrent dislocation of the patella and a shallow trochlea. The lack of a sufficient trochlear contribution to stability subjects the PF ligaments to a greater stress than they were designed for and failure is common. Brattstöm also defined the "Q-angle" as reflecting the direction of the quadriceps vector. This normal quadriceps vector pulls laterally. Brattström explained how this quadriceps vector is

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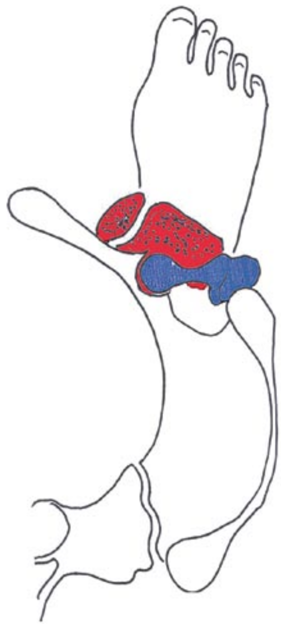

Fig. 30.1 When the femoral anteversion is increased by 30° and the external tibial torsion is increased by 30° and the foot is placed with a foot progression angle of 15°, the knee joint is pointed markedly inward placing the pull of the quadriceps on somewhat of a diagonal

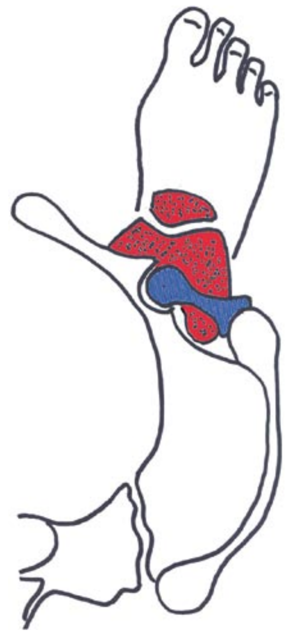

Fig. 30.2 The drawing of the limb in the horizontal plane in the normal male with 13° of femoral anteversion and 21° of external tibial torsion and with the foot progression angle of 15° contrasts greatly with the miserable malalignment depicted in Fig. 30.1. The knee joint is pointed very slightly outward or nearly straight ahead

increased by an inward rotation of the knee joint and would be altered by rotational femoral osteotomy as proposed by prior authors. An increase in the displacing force on the patella which is due to skeletal maltorsion may be sufficient to convert a potentially unstable patella into actual patellar instability. With patellar restraints sufficient to prevent instability these extrinsically generated forces often cause pain.

Insall [7] in 1976 stated chondromalacia is most often due a knee joint which points inward while the hip joint and ankle joint point forward (Figs. 30.1 and 30.2). James [8] in 1979 used the term "Miserable malalignment" to define a skeletal anatomic pattern commonly seen in patients with anterior knee pain. Miserable Malalignment as described by James included "[increased] femoral anteversion, squinting patellae, genu varum, Patella Alta, increased Q angle, [increased] external tibial rotation, tibia varum and compensatory pronation of the feet." He later suggested tibial rotational osteotomy to correct this [16]. Lerat and Moyen [15] noted a $p = <.0001$ correlation between patellar instability and increased femoral anteversion and a $p = <.001$ correlation between femoral anteversion and chondromalacia. Cooke [4] presented a series of seven patients with anterior knee pain and an inward pointing knee treated with internal rotational tibial osteotomy. The condition has most commonly been recognized in children [1, 3, 5, 6]. It is now clear that each of the factors seen by James may act independently or in combination. The relative mechanical importance of each factor has not been measured, but some studies have been undertaken [6, 11–14].

This excess inward pointing of the knee (Fig. 30.3) introduces an excess force pulling on the medial soft tissues and compressing the bone laterally (Fig. 30.4). This may result in pain, in instability or in arthrosis and positive correlations between anterior knee pain, patellar instability, patellar arthrosis/chondromalacia and increased femoral anteversion have been reported [6, 16, 22]. Because anterior knee pain, patellar instability and patellar chondropathy are multifactorial, adequate studies are not available to indicate when to add torsional realignment procedures. I believe limb maltorsion is always a contributing factor, but biomechanical evidence and clinical evidence to suggest what specific angular deformity needs correction does not exist.

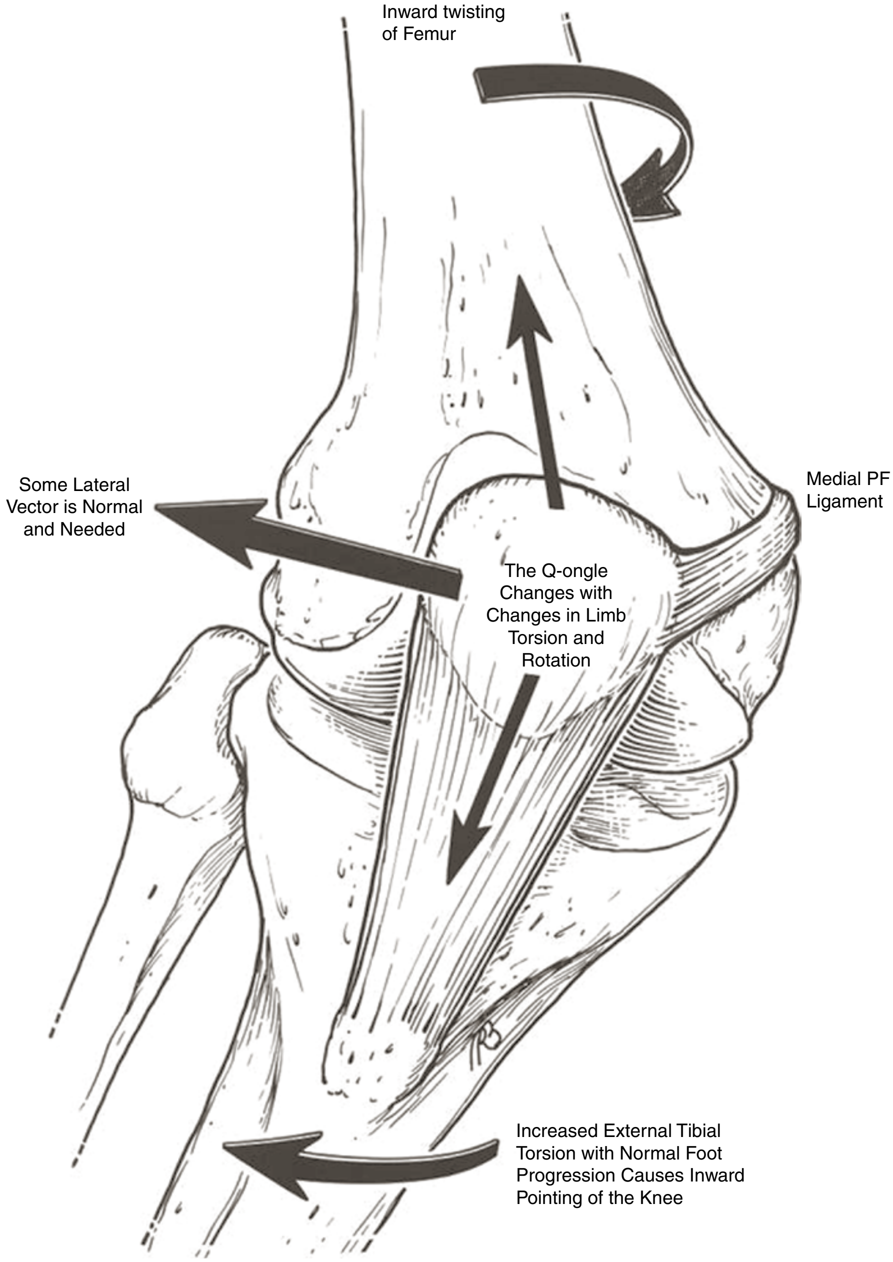

Fig. 30.3 Inward pointing of the knee is most commonly increased when there is increased internal torsion of the femur or when there is excessive external torsion of the tibia. When there is excess femoral anteversion and hip abductor muscle strength is needed the trochanter is moved anteriorly and the knee joint is therefore pointed internally. When there is excess external tibial torsion and the foot is pointed forward the knee joint is pointed inward. As the pull on the quadriceps is lateral, pointing the knee joint more inward increases the magnitude of the lateral pull increasing the pull on the medial structures and increasing the compression on the lateral structures

If osteotomy could be accomplished with absolute precision, and without morbidity then it is this author's opinion that it has a place in every case of PF dysfunction in which it is present. However, absolute precision and complete absence of morbidity does not exist. The absolute mechanical importance of different maltorsions also is unknown. Preliminary mechanical studies indicate a 30° increased femoral anteversion above normal cause a 30% increase in lateral patellar facet pressures and a 14% increase in medial retinacular strain.

Physical exam: Examination in the frontal plane often demonstrates an inward pointing or squinting patella, an apparent varus, and a hyperpronation (pes planus) or hallux valgus (Fig. 30.5). Hip rotation in the prone position (relative hip extension is the hip position during gait) normally has external rotation greater than internal rotation. When hip internal rotation is

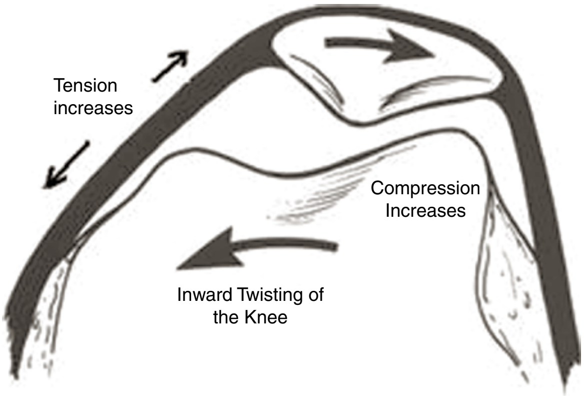

Fig. 30.4 When viewed in the horizontal plane, any increase in the inward twist on the femur increases the medial PF ligament strain and increases the lateral trochlea facet compression

Fig. 30.5 Photograph of a patient with "miserable malalignment" showing the inward pointing knee, squinting patella, apparent varus, pronation of the feet

greater than 50° an abnormal excess of femoral anteversion is generally present.

How do you image: Limb alignment must be considered in all three anatomic planes. In the frontal (coronal) plane a whole limb radiograph is obtained standing on one foot which reflects the single leg stance phase of gait. This film is obtained with the flexion–extension axis in the plane of the film. Unless the patella is subluxed with the knee in extension the patella is should usually be in the center of the distal femur on this film. If the patella is centered in the trochlear on the

Fig. 30.6 In the patient with marked increase in external tibial torsion, a standing radiograph with the patella pointing forward shows the os calcis medial to the ankle joint, an oblique view of the talus and a near lateral view of the foot

film and if there is increased femoral anteversion the lesser trochanter may be excessively prominent or the femoral neck may appear in valgus and if there is an excess of external tibial torsion the os calcis may be seen medial to the ankle joint and with the foot pointing lateral (Fig. 30.6). These findings are a clue to the presence of a torsional deformity, but are not useful to measure the torsion. Radiographs of the entire limb in the *sagittal* plane are not possible due to the interposition of the pelvis so only that true lateral images from the mid thigh to the foot can be obtained. These are useful to measure recurvatum or flexion contracture.

Torsional deformities in the limb are measured with CT scan [9, 10, 19–21, 23]. Femoral torsion is measured as the angle between a line connecting the center of the femoral head and the center of the femoral neck where it meets the femoral shaft and a second line representing the flexion–extension axis of the knee joint (Fig. 30.7). As this distal line is often difficult to locate it is most common to use a line tangent to the posterior aspect of the femoral condyles. This technique has been validated by Murphy [17]. Yoshioka's measurement of femora yielded an average of 13° anteversion when the tangent to the posterior femoral condyles was used [24–26].

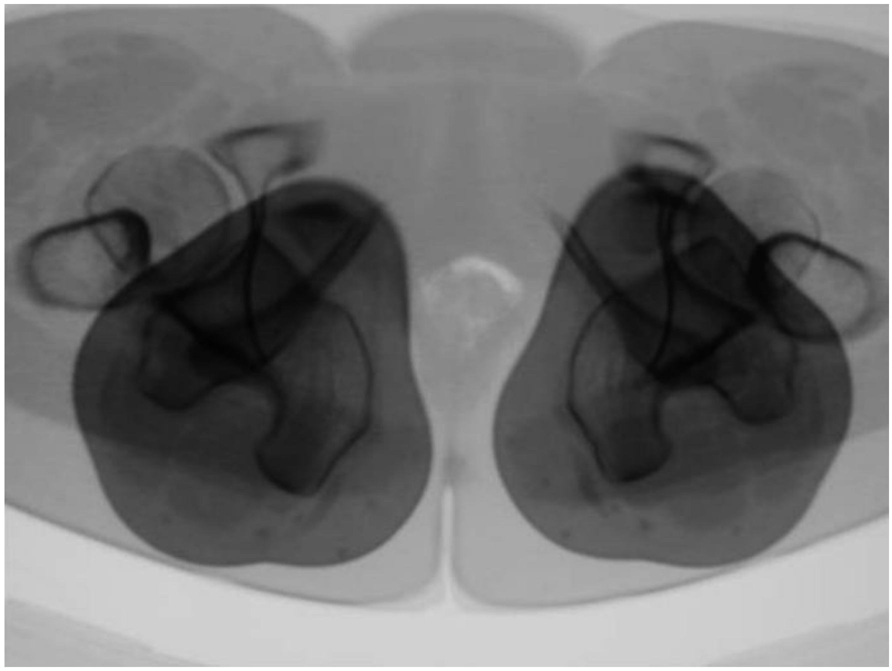

Fig. 30.7 CT of the hips and knees superimposed so the lines may be drawn to measure femoral anteversion. Here the femoral anteversion is 63°

The functional angle of tibial torsion is the angle between the flexion–extension axis of the knee joint and the ankle joint axis. The tibial torsion angle is measured by that line across the top of the tibia which would represent the knee joint flexion–extension axis and a second line representing the ankle joint axis (Fig. 30.8). The location of a line drawn on a CT cut across the proximal tibia may be difficult to reproduce so if the tibial is not rotated abnormally on the femur one can use the epicondylar axis of the femur or even the posterior condyles of the femur as a reference. The epicondylar axis averages 6° more internal than the posterior condyles reference. The line representing the ankle joint axis is a line between the center of the malleoli taken from a CT cut at the level of the top of the talus.

Surgical details: Since torsion is that angle measured between the joints, a change in torsion of the femur may be made anywhere between the hip joint and the knee joint. It is easy to place an intramedullary rod down the femoral canal, but after rotating the distal fragment the normal anterior bow of the femoral shaft is converted in to an S shape so splitting the distal fragment with nail insertion is common. I prefer using an angled blade plate as the insertion of a blade into the proximal fragment gives on excellent control and the distal fragment is more easily aligned to the plate (Fig. 30.9). There is no evidence that proximal, midshaft or distal location of the osteotomy is preferable. I

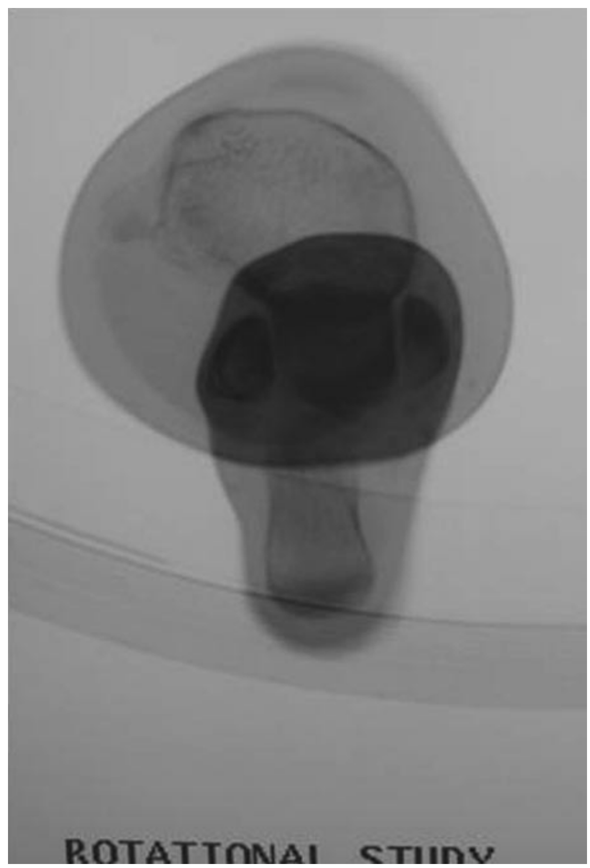

Fig. 30.8 CT of the proximal tibia and distal tibia superimposed so the lines may be drawn to measure tibial torsion. Here the tibial torsion is 31°

Fig. 30.9 The 95° condylar blade plate is a reliable implant for fixation of the osteotomy seen at the level of the lesser trochanter

have most often performed femoral rotational osteotomy at the intertrochanteric level so as to avoid any scarring to the quadriceps muscle in the region of the knee. The femur at this level is more cylindrical so control of varus-valgus and flexion–extension is easier than when dealing with the distal flare of the femur. However if there is a varus or valgus deformity creating an abnormal tibial-femoral angle, then the correction must be made near the knee joint usually in the supracondylar region. This is commonly the case with dysplasia of the lateral femoral condyle.

The situation is similar in the tibia. It matters little whether a rotational correction for maltorsion is performed in the proximal, mid or distal tibia except that it should be performed below the level of the tibial tubercle if one is to maintain the normal TT-TG. The surgeon may select any internal (or external) fixation device which allows maintenance of correction. I prefer angle blade plates except for the difficulty of inserting a seating chisel in the proximal fragment such that the distal fragment will align flush with the plate. Locking plates may seem easier to apply but control of the fragments in three planes while applying the plate and then loading the plate in tension can be quite difficult. Healing seems much more rapid with a blade plate than with a locking plate. It matters little whether the plate is placed medial or lateral, except that when tension is applied to a plate to place compression between the fragments it is normal for the tension introduced into the plate to pull the fragment to the tensioned side, valgus if the plate is lateral and varus if the plate is medial. Plating of the tibial distally as is common in children can be used in the adult as well, with the will know problem of a distal tibial plate not fitting between the tibia and fibula and the prominent plate when placed subcutaneously medially. If an intramedullary nail is selected, one must insure that it is well centered on the tibial axis and the canal reamed in a straight line so the tibia is not shifted into varus or valgus by a curved intramedullary canal during nail insertion.

Post-op rehab: Aftercare *Is* essentially that of any well fixed fracture. With osteotomy I drain the wounds, begin continuous passive motion and foot compression pumps in the recovery room, use no external immobilization, encourage full range of knee motion. I recommend crutches with approximately 20 kg weight bearing, At times if the patient is anxious I will allow a knee immobilizer temporarily for comfort or confidence to encourage ambulation. Usually weight bearing can be increased by 4 weeks so full wt bearing can be achieved 6 weeks. Resistive exercises are delayed until the bone shows evidence of healing.

Results: Paul Ruesch, M.D. in 1995 reviewed a series of 35 femoral external rotational osteotomies (Fig. 30.10) performed for anterior knee pain and/or instability in 31 patients at an average follow-up time of 5.3 years [18]. Only three patients had not had prior surgery. Two PF rating scores were used. The average Schwartz score was 24.6 of 29 with 15 of 35 excellent, 6 good, 5 fair and 9 poor. The average Shea and Fulkerson score was 82.5 or 100 with 20 excellent, 6 good, 1 fair, and 8 poor. The poor mostly reflected pre existing arthrosis. Subjectively, however, 77% of patients indicated a decrease in the amount of pain, 86% indicated less giving way, 80% reported improvement in quality of life and 42% indicated a reduction in retropatellar crepitation. Of the

Fig. 30.10 A patient is seen post-op after the left hip osteotomy depicted in Fig. 30.8. Of note is the squinting of the right patella, the apparent varus of the right lower extremity, the apparent outward pointing of the right foot due to increased foot pronation associated with inward pointing of the lower extremity

3 patients without prior surgery Shea and Fulkerson score was 100 of 100 and the Schwartz score was 28.7 of 29.

Michael Latteier, M.D. followed up seventy two intertrochanteric external rotational osteotomies in 53 patients presenting with patellofemoral dysfunction. The average time of follow-up was 9.7 years with a range of 2–17 years. At follow-up Kujala scores had improved from 53 to 86, Lysholm scores had improved from 49 to 89 and Tegner activity scores had improved from 2.2 to 4.0.

Our 20 years experience with tibial rotational osteotomy for anterior knee pain suggests equal results as the femoral osteotomy. Meister and James [16] and Cooke [4] have reported similar results.

30.3 Conclusions

1. Miserable Malalignment as described by James exists and must be recognized in the patient with PF pain, instability or arthrosis. Not all components are usually present and the abnormal femoral and tibial torsion are usually primary.
2. Abnormal femoral or abnormal tibial torsion which contribute to the miserable malalignment syndrome needs to be recognized and can be treated by osteotomy which restores the normal femoral or tibial anatomy.
3. The clinical assessment of torsional malalignment may be difficult and validated CT rotational studies are indicated when the condition is present and when surgical treatment is to be under taken.
4. When PF symptoms or intrinsic PF pathology is the result of skeletal maltorsion, rotational osteotomy may be the only appropriate surgical treatment.
5. Surgical morbidity must not be underestimated.

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31 Long-Term Results After Autologous Chondrocyte Implantation in Cartilage Lesions of the Patellofemoral Joint

Lars Peterson and Haris S. Vasiliadis

31.1 Introduction

Patellofemoral pain syndrome (anterior knee pain) is very common in the general population. It is more often anticipated in teenage girls and young women and generally in young people who are very physically active in competitive and recreational sports. However it is also very often met in young people sustaining sedentary work (white collars or students). The cause of the pain is very often related to patella malalignment and instability with or without articular cartilage lesions in the patellofemoral joint. Articular cartilage injuries are very common in this patient group. Hielle et al. found from patients who underwent an arthroscopy that 17% of them had an articular cartilage injury located in the patella or trochlea [11]. Nomura et al. also assessed 37 patients with a first time acute patellar dislocation, finding severe articular cartilage injuries of the patella in 35 of them [19].

Trauma with direct contusion of the patella is very common in many contact sports such as football, handball, ice-hockey, etc. Repetitive microtrauma with repeated loading/overloading is another common mechanism for cartilage erosions. Stress concentration between the articular surfaces results in progressive wear of the cartilage, subsequently causing kissing lesions.

Patellar malalignment and instability is a very common cause and very often acts as an undiagnosed background factor for articular cartilage lesions in the patella and trochlea [9]. The factors that may cause patellofemoral instability or contribute to it, can be divided into three groups; skeletal, ligamentous and muscular factors (Fig. 31.5).

Skeletal, factors include trochlear dysplasia, genu valgum, lateralized tibial tuberosity with increased Q-angle and Patella Alta. Beside of the knee structures, other factors can also contribute including an increased femoral neck anteversion, excessive tibial torsion, tibia vara and also flat foot [23].

Ligamentous factors include partial or total ruptures of the patella or knee joint stabilizers, ligament insufficiency after ruptures or secondary lengthening [2].

Muscular factors include muscle imbalance especially between VMO and VL. VMO-weakness or retarded VMO activation during the knee flexion have been accused. Besides, the pain inhibition will cause a prolonged reaction time of the VMO reducing the speed and strength of muscular function. That will also contribute to patellofemoral instability.

Main symptoms and signs of patellar instability are given in Tables 31.1 and 31.2. Background factors potentially contributing to patellar malalignment or instability and radiological and other investigation needed are shown briefly in Tables 31.3 and 31.4.

It is generally believed that treatment of the cartilage lesions of the patellofemoral joint should be accompanied by the assessment of any potential malalignment or instability of the patella focusing on the correction of the background factors. The correction of those abnormalities is considered to be necessary for the cartilage treatment to be effective and durable [8].

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Table 31.1 Symptoms of patellar instability

Symptoms
Anterior knee pain around or behind the patella
– During or after activities
– During sitting with bent knee
– Walking up and downstairs
– Running up and downhills
Catching, locking, or crepitations
Swelling, effusion
Stiffness
Give way

Table 31.2 Signs of patellar instability

Signs
Peripatellar tenderness
Effusion, crepitation on flexion-extension against resistance (painful or not)
Positive apprehension test
Signs from background factors.

Table 31.3 Background factors contributing to the patellar instability

Background factors
Patella Alta
Lateral patellar tracking
Patellar tilt
Lateral patellar subluxation
Patellar dislocation
Patellofemoral dysplasia focused on trochlear dysplasia
Increased Q-angle (over 15°–20°)

31.2 Autologous Chondrocyte Implantation: Surgical Procedure and Rehabilitation

Autologous chondrocyte implantation (ACI) is a two step procedure indicated for symptomatic chondral lesions in the patellofemoral joint. The first step consists of the arthroscopic evaluation of the intra-articular pathology, confirmation of the cartilage lesion and set of the indications for ACI. Biopsies are then retrieved from minor weight bearing surfaces for cell culture.

Table 31.4 Further investigation for identifying the background factors that potentially contribute to the instability of the patella

Further investigations
Long standing x-rays
Sky-views
CT including knee in extension with and without quadriceps contraction and contrast enhancement
MRI with and without contrast enhancement
Dynamic MRI
Arthroscopy (definite decision for surgery)

31.2.1 Arthroscopy and Biopsy (1st Step of Procedure)

Evaluation of intra-articular pathology especially cartilage lesions. Assess the defect size, depth, location and containment as well as assessment of the opposing surfaces (potential diagnosis of kissing lesions). Planning for the open procedure is undertaken, including access to the lesions and potential need for correcting background factors f. ex. reconstruction of the extensor mechanism. Cartilage biopsies are taken from minor weight bearing areas, usually from the upper medial trochlea, upper lateral trochlea or from the lateral intercondylar notch. Our experience of approximately 1,600 biopsies (about 98% taken from the upper medial trochlea) shows no donor site morbidity.

At the end of the arthroscopy any meniscus pathology should be corrected if needed.

31.2.2 In Vitro Culture of Chondrocytes

The harvested cartilage pieces are transferred from the operation theater to the cell-culture laboratory, placed in a sterile glass tube containing 0.9% NaCl. Cell isolation procedure is initiated upon the arrival. The cartilage pieces are minced and washed twice in medium supplemented with antibiotics (gentamicin sulfate, amphotericin B, L-ascorbic acid and glutamine). The minced cartilage is digested overnight (for 16–20 h) in a collagenase solution. The isolated cells are then washed and then resuspended in flasks containing culture media with the addition of 10% of the patient's own serum and antibiotics. The suspension is incubated in 7% CO_2 in air at 37°C. After 1 week, the multiplied cells are trypsinized and resuspended to more flasks. Finally, after about 2 weeks from the cartilage biopsy, the cultured cells are ready for the implantation. Then, they can be trypsinized, isolated and suspended in 0.3–0.4 mL of implantation medium, in a tuberculin syringe, in which they are transferred to the operation theater for the implantation. Another option is to be cryopreserved for future use, being on demand of the surgeon.

31.2.3 Chondrocyte Implantation (2nd Step of Procedure)

Use a short medial or lateral skin incision which should be adapted to the specific location of the cartilage defect, followed by a mini medial or lateral arthrotomy allowing tilting of the patella about 90° to be able to perform the surgery adequately. Specifically in case of patellofemoral joint realignment procedures for cartilage lesions, a central skin incision is recommended allowing either medial or lateral parapatellar arthrotomy. When necessary adapt the incision accordingly to allow optimal access.

Now proceed to the ACI (Fig. 31.1). Incise around the lesion and include all damaged cartilage. Gently debride the damaged cartilage down to the subchondral bone without causing any bleeding. Make a template of the defect and go to the proximal medial tibia for harvesting the periosteal flap. Make a skin incision in proximal medial tibia distal to the pes anserinus insertion, dissecting down to the bone and remove all fat fibers and vessels covering the periosteum. Gently remove remaining fibers and the thin fascia covering the area and also remove the thin fat layer directly overlying the periosteum making the harvested flap as thin as possible. Place the template on the periosteum and oversize the flap by 1–2 mm when incising the periosteum. Gently dissect the flap free from the cortical bone. Return to the knee joint and suture the flap to the vertical edges of the defect by anchoring it with sutures in four corners. Be sure that the cambium layer is facing the bone of the defect. Then complete the suturing using 6-0 reabsorbable sutures with a 4–6 mm interval between them and trying to grasp 5–6 mm into the normal cartilage (Figs. 31.1, 31.2, and 31.3). Leave a small area on the top of the defect (making a hole small enough to be closed with one suture). Seal the intervals between the sutures with fibrin glue in order to make it watertight and then insert a plastic driver of a 20 gauge syringe through that hole. Test for leakage by gently injecting saline into the defect through the plastic syringe driver. When water sealing is achieved, aspirate the saline and inject the chondrocytes into the defect starting from distally and slowly withdrawing the syringe (Figs. 31.1 and 31.4). Close the injection site with a suture and some fibrin glue (Fig. 31.1).

31.2.4 Postoperative Treatment-Rehabilitation

In case of realignment procedures, use a brace allowing 0°–90° of motion for the first 3 weeks and then open the brace to 0°–120° for another 3 weeks. In case of isolated cartilage lesions, the use of a brace is not necessary. Antibiotics and thrombosis prophylaxis should be administered postoperatively, according to your routines. Use continuous passive motion machine (CPM), 0°–30°–40° to start with, after 8 h, for 48 h. Start quadriceps training and active range of motion training the first postoperative day. Mobilize the patient allowing full weight bearing as tolerated by pain. However, partial weight bearing should be advised when going up and downstairs. Use crutches for support and safety for 3–6 weeks. Try to reach 60°–90° flexion after 3 weeks and 100°–120° at 6 weeks. In case of bracing, the brace is gradually removed after 6 weeks.

Physiotherapy is focused on full extension and full flexion. Isometric quadriceps training and closed chain strength training should be performed up to 4–6 months.

Functional training includes walking for increasing distances, bicycling with low resistance when at least 90° of flexion is reached on a stationary bike. Later on, outdoor biking with increasing distances is allowed. Swimming is also allowed when the wound is healed using freestyle leg work.

Return to sports is assessed on individual basis.

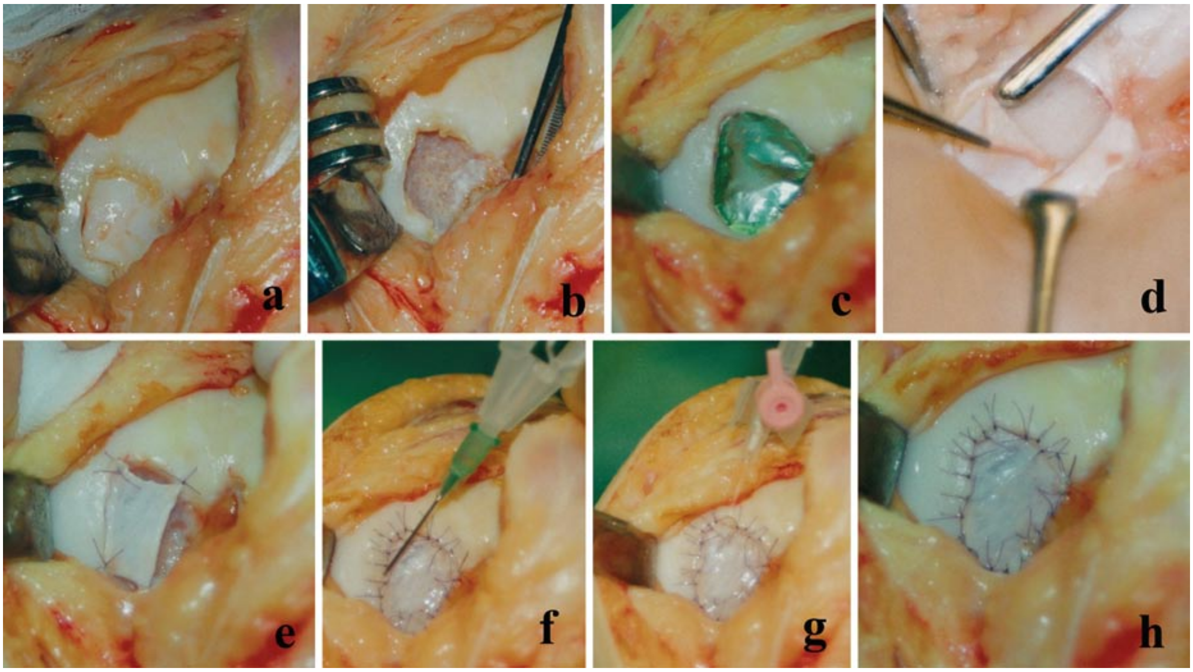

Fig. 31.1 Autologous Chondrocyte Implantation. Stages of the procedure: (**a**) cartilage lesion as first seen after an open arthrotomy; (**b**) the lesion area after debridement of the defect tissue; (**c**) a piece of foil is used to make a template of the debrided lesion area; (**d**) retreaval of a periosteal patch from the proximal tibia. Orientation of the patch is performed with the use of the template. (**e**) Suturing of the patch on the defect area; (**f**) use of fibrin glue to water seal the area; (**g**) after water sealing injection of the suspension of chondrocytes beneath the periosteal patch; (**h**) the treated defect area before closure of the incision

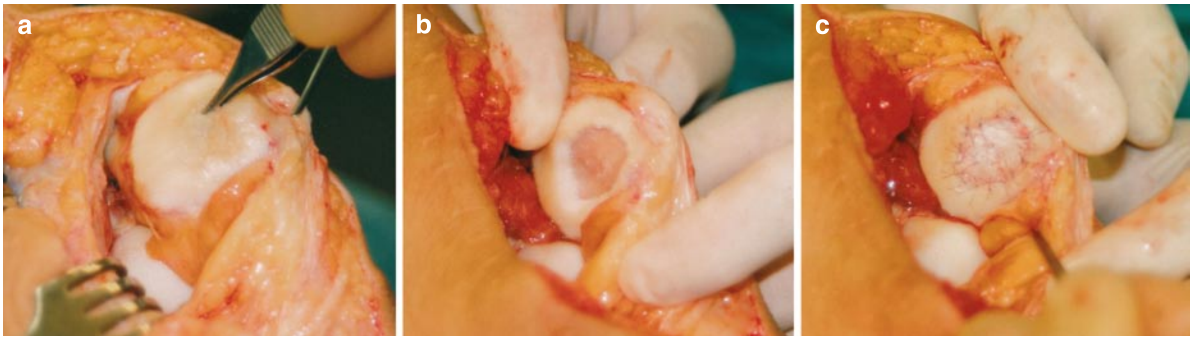

Fig. 31.2 (**a**) Large cartilage lesion of the patella. The defect is covered by necrotic cartilage tissue. It is fragile thus the subchondral bone is easily reached with a forceps, (**b**) the patellar lesion after the debridement and removal of the necrotic non-functional tissue, (**c**) the same lesion after the chondrocyte implantation

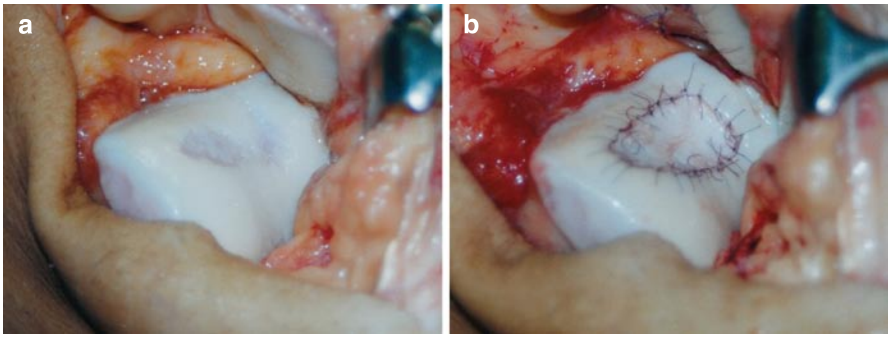

Fig. 31.3 Trochlea lesion before debridement and after the autologous chondrocyte implantation (ACI) and suturing of the periosteum

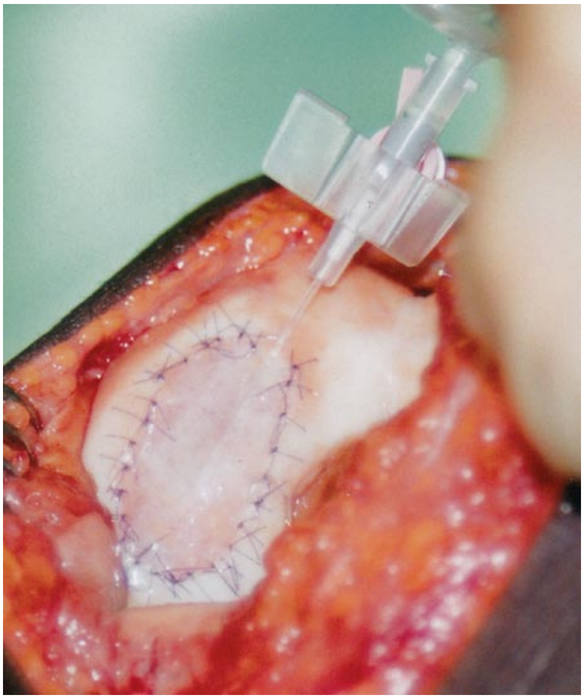

Fig. 31.4 After the suturing and waterproof sealing of the periosteal patch on the surrounding cartilage, the suspension of chondrocytes is inserted beneath the patch, through a small open area at the top of the graft

31.3 Long-Term Follow-Up of ACI Patients

31.3.1 Material

Since 1987 ACI has been performed in Gothenburg, Sweden in more than 1,600 patients. Out of the first 442 patients operated with ACI, 244 included patellar or trochlear lesions; 153 (35%) had patella lesions, while 78 of them (18%) had isolated patella lesions. Trochlea lesions were found in 91 patients (21%), while in 18 of them (4.1%) it was the only cartilage defect. Out of them, 42 patients (9.5%) had kissing lesions of patellofemoral joint; in 28 of them other concomitant lesions of femoral condyles or tibia plateau were also found.

A 10–20 years follow-up study has been performed recently, aiming to show the long-term results of ACI. All patients who accepted to participate in the study were filling in questionnaires including Brittberg, Lysholm, Modified Cincinnati (Noyes), KOOS and Tegner-Wallgren activity score. In this presentation we present Lysholm and Tegner-Wallgren scores.

Two hundred and twenty-four patients who returned the questionnaires participated. Of the total number of patients, 80 were women and 144 were men. The average age was 33.3 years (range 15–61.6, SD 9.5) at the time of surgery while being 46.1 (range 25.8–74.2, SD 9.5) at the time of follow-up. The evaluation has been performed 10–20 years after the implantation (average 12.8 years).

31.3.2 Results

From 224 patients with a follow-up of 10–20 years:

(i) We had in total, 73 patients with *patella lesions* (average 5.1 cm^2, range 1–12, SD 2.61). They had 1.7 lesions in average (from 1 to 4). Fifty-one (69.9%) responded that they were improved or the same compared to the previous years and 68 (93.2%) would do the operation again. Lysholm score in latest follow-up was 67.3 (range 17–100), and Tegner-Wallgren was 7.9 (3–14).

(ii) Fifty-five of those patients sustained a *patellar lesion without concomitant trochlea lesions*. Eleven had also a medial femoral lesion and four had a lateral femoral lesion. Two patients had two patellar lesions. 43 (78.2%) responded that they were better or the same compared to previous years, while 51 (92.73%) would do the ACI again. Lysholm score in 10–20 years follow-up, was 69.5 (range 17–100), while Tegner-Wallgren was 8.2 (3–14).

(iii) Thirty-nine patients (out of the 73) had an *isolated patellar lesion* (average 6.1 cm^2, range 1–12, SD 2.7). 31 (79.5%) responded that they were improved or the same compared to the previous years while 35 (89.7%) would do the operation again. Lysholm score was 66.4 (range 17–100), while Tegner-Wallgren was 7.9 (3–14).

(iv) Thirty-seven patients had *trochlea lesions* (average 6.53 cm^2, range 1.2–20, SD 4.75). They had 2.3 lesions in average (from 1 to 4). 23 (62.2%)

responded that they were improved or the same compared to the previous years while 34 (92%) would do the operation again. Lysholm score was 66.1 (range 17–100), while Tegner-Wallgren was 7.9 (3–14).

(v) Nineteen of those patients sustained *trochlea lesions without concomitant patella lesions*. Ten had also a medial femoral lesion and five had a lateral femoral lesion. One patient had two medial femoral lesions and one had a double trochlear lesion. Fifteen (79%) responded that they were better of the same compared to previous years, while 17 (90%) would do the ACI again. Lysholm score in 10–20 years follow-up, was 71.3 (range 43–100), while Tegner-Wallgren was 8.7 (5–14).

(vi) Eight patients (out of the 37) had an *isolated trochlea lesion* (average 7.38 cm^2, range 2.8–15.8, SD 4.96).

Eight (100%) responded that they were improved or the same compared to the previous years while all of them (100%) would do the operation again. Lysholm score was 72.3 (range 50–91), while Tegner-Wallgren was 8.9 (6–14).

(vii) Eighteen patients had *kissing lesions in the patellofemoral joint* (patella lesion; average 3.7 cm^2, range 1–7.5, SD 1.9 and trochlea lesion; 6.77 cm^2, range 1.3–20, SD 5). Eleven of those had also other lesions except from the trochlea and patella. Eight (44.4%) responded that they were improved or the same compared to the previous years while 17 (94.4%) would do the operation again. Lysholm score was 60.9 (range 17–100), while Tegner-Wallgren was 7.2 (3–10).

(viii) In total, 92 patients had *either a patella or trochlea lesion* (39 isolated patella, 8 isolated trochlea, 18 kissing). The mean age at the time of the ACI was 34.6 years (range 14–57) and the follow-up was 12.6 years after the surgery (range 10–20). The mean size per lesion was 5.5 cm^2 (range 1–16), with a mean ratio of 1.7 lesions per patient.

Tegner-Wallgren score was 7.1, improved by 1 compared to the preoperative values (Wilcoxon signed-rank test $p = 0.01$). The mean Lysholm score was 68.1. The statistical analysis showed an improvement of nine points in average from the preoperative values. However, this improvement was not found to be statistically significant (Wilcoxon signed-rank test $p = 0.3$). Seventy-two percent of the patients reported that they were better or unchanged while 93% would do the operation again.

Thirty-eight of those 92 patients had also a type of realignment surgery. Twenty-two have had an extensor mechanism reconstruction and trochleoplasty (one had it 7 years before the ACI). Nine had only an extensor mechanism reconstruction (one of those had it 6 years after the ACI), one had medial plication and trochleoplasty, and one lateral release and trochleoplasty. Five had a tibia osteotomy for varus or valgus deformity (one of those had it 4 years after the ACI). Twenty-seven of the 38 patients (71%) responded that they were improved or the same compared to previous years while 35 (92.1%) would do the operation again. Lysholm score was 66.3 (range 17–100), while Tegner-Wallgren was 8.1 (range 3–14). Patients with no realignment procedures had a final Lysholm of 69.3 and Tegner-Wallgren of 8.05. Patients with malalignment or instability, that had a realignment procedure of any form, had comparable outcomes to the cases which did not need any additional surgery ($p = 0.5$ for Lysholm and $p = 0.9$ for Tegner-Wallgren).

Patients with no kissing lesions appeared to have a better prognosis. Seventy-eight percent reported to be better or the same compared to previous years and mean Tegner-Wallgren score was 8.3. On the other hand, 44% of the patients with kissing patellar and trochlear lesions appeared to the better or the same, with a mean Tegner-Wallgren of 7.2 ($p = 0.004$ and $p = 0.04$, respectively). However, 94% of the patients with kissing lesions would do the ACI again, similar to the patients with no kissing lesions (92%).

31.3.3 Complications

In 92 patients there were no general complications, no deep or superficial infections or deep venous thrombosis. Focal complications occurred in 52 patients (56%) most of them being minor.

Five of the patients sustained a failure (5.4%), three of them due to the trochlea or patellar lesion (3.2%). One of them had a revision of ACI on the trochlea, one had a revision of patella lesion with carbon fibers by another surgeon, and one patient had finally a

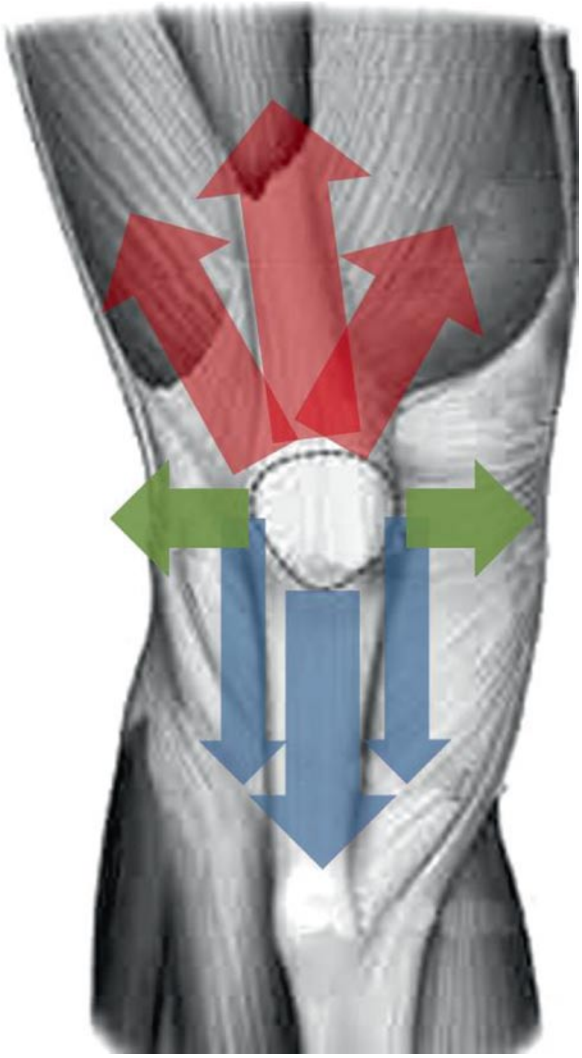

Fig. 31.5 Active and passive stabilizers of the patella. The *red arrows* show active muscle stabilizers, VMO, rectus femoris and VL. The *green arrows* show passive stabilizers, medial patellofemoral ligament (medial transverse retinaculum), lateral patellofemoral ligament (lateral transverse retinaculum). The *blue arrows* show passive and active stabilizers, patellar ligament, longitudinal medial and lateral retinacula

patellectomy. Two of the cases had a revision ACI on the medial femoral condyle (Fig. 31.5).

After having excluded 18 screw extractions which were expected operations the number of complications was as follow. Twenty-seven patients (29%) sustained a periosteal hypertrophy. Most of them were focal or overlapping hypertrophy or fibrillation or flaps from the periosteum (Fig. 31.6). About half of them were symptomatic. Nine had kissing patellofemoral lesions, and seven had concomitant procedures (three including trochleoplasty, one osteotomy, one posterolateral corner reconstruction). In all the cases, it was treated with debridement of the hypertrophic tissue.

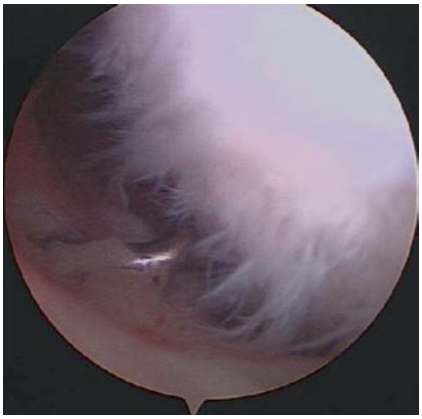

Fig. 31.6 Fibrillation of articular surface

Seven cases (five with patellar and two with kissing patellofemoral lesions) had an arthrofibrosis requiring arthroscopic mobilization shortly postoperatively. Four had also a realignment procedure, including trochleoplasty and two had an ACL reconstruction during the ACI. One case finally led to a patellectomy. Excluding that patient, which was considered as failure, no clinical impact was noticed on the long-term follow-up evaluation. Most of the arthrofibrosis complications occurred early in the study. Any restriction in extension-flexion was later on carefully watched and when present, active physiotherapy treatment was applied, which reduced the final incidence.

Three patients sustained a partial delamination, two of which referring only to the periosteal flap and were managed by arthroscopic resection. One partial graft delamination was found on a concomitant lesion of a medial femoral condyle; the trochlea and patellar lesions of that patient were found intact. Two of the three cases had kissing lesions. There was a slight clinical impact for the two partial delamination patients, but not statistically significant ($p > 0.05$). There were no cases with graft delamination on the patella or trochlea.

Two patients sustained a persistent bone marrow edema. Both of them were located on the medial femoral condyle and the patients had a tibial osteotomy during the ACI. One patient had four lesions (two on the medial femoral condyle, one on the lateral condyle and one on the trochlea) and the other one had a large lesion of medial femoral condyle and patella. No bone marrow oedema was seen in the subchondral bone of the patella or trochlea.

Realignment procedures were associated with a decreased incidence of periosteal hypertrophy (16% in those with realignment procedures, 39% in cases without realignment procedures, $p = 0.01$). On the other hand realignment procedures increased the incidence of serious complications (failures, arthrofibrosis, delamination, multiple surgeries). Thirteen percent of cases without realignment procedures and 29% from those with realignment procedures sustained one of those complications ($p = 0.05$). Although periosteal hypertrophy was the most common complication, no impact was found on the final clinical outcome (Tegner-Wallgren $p = 0.4$, Lysholm $p = 0.1$, operated again $p = 0.3$, improvement $p = 0.9$).

No association was found between the age at the time of the ACI or the size per lesion and any of the clinical outcomes.

31.3.4 Discussion

Articular cartilage injuries and anterior knee pain are difficult problems to adequately diagnose and treat. Especially in the young and middle aged patients it is important to analyze the history, clinical signs and background factors of the condition. To treat articular cartilage lesions in the patellofemoral joint is the most challenging task for the treating physician. The complexity of the mechanical function and the extraordinary loading acting over the joint creating compression and shearing forces has resulted in an increased thickness with impact resistance that is unique in human joints. These factors put specific demands on the treatment for a successful outcome.

Arthroscopy, MRI and computerized tomography with and without quadriceps contraction have helped a lot to understand the mechanisms and anatomic abnormalities, giving information needed for an optimal treatment [5]. Articular cartilage lesions are much more common than earlier recognized and if remained undiagnosed and untreated will lead to osteoarthritis over time. Curl et al. found that over 60% of patients who underwent arthroscopy had articular cartilage lesions with the potential to deteriorate by enzymatic degradation and mechanic wear [7]. Hjelle et al. found about 20% cartilage lesions on the patella and the trochlea in over 1,000 arthroscopies [11].

Earlier treatment options of chondral lesions mostly resulted in fibrous tissue coverage of the cartilage defect area. Spongialization, drilling, abrasion or microfracturing of the subchondral bone plate or trabecular bone create a bleeding into the defect area, thus bringing mesenchymal stem cells and fibroblasts and causing vascularization. Finally, the cartilage lesion area is mainly covered by fibrous tissue or fibrocartilage, with inferior functional and mechanical properties compared to normal hyaline cartilage; that tissue fails to withstand the subjected forces during daily activities and sports and is subsequently leading to tissue wear down. Coverage of the defect area by a periosteal or a perichondral autologous flap has also been tried in the past, unfortunately also ending up in fibro cartilage or bone formation [1, 12].

Since 1987, Autologous Chondrocyte Implantation (transplantation) has been used in the treatment of chondral lesions in the knee or other joints [3, 6, 17, 22]. Isolated femoral lesions and osteochondritis dissecans have been followed for 5–11 years after ACI treatment, with Good/Excellent result in about 90% and biopsies showing hyaline cartilage in 80% of the patients.

In the patella the results were initially not satisfactory with only 28% G/E result in 36 months follow-up [4]. Continued treatment with ACI combined with correction of background factors when indicated showed an improvement of the results. Contributing to this was also the modification of the rehabilitation program for trochlea or patellar lesions focusing on early weight bearing and to closed chain excercises during the first 6 months postoperatively. This change of treatment showed improved results in later follow-ups (Figs. 31.7 and 31.8) [8, 16, 21, 22].

Other techniques using microfractures have not been successful for the patellofemoral joint lesions. Microfracture technique seems to provide a short term clinical improvement; however, there is clinical deterioration over time [15]. This is probably due to the inferior quality of the resultant repair tissue, as shown by several studies [14, 18, 24]. In a comparative randomized controlled study between ACI and autologous osteochondral cylinders (mosaicplasty), ACI was found superior, especially in the patellofemoral joint [3].

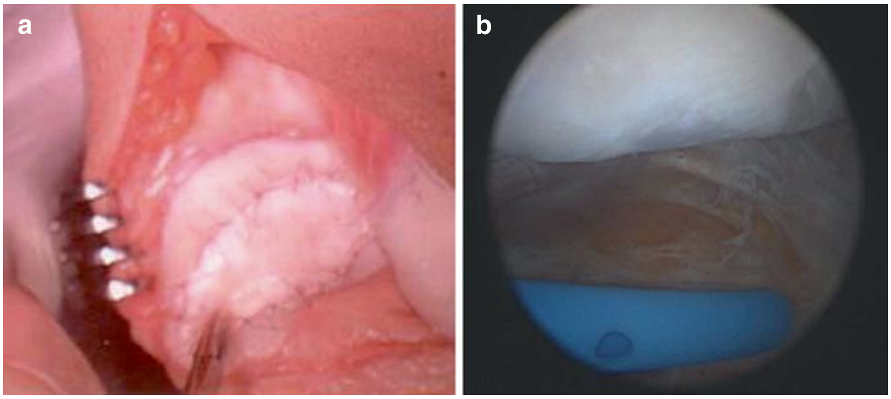

Fig. 31.7 (**a**) Patellar lesion after debridement and implantation, (**b**) second look arthroscopy 5 years after surgery. Patient was asymptomatic

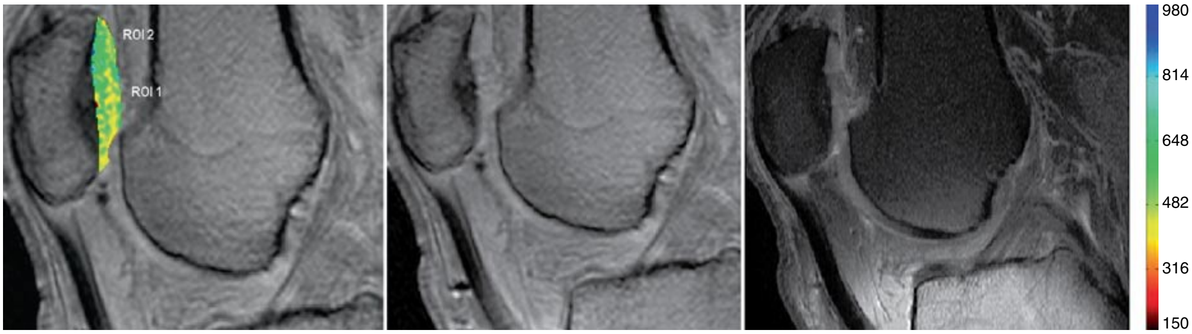

Fig. 31.8 Patella lesion in female, age of 29 at time of implantation. MRI with dGEMRIC technique 10.5 years after the surgery showing restoration of proteoglycan concentration in the defect area

Periosteal hypertrophy is the most common complication to the ACI technique and is treated, when symptomatic, with arthroscopic debridement. It seems that patella and trochlea are more prone to hypertrophy due to the high compression and friction forces during weight bearing activities. Especially in patella-trochlea kissing lesions we see hypertrophy on both articulating surfaces [4, 10]. Our study provides evidence to show that decreasing the applied forces on the patellar or trochlear cartilage lesion, with an unloading procedure, we decrease the incidence of periosteal hypertrophies after an ACI. Meticulous dissection, sizing and suturing of the periosteal patch could also reduce the frequency of this complication [13, 20]. However, despite the high rate of periosteal complications reported it seems that these complications can be handled arthroscopically when symptomatic and would not affect the final result.

From our last follow-up study of 10–20 years' evaluation it seems that correcting the background factors with realignment, stabilizing or unloading procedures is improving the results over time. Even if they may contribute to some complications like arthrofibrosis and periosteal hypertrophy an overall improvement in the result was shown, along with a long-term durability of good results of ACI.

31.3.5 Summary Statement

- Despite the initial controversy about the results and indication for ACI in patellofemoral lesions, it seems that ACI provides a satisfactory result even for the difficult cases with concomitant patellar instability.
- Our study reveals preservation of the good results and of high level of patients' activities, even 10–20 years after the implantation.
- Remarkable improvement of the results from the initial study to this last follow up, shows long-term durability in both isolated trochlea and patella lesions and

also in multiple and kissing lesions where an intervention could be considered as a salvage procedure.
- Over 90% of the treated patients were satisfied with the ACI and would have the procedure again.

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Novel Nano-composite Multilayered Biomaterial for the Treatment of Patellofemoral Cartilage Lesions

32

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32.1 Introduction

The treatment of patellofemoral articular cartilage lesions remains challenging. Aside from their inherent limited capacity to heal and their articular location, the complexity of the patellofemoral joint proves to be refractory to treatment [30], even though recent research has reported different treatments that give satisfactory results [8, 11, 12,21,26].

The pathogenesis of patellar damage is complex and multifactorial, and a single procedure is often not enough to solve the problem. Therefore, the first step of any treatment option must be a complete and deep understanding of the causative factors that must be recognized and addressed to obtain symptoms resolution and healing of cartilage lesions. In fact, all associated abnormalities should be treated before considering cartilage tissue damage. Small articular cartilage changes such as chondromalacia usually depend on unrecognized malalignment syndromes, and patellar realignment without regard for cartilage damage whose treatment may be sufficient to relieve symptoms [16, 17]. Articular cartilage abnormalities may consist of swelling and softening, and deep fissures can often be present and extend through the full thickness of the cartilage. In more severe cases the tissue may have a jelly-like consistency, and in some cases almost the entire articular surface may have degenerated. When the cartilage defect is severe, the treatment of the etiopathogenetic factors may not be sufficient and must be combined with the cartilage damage treatment in order to obtain a satisfactory clinical outcome.

Various therapeutic modalities have been used in clinical practice. Arthroscopic shaving has been proposed as a minimally invasive procedure, easy and not followed by prolonged morbidity. Shaving can be used when the lesion is a circumscribed blister and when there is articular fasciculation. In these disorders, the procedure most likely should be confined to the restoration of gross articular smoothness. Debridement consisting of excision and drilling may have some use in treating osteoarthritis, and improvement can be expected in approximately two thirds of the patients. Moreover, it may also be an alternative to

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shaving in the knees with basal chondromalacia. Cartilage repair, although unpredictable, does sometimes occur, and can be promoted by early motion [31]. These methods can be used for superficial defect, but for a deeper lesion expanding to bone, deep excision through the subchondral bone is carried out with concurrent bevelling of the margin of the defect. However, this method cannot be considered an ideal solution, considering the contradictory results observed in the literature and the worsening at long-term follow-up [3, 9]. In cases of very extensive and deep alterations of the patellar surface, total patellectomy has also been performed [4, 14, 38]. While the symptoms related to the lesion in the chondral surface were abolished, the shortcomings of this procedure are obvious: habitual lateral gliding of the quadriceps tendon and insufficiency of the extension mechanism due to a lack of patellar leverage. Other approaches include the insertion of periostium flaps into the debrided defects and the use of synovial tissue flaps for covering the entire articular surface of the patella [15,29,36].

More recently, other surgical solutions have been proposed aiming to preserve a more physiologic cartilaginous superficial layer. Mosaicplasty consists of the reconstruction of the chondral defect using small, cylindrical autologous osteochondral grafts taken from non-weight-bearing areas of the joint. This technique presents several advantages: a single procedure, low cost, press-fit fixation by compressed grafts, and host bone impaction. However, despite these positive aspects, the clinical experience showed lower results with respect to femoral and tibial grafts; this may be due to the higher concentration of shear stress in this location [13].

Regenerative techniques, such as autologous chondrocyte implantation (ACI), have emerged as a potential therapeutic option. Some studies [6, 34] suggest the durability of this treatment, especially at long-term follow-up, because of its ability to produce hyaline-like cartilage that is mechanically and functionally stable, and the allowance for integration with the adjacent articular surface. This approach, introduced in 1994 by Brittberg and Peterson [5], seems to offer good results, as reported in a previous chapter, even with patellar lesions shown to have a less predictable outcome with lower satisfactory results compared to the treatment of femoral defects [8, 26]. The use of classic ACI has been associated with several limitations related to the complexity and the morbidity of the surgical procedure. This technique requires a large joint exposure and implies a higher risk of joint stiffness and arthrofibrosis; there is a frequent occurrence of periosteal hypertrophy, that occurs between 3 and 7 months after surgery in 10–25% of cases and often requires revision surgery [7, 28]. Some authors have shown a reoperation rate of up to 42%, due to joint stiffness, and have indicated that the use of the periosteal flap increases the risk of complications during the recovery period and produces more difficult rehabilitation [25, 27]. Other problems can be observed with standard ACI methods. These include the difficulty in handling a delicate liquid suspension of chondrocytes at implantation surgery, the need to make a hermetic periosteum seal using sutures, and the concerns related to the maintenance of the condrogenic phenotype in the liquid suspension. The development of the second-generation ACI [19], that used a tissue engineering technology to create a cartilage-like tissue in a three-dimensional culture system, allows one to address most of the concerns related to the cell culture and the surgical technique. Numerous biodegradable polymers such as hyaluronan, collagen, fibrin glue, alginate, agarose, and various synthetic polymers were developed [19] and used as temporary scaffolds for the in vitro growth of living cells and their subsequent transplantation onto the defect site. Promising results have been obtained with this tissue engineering approach and nowadays matrix-assisted autologous chondrocyte transplantation is widely used in Europe [1,23]. The results obtained are still controversial and there is no agreement about the effective superiority of this procedure to others. Moreover, despite the good potential reported, patellar lesions still present lower clinical outcome with respect to other location, and there is a worsening of the results over time even at medium term follow-up [11, 12]. This approach is also plagued by high cost and the need for a two-step surgery. To overcome all these problems, we developed and applied in clinical practice a new bi-composite, multilayer, biomimetic scaffold, which can mimic the osteocartilaginous anatomical structure in all of its components. This scaffold allows for the restoration of the articular surface in a one-step surgery without the need for cells and, thanks to the plasticity of the graft, even big osteochondral lesions can be treated through minor incisions.

32.2 Scaffold

The osteochondral nanostructured biomimetic scaffold (Fin-Ceramica S.p.A., Faenza, Italy) has a porous 3D tri-layer composite structure, mimicking the whole osteochondral anatomy. The cartilaginous layer, consisting of Type I collagen, has a smooth surface to favor the joint flow. The intermediate layer (tide-mark-like) consists of a combination of Type I collagen (60%) and HA (40%), whereas the lower layer consists of a mineralized blend of Type I collagen (30%) and HA (70%) reproducing the subchondral bone layer (Fig. 32.1). Each layer is separately synthesized by a standardized process starting from an atelocollagen aqueous solution (1% w/w) in acetic acid, isolated from equine tendon. The upper non-mineralized chondral layer is of Type I collagen (Opocrin S.p.A., Modena, Italy), the intermediate and the lower layers are obtained by nucleating bone-like nanostructured nonstoichiometric hydroxyapatite into self-assembling collagen fibers, as occurs in the biological neo-ossification process. The final construct is obtained by physically combining the layers on top of a Mylar sheet and finally freeze-dried and gamma-sterilized at 25 KGray.

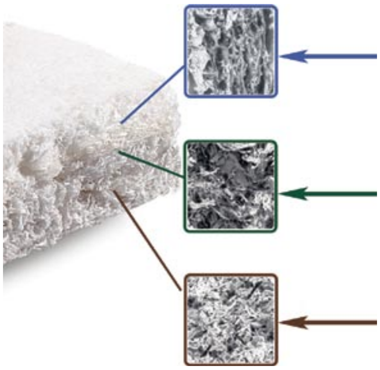

Fig. 32.1 Three-gradient multilayer scaffold that mimics the articular osteochondral compartment, reproducing the cartilage and subchondral bone layer, morphologically, and at a molecular level

32.3 Surgical Procedure and Postoperative Treatment

The surgical procedure was done with the patient under general anesthesia in the supine position. A pneumatic tourniquet was placed on the proximal thigh and, an arthrotomic medial para-patellar approach was used to expose the lesions. Then, the defects were prepared using a specifically designed drill: the sclerotic subchondral bone was removed and 9-mm deep lodgings with a stable shoulder were created to place the implants. The lesions were templated using an aluminum foil, to obtain the exact size of the grafts needed. The templates were then used to prepare the grafts that were implanted through a press-fit technique. The stability of the transplant was tested by cyclic bending of the knee while visualizing the graft before and after the tourniquet removal (Fig. 32.2).

The management of postoperative pain allows early mobilization that contributes to a faster resolution of swelling, to promote defect healing and joint nutrition

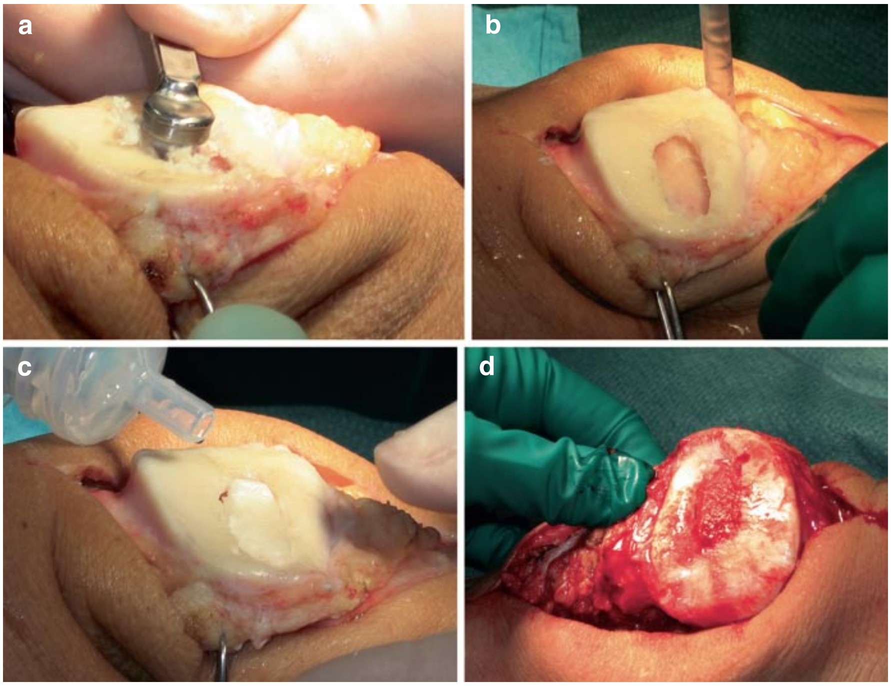

Fig. 32.2 The defect is prepared (**a**, **b**) using a specifically designed drill; the graft is implanted through a press-fit technique and the stability is tested visualizing the graft before and after the tourniquet removal (**c**, **d**)

and to prevent the development of adhesions. On the second postoperative day self-assisted mobilization of the knee or continuous passive motion (CPM) 6 h daily with 1 cycle/min is recommended until 90° of flexion is reached. Early isometric and isotonic exercises and controlled mechanical compression are performed. Muscular voluntary contraction and neuromuscular electrical stimulation (NMES) is indicated and can be started at discharge with the patient. In the third or fourth week toe-touch weight bearing with crutches is allowed and full weight bearing is progressively achieved.

32.4 Clinical Experience

We utilized this procedure for the treatment of full-thickness patellofemoral chondral lesions of the knee. Sixteen patients were consecutively enrolled in a pilot study: they were treated with the implantation of the osteochondral scaffold and the correction of their associated abnormalities, and were evaluated at a 1-year follow-up. The study was approved by the local Ethics Committee.

The treatment was indicated in patients with chondral or osteochondral lesions involving the patellofemoral region together with clinical symptoms of pain, swelling, locking, or giving way. Exclusion criteria were: ages younger than 15 and older than 55, those with untreated patellofemoral (>10° tilt on axial radiographs) or tibiofemoral (=10° angulation on full-length standing AP radiographs) malalignment, diffuse arthritis, or lesions, as well as those with other general medical conditions (diabetes, rheumatoid arthritis, etc.). Consent for participation in this investigation was obtained from all patients. In addition, only those who completed the required postoperative regimen were included.

32.4.1 Patient Data

Sixteen patients, 11 males, and 5 females with a mean age of 37 years (range: 16–51 years), were evaluated at a 1-year follow-up. Nine patients had right knee involvement and seven had left knee involvement. Eleven patients had degenerative origin, three had previous trauma, and two had osteochondritis dissecans. Previous surgeries for 12 patients included debridement and shaving (8), patellar realignment procedures (3), meniscectomy (3), ACL reconstruction (1), bursectomy (1), synovial fold removal (2), and fixation for tibial fracture (1). In 9 patients, associated procedures were performed: patellar realignment procedure (4), tibial osteotomy (2), femoral osteotomy (1), tendon suture (1), and lateral facet remodeling (1).

The 16 knees investigated in this study had chondral lesions with a mean size of 2.75 cm^2 (range, 1–5 cm^2). Twelve patients presented with patellar lesions, while in four patients the trochlea was involved. The 16 patients had a mean Tegner score at preinjury of 5.07 (SD 2.17), whereas preoperatively the sport activity level decreased to 1.63 (SD 1.15). The IKDC objective evaluation showed eight nearly normal knees, five abnormal, and three severely abnormal knees; the subjective evaluation showed a mean value of 41.23 (SD 14.78); and the Kujala presented preoperatively a mean score of 59.63 (SD 18.7).

32.4.2 Results

The evaluation at 1-year follow-up showed a statistically significant improvement in all the questionnaires applied. The IKDC objective score improved from 50% of nearly normal knees at the baseline condition to 93.75% of normal (10) or nearly normal (5) knees at 1 year after the operation. IKDC subjective evaluation and Kujala score showed a significant improvement ($p < 0.05$), achieving a score of 70.07 (SD 16.2) and 83.06 (SD 15.4), respectively (Figs. 32.3 and 32.4). Finally, the mean Tegner score obtained at 1-year follow-up was 4.06 (SD 1.34),

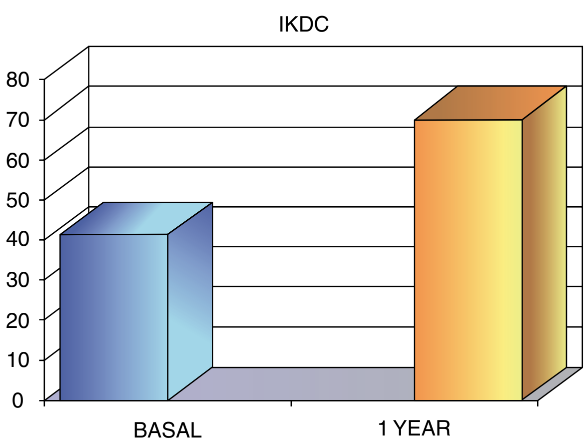

Fig. 32.3 IKDC subjective evaluation

with a significant improvement with respect to the mean preoperative values ($p < 0.05$). However, at 1 year after the operation, patients did not yet achieve their preinjury level ($p < 0.05$) (Figs. 32.5 and 32.6).

Probably due to the low number of patients studied, further evaluation showed no statistically significant correlation with regards to the different variables.

32.5 Discussion

Patellofemoral lesions represent a very troublesome condition to treat in orthopedic practice. Even after the treatment of all the associated abnormalities, the

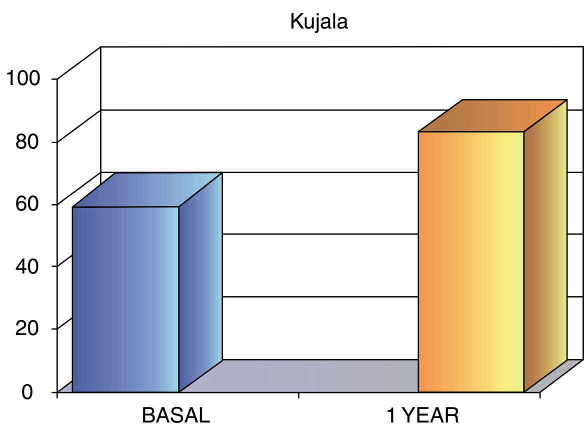

Fig. 32.4 Kujala score evaluation

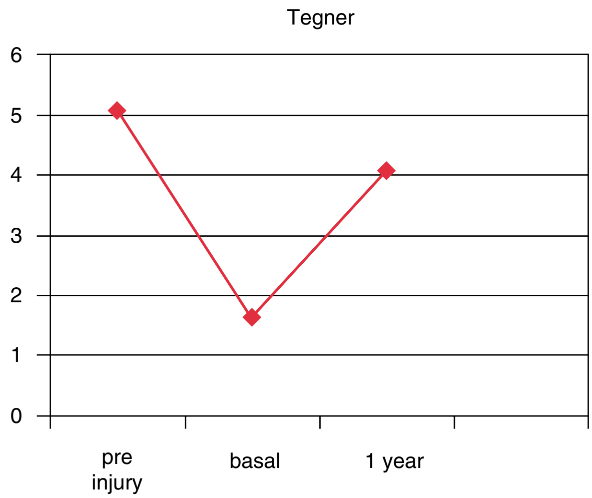

Fig. 32.5 Tegner score evaluation

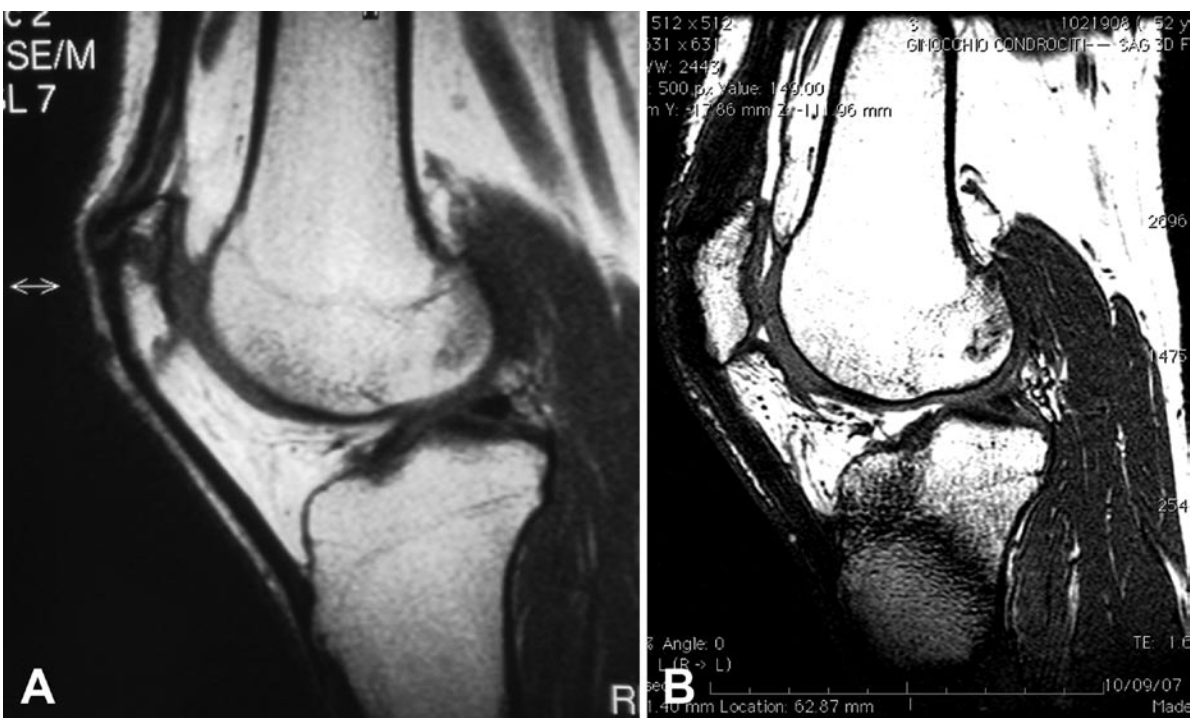

Fig. 32.6 MRI evaluation of a patellar defect before (**a**) and at 8 months after the osteochondral scaffold implantation (**b**)

treatment of the chondral defect remains a major problem for achieving a satisfactory clinical outcome.

Despite the still controversial results, tissue engineering is a promising approach for the regeneration of the articular surface [1,2,23]. Biomaterials may provide the template for tissue development with several potential advantages with respect to other classic techniques. Donor-site morbidity can be totally avoided, and it is possible to easily adjust the construct shape to the appropriate size and orient it according to the defect characteristics. Moreover, 3D tissue engineered grafts can be created by combining the patient's own cells with 3D porous biomaterials.

For osteochondral defect repair or even for deep/large chondral defect, where the subchondral bone is also primarily or secondarily involved in the degenerative process, several authors have highlighted the need for biphasic scaffolds to reproduce the different biological and functional requirements for guiding the growth of the two tissues [18,22,33]. The integration should occur at three levels: repaired cartilage with native cartilage, repaired bone with native bone, and repaired cartilage with repaired bone. To create constructs with more favorable integrative properties, several researchers are exploring the development of composite constructs consisting of either two or even three layers [10,24,32]. Articular cartilage repair should be accompanied by an adequate restoration of the underlying subchondral bony structure, enhancing the effective union with surrounding host tissues [35]. Because the bone-to-bone interface integrates faster than the cartilage-to-cartilage interface, a multilayered osteochondral construct may be the most promising way to firmly anchor a cartilage substitute to natural surrounding tissues. In our opinion, the composite scaffold should consist of three distinct, but adherent integrated layers, corresponding to cartilage, calcified cartilage, and bone components. This structure design, thanks to this ideal composition, aims to achieve fast anchoring to host tissues after implantation on osteochondral full-thickness defects, promoting orderly and durable tissue regeneration.

Following this rationale, we tested a recently developed composite nanostructured collagen-hydroxyapatite scaffold, which mimics the biochemical and biophysical properties of the different layers of native osteochondral structures [39]. This scaffold, loaded with differentiated cells (e.g., articular chondrocytes) or bone marrow stromal cells, has been shown to support cartilage and bone tissue formation selectively in ectopic models [40]. The scaffold was chemically cross-linked to provide stability, thus increasing in situ hydrophilic properties and good handling properties, including flexibility. Its structure is conceived with the aim to confine the bone formation into the deepest portion of the construct without involving any superficial layer where the process of cartilaginous-like connective tissue formation should begin. We previously tested this novel biomaterial in both in vitro and animal studies (horse and sheep model), and obtained good results with cartilage and bone tissue formation [20]. The implant of the gradient biomimetic scaffold led to a reconstruction of both hyaline-like cartilage and structured bone tissue anchored to the interface of adjacent healthy tissues, even with no other bioactive agents added. We observed same macroscopic, histological and radiographic results when implanting scaffold loaded with autologous chondrocytes or scaffold alone. The scaffold demonstrated the ability to induce an in situ regeneration. Most likely this occurred through a process mediated by mesenchymal precursor cells resident in the subchondral bone, recruited within the material and differentiated in osteogenic and chondrogenic lineages [20]. Thus, after a preliminary MRI study, which demonstrated a good stability of the scaffold without any fixation device, we applied this innovative scaffold as a cell-free approach for chondral and osteochondral reconstruction into clinical practice. In particular, we treated and prospectively evaluated 16 patients affected by patellofemoral lesions. We observed a statistically significant improvement in all scores evaluated at 1-year follow-up. As cartilage maturation takes a long time, and many activities were restricted by the surgeon in the first year after the surgical treatment, a further clinical improvement is expected with a longer follow-up. However, the scores obtained already documented a marked improvement with respect to the preoperative level, showing good results and an interesting potential of this osteochondral scaffold.

The implant of biomaterials for in situ cartilage and bone regeneration represent an innovative promising approach for the restoration of the articular surface. Many biomaterials have been tested for cartilage and osteochondral repair in both in vitro and in vivo studies [20], but biomaterials which aim to induce "in situ" cartilage regeneration after direct transplantation onto the defect site were only recently proposed, and there are few clinical studies available [20,37]. The potential advantages of this surgical approach are very attractive, and this scaffold meets many of the properties of an ideal graft. The properties of the graft are specifically tailored to introduce the structural, biological, and biomechanical cues into the affected joints, leading to a reproducible and durable repair. This also implies further advantages, such as reduced costs and a simplified procedure. In fact, the technique is reproducible with a short learning curve. Moreover, the ability of the scaffold to induce orderly osteochondral tissue repair without necessarily including autologous cells makes it attractive from a practical and commercial standpoint, since it could be used as an off-the-shelf graft in a one-step surgical procedure, from a surgical standpoint, since due to its flexibility it could inserted under minimally invasive conditions, and from a biological standpoint, since the component introducing the largest degree of variability would be eliminated.

However, despite all the advantages theoretically offered by this new approach, certainly randomized independent long-term studies with restricted and selected groups of patients, as well as imaging and histological evaluations, are needed to confirm the real potential of this osteochondral scaffold in the regeneration of the damaged articular surface.

32.6 Conclusion

The results obtained with this novel nano-composite multilayered biomaterial for the treatment of patellofemoral chondral lesions showed a significant clinical improvement already at the 1-year follow-up. Advantages offered by this treatment approach include a simplified procedure with a short learning curve, easy handling and application of graft material via minimally invasive techniques, short surgical time, and the need of a one-step surgery. Long-term follow-up studies with a larger number of patients are required to confirm these preliminary results, identify particular patients that would benefit from it, assess the durability of the tissue repair produced, and the possibility to prevent the knee degenerative processes.

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Isolated Patellofemoral Osteoarthritis: Natural History and Clinical Presentation

33

David Dejour, J. Allain, and SOFCOT

33.1 Introduction

Arthritis affects the patellofemoral joint less than any other compartment of the knee. The characteristics of this isolated arthritis remain badly understood with few references in the literature. When seen it is usually bilateral and predominately in females. Its presenting symptoms are activities of bending the knee, climbing or descending stairs, or walking on inclined terrain. Other etiologies have been advanced such as extensor mechanism "malalignment"; in particular with a valgus knee, or hypermobile kneecap, the excessive lateral hyperpressure syndrome (ELHP) or a high (Patella Alta) or low riding (Patella Infera) kneecap. reflex sympathetic dystrophy has also been described as a possible cause. The two etiologies most often discussed are sequelae to articular fractures and rheumatoid disease like chondrocalcinosis.

In 2003, the primary author organized a symposium [3] in the French Orthopedic Society (SOFCOT) to understand and try to propose the best therapeutic solution for patients with isolated patellofemoral arthritis. This chapter summarizes the natural evolution and history of this arthritis obtained from this retrospective multi center study of 367 isolated patellofemoral arthritis joints.

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33.1.1 *Epidemiologic Data [1]*

Like arthritis of the femoro-tibial compartment, osteoarthritis of the patellofemoral joint is found predominantly in females (72%) with 51% of the patients having contralateral symptoms. The average age at the time of the first symptoms is 46 years old. The radiologic evolution is slower to be observed with an average delay of 18 years to pass from stage I IWANO to stage IV. This arthritis is not statistically correlated with the body mass index but 29% of patients were obese and 38% were overweight. The weight accentuates the symptomatology clinically so that there will be a relationship between weight and symptoms.

33.1.2 *Clinical Impact [1]*

Activities that engage the patellofemoral joint are altered. The ability to use stairs is problematic for 65% of cases, 15% do not use stairs and 92% need an aid to lift themselves out of a chair. The limitations of their activities on flat ground are also important; 80% report that they cannot walk more than one kilometer. The average Knee International Knee Score (IKS) was 59 points (0–75) and 47 points (0–76) for the function IKS score. These are normal scores observed in the femoro-tibial arthritis population for clinical score and function.

33.2 Etiologies of PF Arthritis

Four etiologies [1] were identified.

- Primary arthritis population (49%): patient had no orthopedic antecedent and especially no history of

S. Zaffagnini et al. (eds.), *Patellofemoral Pain, Instabilty, and Arthritis*,
DOI: 10.1007/978-3-642-05424-2_33,

Fig. 33.1 Primary isolated patellofemoral arthritis:
- Lateral facet joint line narrowing;
- Normal sulcus angle;
- No crossing sign

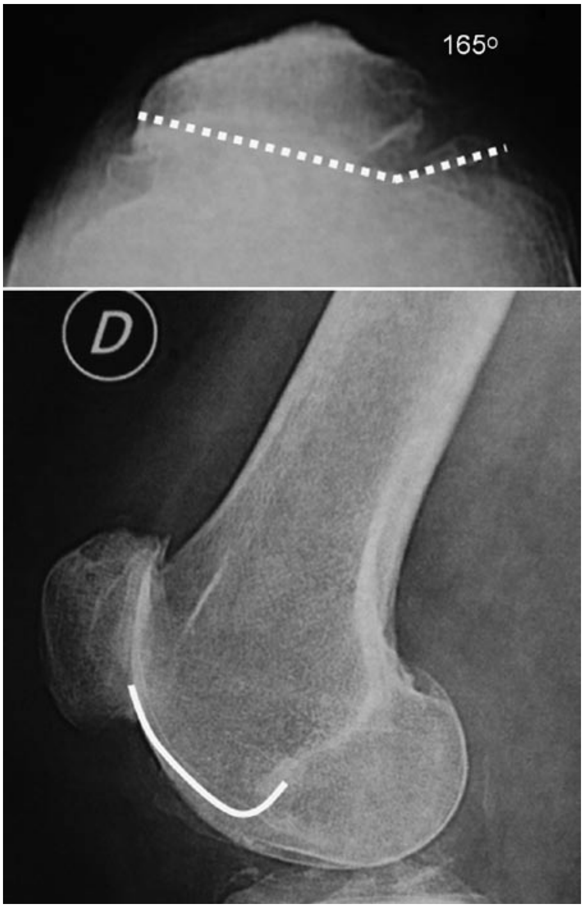


Fig. 33.2 Postinstability Isolated patellofemoral arthritis:
- Lateral facet joint line narrowing;
- Dysplastic sulcus angle;
- Crossing sign with trochlear dysplasia

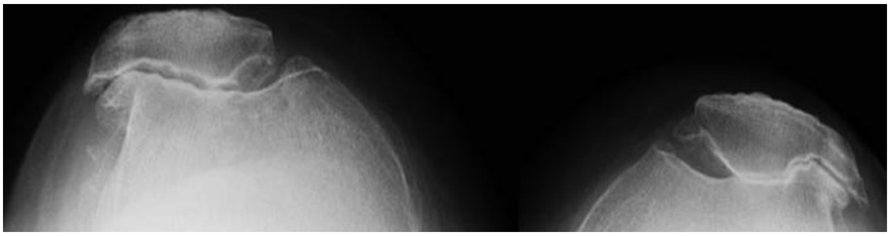


Fig. 33.3 Chondrocalcinosis (rheumatoide disease), bilateral arthritis with typical edge notching

dislocation (Fig. 33.1). Mean age at surgery was 58 years old.

- Post patellar instability population (33%): patient had a history of objective patellar dislocation (Fig. 33.2). Mean age at surgery was 54 years old.
- Posttraumatic population (9%): patient had had an articular patellar fracture. Mean age at surgery was 54 years old.
- Chrodrocalcinosis population (Fig. 33.3) (rheumatoid disease) (9%). Mean age at surgery was 72 years old.

Fig. 33.4 Standard x-ray check for patellofemoral arthritis diagnosis. AP Rosenberg Weight bearing view; True sagittal view (WB) (both condyle on the same line); Axial View 30° flexion

There was no significant difference in the IKS scores (knee and function) between the four etiologies [1].

33.3 Radiographic Analysis of Isolated Patellofemoral Arthritis (Fig. 33.4)

The radiographic definition of patellofemoral arthritis is made from standard radiographs (AP view and lateral view in monopodal stance at 20° of flexion (weight bearing) and a 30° axial view. A Rosenberg view [16] (weight-bearing AP view in 45° of flexion) should be added in patients over the age of 50 years, and in those with a history of orthopedic surgery (meniscectomy etc.).

Two criteria are essential for an analysis of the patellofemoral joint: the posterior femoral condyles must be superimposed on the lateral view [8] and a true 30° axial view must be obtained, using Knutsson's technique. This is a craniopodal view taken with the patient lying supine, with the quadriceps relaxed. On a good 30° axial view, the lateral facet of the trochlea will occupy about two thirds of the total trochlear width.

The patellofemoral joint space is studied on the 30° axial view, which, in OA, will show narrowing of the joint space and, in severe cases, bone-to-bone contact between the trochlea and the patella. Information is also provided on the size of osteophytes, and on whether the patella is well centered or subluxed.

Iwano [12] have produced a simple staging system of lateral patellofemoral OA:

Stage I: Mild OA; joint space at least 3 mm.

Stage II: Moderate OA: Joint space less than 3 mm, but no bony contact.

Stage III: Severe OA: Bony contact less than one-quarter of the joint surface.

Stage IV: Very severe OA: Joint surfaces entirely touch each other.

33.4 CT Arthrography

This exam could be interesting in cases of mild arthritis.

- In OA patients with a patellar dislocation, CT arthrography will show the extent of the cartilage damage, and indicate whether surgical recentering of the patella for the unstable patella may restore a satisfactory pattern. The CT scan will measure such factors as the TT-TG and the patellar tilt [5].
- In secondary arthritis with a medial patellofemoral impingement, as a result of excessive medialization, CT arthrography will show cartilage lesions on the medial facet (Fig. 33.5), and the extent of medialization as compared with the pattern in the contralateral knee, which is used as the reference.

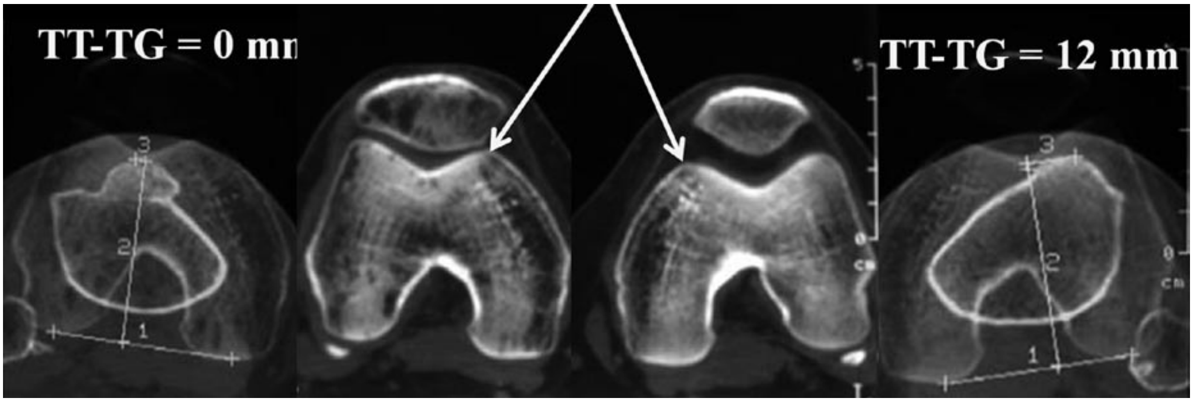


Fig. 33.5 Iatrogenic medial arthritis after hypermedialization. The CT scan allowed to compare involved and none involved knee. The cartilage analysis is optimize if combined to arthro CT

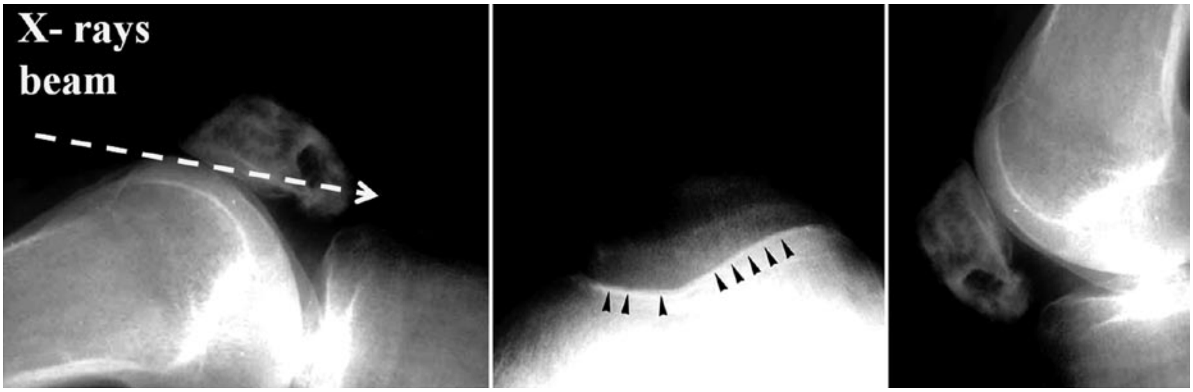


Fig. 33.6 Patella Infera is a classical differential diagnosis. Axial view shows a false joint line narrowing sunset view), the patella in a low position fixed in the notch

Magnetic resonance imaging (MRI) is not indicated in the work-up of patients with OA or a pre-osteoarthritic condition of the patellofemoral joint.

33.5 Differential Diagnosis: Patella Infera

Patella Infera manifests itself by anterior knee pain, which may be perceived by the patient as a burning sensation. The knee will feel extremely tight. The pain is constant, and made worse with effort. The patient invariably has had several previous knee surgeries, with difficult and painful postoperative rehabilitation. The diagnosis may be made from the radiographs [2, 4] (Fig. 33.6). The lateral film shows a Caton-Deschamps patellar index inferior to 0.6. On a correctly produced 30° axial view, the patella will have an unmistakable position: it appears wedged in the intercondylar notch, producing a superimposition of the trochlear groove and the patella mimicking complete loss of the patellofemoral joint space called a "sunset" pattern. The three views (AP, lateral, axial) must be studied together, to extract all the relevant information.

33.6 Predisposing Factors to Patellofemoral Arthritis

The preoperative radiographic analysis of this clinical series permits one to identify the anatomic factors favorable for the development of patellofemoral arthritis.

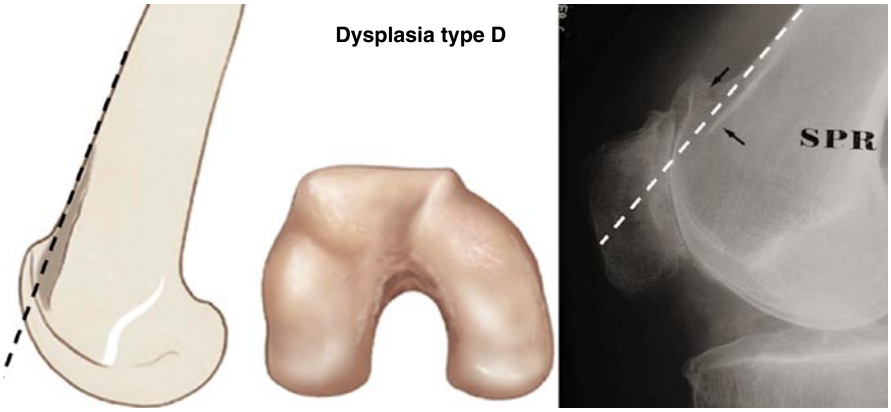


Fig. 33.7 High grade trochlear dysplasia with a prominence (Type B and D) is correlated to patellofemoral arthritis; it produces an "antimaquet effect"

Table 33.1 Type of trochlear dysplasia and isolated patellofemoral arthritis

	Primary arthritis		Postinstability	
No dysplasia	44	27%	6	5%
Type A	58	35%	35	29%
Type B	24	14%	44	36%
Type C	21	13%	16	13%
Type D	19	11%	20	17%

33.6.1 Trochlear Dysplasia

The principal factor is the presence of dysplasia in the patellofemoral joint. In this series, 78% of patients had trochlear dysplasia with the crossing sign [3]. The crossing sign is a convergence of the trochlea and the lateral femoral condyle; on a normal trochlea, the two lines remain distinct to the origin of the trochlea. Trochlear dysplasia is found in 3% of a control population but it presents in 96% of the cases in a population with objective patellar dislocation [5]. It shows perfectly the link between PF instability and the risk factor to have PF arthritis. There is also a statistical correlation between arthritis and the various forms of dysplasia [3,10]. There is a stronger proportion of dysplasia (Fig. 33.7) of the higher-grade type B and D ($p = 0.0046$). There is more dysplasia of the higher grade in the population of arthritis with instability (66%) than within the isolated arthritis group (38%). The more the trochlea is dysplastic and prominent the higher the level of arthritis (Table 33.1).

The trochlear prominence increases the compressive forces of the patellofemoral joint in flexion like an "antimaquet" effect, the asymmetry of the trochlear facet contributes to an asymmetric kinematic of the patellofemoral joint with a permanent lateral riding of the kneecap. The cartilaginous lesions are characterized by the central side of the patella being turned externally to the trochlear in the mirror where one can observe the instability of the patella and is certain to cause future arthritis. These elements explain why the arthritis postinstability population is younger than the primary arthritis population.

33.6.2 Dysplasia of the Patella [3,10]

Patellar dysplasia is also a significant factor in nearly 42% of patients where there was a patella dysplasia of type Wiberg II ($p < 0.0001$). This is the framework of a dysplastic patellofemoral joint with a significant relationship between the presence of trochlear dysplasia and a dysplastic patella ($p < 0.001$).

33.6.3 Other Factors [3]

The centering of the patella on the axial view can be seen and the subluxed aspect is correlated by level with arthritis ($p < 0.0001$), the grade of trochlear dysplasia ($p = 0.003$), and the grade of patella dysplasia

($p = 0.001$). The default of center is equally a consequence of arthritis by the slimming of the cartilage of the external side nearly the proportion of the center patella or subluxed is of 53% the same of absence of patellofemoral dysplasia. The arthritis is either external or centralized but never internal.

The patella height was not a determining factor in the development of this arthritis. No statistical correlation was found between the Caton-Deschamps index and the type of arthritis.

A parallel study [3] analyzing 44 CT scans on 44 patients with isolated patellofemoral arthritis did not show any correlation between the femoral and tibial torsion or the epicondylar index. The study confirmed what was shown by Goutallier [9], that the TT-TG has a tendency to diminish its value in patient with arthritis and the measured values return within the norm inferiorly to 20 mm.

There was no correlation with the axial deformity (varus or varus) of the lower legs.

33.7 Natural History and Treatment Implications

The higher the stage of arthritis the more likely surgery was indicated. In this series, there exists a relationship between the level of arthritis and the surgical indications. In the series of patients all interventions were confounded. Seventy-six percent had arthritis stage III or IV (Table 33.2). These data must be thought about because the survival curve of nonoperative treatment in the work of Guilbert [11] who found 90% of patients were not operated on by a 9 years follow-up and 71% of patients were satisfied with their medical treatment. He stresses that 50% have a progressive globalization of their arthritis thus within this series over 9 years 37% developed a tricompartmental arthritis and 23% remodeled the femoral-tibial joint.

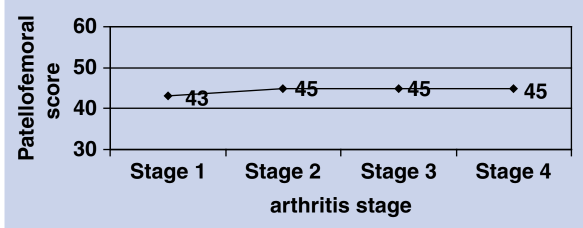
It is difficult to make a comparative study with the data in the literature because few of the studies are interested in the natural history of nonoperative patellofemoral arthritis. One might say that all surgery occurs at a radiology stage of III or IV but the clinical tolerance even with a high stage of arthritis raised well. One is not able to conclude as it is normally written that the PF arthritis functional consequence is weak because one can see the patellofemoral scores on the IKS are weak. It is in certain contrast that there is not a statistical relationship between the stage of arthritis and the functional score of the IKS on patellofemoral disease (Table 33.3). One does not find a relationship between the age of surgery and the stage of arthritis and it is difficult to establish the predictive factors for surgery beside the stages of arthritis.

One of the data most important in this study is the finding of an evolution where a global arthritis touches the femoro-tibial compartment statistically different between the patient with primary arthritis and the patients who had arthritis post instability [3]. The first group of PF arthritis evolves in 41% to a global arthritis against the second with only 32% of global arthritis at the follow-up ($p < 0.001$).

Table 33.2 Distribution of the PF Arthritis between a population with a non surgical treatment and the population with surgical treatment

	Surgical population	Non surgical population
Arthritis stage I, II	24 %	44 %
Arthritis stage III, IV	76 %	56 %

Table 33.3 Correlation patellofemoral score (Lillois) and arthritis stage



33.8 Therapeutic Consequences

There exist two anatomic situations within the patellofemoral arthritis; one patellofemoral arthritis with normal patellofemoral anatomy and one with patellofemoral dysplasia. In the two situations, the level of wear is important at the level of the trochlea but especially at the level of the patella because of the thickness.

33.8.1 Patellofemoral Arthritis Without Dysplasia

Nonprosthetic treatment is possible [17]. The patellofemoral ligament balancing will be easy because there is no phenomenon of retraction or distraction of the lateral and medial retinaculum. The options are to correct the malalignment with a tibial tubercle osteotomy and do a medialization or an antero medialization [6,7] or to be symptomatic and remove the lateral osteophyte with an isolated facetectomy [18], which could be combined, to an internal procedure like medial reefing or an Insall plasty. Patellofemoral joint replacement is also a possibility with no particular associated procedure.

33.8.2 Patellofemoral Arthritis with Dysplasia

The absence of the correction of patellofemoral dysplasia makes the procedures like tibial tubercle medialization or anteriormedialization or lateral facetectomy hazardous. The patellofemoral dysplasia will not be modified and the unbalance of the patellofemoral joint will stay with rocking patella, chronic retraction and distraction between lateral and medial retinaculum. In this situation, the partial or total arthroplasty will be more interesting because it will permit the removal of the patellofemoral dysplasia at the time of the turning of the trochlear and on the turned patella. Therefore, one utilizes a patellofemoral joint with a cut of the dysplastic trochlea the prominence is removed, the medio-lateral positioning and the rotation of the component could permit correction of the extensor mechanism malalignment. The TT-TG is diminished by doing a slight lateralization of the femoral component without doing anything on the tibial tubercle.

Concerning the correction of the patella, it is necessary to pay better attention to conserve a satisfactory thickness of the patella if possible with a minimum of 13–14 mm, it is necessary to measure this thickness before and after the patella resurfacing. The positioning of the patella implant authorizes if it is slightly undersized, to correct a higher Patella Alta or a Patella Infera. The medio-lateral positioning of the patella implant also contributes to correction of the malalignment. Within the prosthetic gesture and resurfacing of the patella, it is not always necessary to practice a lateral release because most of the time lateral osteophyte removal is sufficient. It constitutes a sort of a lateral facetectomy from the inside joint and this permits decompression of the lateral compartment.

The clinical results of the two French series [14] of patellofemoral joint replacement shows clearly that if the surgeon uses a femoral component with not cut (resurfacing implant) the best result in terms of survival curve is when it is combined with a distal realignment (tibial tubercle osteotomy). Two implants were tested (Sherocentric and Autocentric), the survival curve at 5 years follow-up, if no distal realignment was done, was 86% and 76% and they continue to decrease up to 58% at 11 years. For the same implants combined with a distal realignment the survival curve was at 5 years follow-up 93% and 86% at 10 years [15] (Fig. 33.8). The difference was statically positive $p = 0.0001$. For the series, using a femoral component with a trochlear cut (Hermes Ceraver) the survival curve was at 5 years follow-up 95%.

In conclusion, the prosthetic treatment must deal with the wear especially on the patella side, to prevent any patellar fracture. The surgeon has to keep at least 13 mm bone. The procedure has also to deal with the trochlear dysplasia especially if there is a prominence (type B or D trochlear dysplasia) in removing it by using a femoral component with cut and correcting the TT-TG with a proximal realignment if using "cut prosthesis" (Fig. 33.9) or with a distal realignment if using a "resurfacing prosthesis" with no cuts.

The surgical indication must also include the etiology because this series has shown statistically more global degradation of the articulation when there is no history of dislocation of the patella (Primary arthritis population). In elderly patients, the total knee arthroplasty is giving as good results [13] as in femoro-tibial arthritis with no specific features in the procedure.

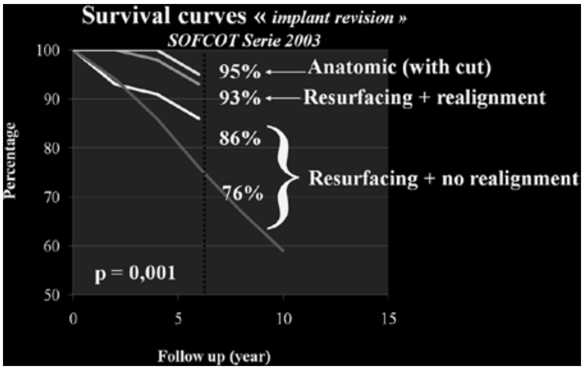


Fig. 33.8 Survival curve of the patellofemoral arthroplasty, showing the best results were if there is a proximal (trochlear component positioning) or a distal realignment (tibial tubercle osteotomy). Result of SOFCOT Symposium 2003 (autocentric®, sherocentric®, Hemes®)

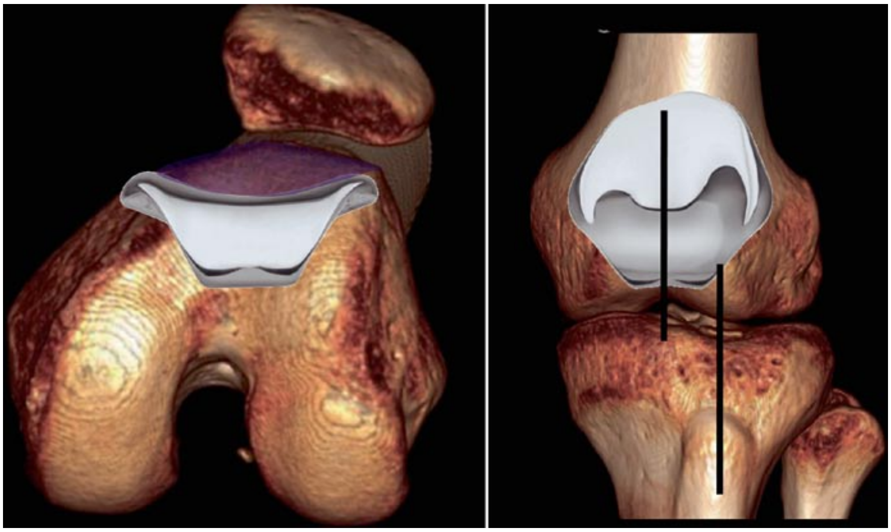


Fig. 33.9 In case of using a PF Arthroplasty with a trochlear cut: The trochlear dysplasia is removed; A proximal realignment could be done with a slight lateralization

33.9 Conclusion

The indication must therefore take into account the very slow evolution of this specific arthritis, the etiology is important to analyze because of the natural history differences and the surgical procedure could change depending on the amount of patellofemoral dysplasia and bony wear.

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34 The Nonoperative Treatment of Patellofemoral Arthritis

Ronald Grelsamer and Jenny McConnell

The nonoperative treatment of patellofemoral arthritis is a cross between the nonoperative treatment of knee arthritis and the nonoperative treatment of conditions that produce patellar pain, such as a tight lateral retinaculum, VMO dysplasia, core deficiency, and the like. Treatment options include activity modification, anti-inflammatory medications/analgesics, bracing, physical therapy, steroid injections, viscosupplementation, weight control, water exercises, and, possibly, nutritional supplements.

The specific physical therapy protocol depends entirely on the specific etiology of the patellofemoral arthritis.

34.1 Activity Modification

A Sports doctor will be reluctant to advise a patient to avoid the very activity that the patient enjoys, and yet there remains in modern medicine a role for diminishing or altering certain activities. As a general principle of exercise, patients should be admonished that pain is not to be worked through but avoided completely. During activities that require flexion or extension of the knee against body weight the patellofemoral compartment is subject to up to eight times a subject's body weight [7,11]. Thus, squats, wall slides, and steps will be particularly noxious, and should be avoided.

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34.2 Weight Control

During activities of daily living, such as arising from a chair or climbing steps, the knee, and in particular the patellofemoral compartment, is subject to many times a subject's body weight [7]. It stands to reason that an increased body mass index (BMI) correlates with increased rates of patellofemoral arthritis [12]. Conversely, a reduction in weight will significantly diminish the stresses borne by the patellofemoral compartment and can moderate the pain. Since a person's weight is the only anatomical factor that is somewhat under his or her control, overweight patients can partially direct their own patellofemoral destiny through a weight reduction program.

34.3 Water Exercise

At least two aspects of water therapy are beneficial: buoyancy and resistance. Buoyancy allows the patient to attempt activities that would be stressful to the patellofemoral compartment and painful. These include squats, lunges, and wall slides. A person might try these in the shallow end of a pool and use pain as a guide. As with land exercises, no activity in the water should be painful.

The resistance provided by water as a subject walks, jogs, or kicks will strengthen all muscle groups. The breast stroke may help strengthen the adductors and vastus medialis.

34.4 Medications

A number of medications will calm the pain in the short run. Anti-inflammatory medications [1] and analgesics

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(acetaminophen, tramadol, etc.) can be used in isolation or in combination. Patients must be made aware that certain medications are actually combination of medications. Acetaminophen, for example, is present in a number of combinations, and it would not be prudent for a patient to take acetaminophen in isolation when it is already being taken in combination. On the other hand, with the appropriate liver and kidney precautions, it can be quite efficacious to combine an anti-inflammatory medication, acetaminophen, and a third medication such as tramadol. Patients taking any of these medications on a regular basis require complete blood count and blood chemistries every 3–4 months.

34.4.1 Steroid Injection

Steroid injections are commonly used to address musculoskeletal inflammation in any part of the body, and injections about the patellofemoral joint are no more or less efficacious than anywhere else. They are inexpensive and readily available. With repeated use, they can have a deleterious effect on the mechanical properties of tissues and on the local immune response (and thus a potential increased risk of infection with any eventual procedure). The use of injections should be limited to two or three times per year in any potential surgical candidate.

34.4.2 Viscosupplementation

The synovial fluid of an arthritic knee is more watery, less viscous than normal, and therefore is deficient in some of its biomechanical properties. Accordingly, hyaluronic acid injections are an accepted adjunct to the treatment of knee arthritis. The patellofemoral compartment has not been reported to respond better or less well to this approach than the femoro-tibial compartments [4]. Because the products injected are synthetic versions of a person's own joint fluid, there is no medical limit on the frequency with which they can be injected.

34.5 Nutritional Supplements

Over the counter, nonprescription supplements such as glucosamine and chondroitin sulfate were initially welcome additions to the battle against arthritis. Proponents saw safe, chondro-protective, cartilage-generating, and pain-reducing properties in these tablets [14] Although it is clear that some patients have indeed reported benefits from these supplements, it is less clear that they provide relief at more than the 30% placebo rate that is found in most pain reduction remedies. As of 2009 the American Academy of Orthopedic Surgeons does not endorse the use of nutritional supplements in the treatment of arthritis.

34.6 Knee Supports

While, anecdotally, it would seem that bracing should provide pain relief, the beneficial effects have not been clearly validated. The cutout at the front of a knee support is designed to minimize pressure on the patella, but this concept is only effective when the patella is centered over the trochlea. In situations where the patella is laterally positioned, the cutout will be improperly positioned and may actually increase pressure on the patellofemoral compartment.

34.7 Orthotics

The position of the foot affects the mechanics of the knee. Specifically, a pronated foot will lead to internal torsion of the lower limb and a resultant valgus moment about the knee. Orthotics can compensate for an abnormal foot position, and can occasionally improve patellar pain. Mundermann et al. [13] found that, while running, patients with anterior knee pain demonstrate increases in global EMG intensity, confirming at the very least the concept that foot orthoses affect the knee.

34.8 Physical Therapy

34.8.1 Muscle Strengthening

Pain decreases quadriceps muscle activity and decreased quadriceps strength is strongly associated with increased symptoms [3, 9]. Moreover, coordinated thigh, gluteal and abdominal strength diminishes the pressure through the PF joint by optimizing the magnitude and distribution of the loads through that compartment [2].Thus, strengthening is recommended. A number of exercise regimens are acceptable. A guiding principle is that exercise must not be painful, as this will be counterproductive.

Cycling is a useful low impact activity for the PF joint. The compressive force is only 1.3 × body weight, provided the resistance is kept low and the seat high. The time of usage should be increased only gradually [6].

Closed (kinetic) chain training is effective in activating the vasti. Stensdotter et al. [15] found that in asymptomatic subjects closed-chain knee extension, compared with open chain extension, promoted a more simultaneous onset of EMG activity of the four quadriceps muscles. In the open chain mode, the rectus femoris demonstrated the earliest EMG onset, while the VMO was activated last, and its amplitude was smaller than in the closed-chain mode. These authors concluded that closed kinetic chain exercise promotes a more balanced initial quadriceps activation than open kinetic chain exercise. This complements the finding of Escamilla and coworkers, who found that open kinetic chain exercises produce more rectus femoris activity, while closed-chain exercises produce more vasti activity. Closed kinetic training allows simultaneous training of the vasti, the gluteals, and the trunk muscles in controlling the limb position during weight bearing. A stable pelvis minimizes stresses about the knee. Training of the gluteus medius (especially the posterior fibers) decreases internal rotation of the hip and the consequent valgus force at the knee

Jan et al. [10] found that in patients with knee osteoarthritis, closed and open chain exercises performed over an 8-week period resulted in significant improvement in the WOMAC function scale and knee strength compared with the control group. They found that weight-bearing exercises improved position sense, which enhances complex walking tasks and improves balance. This is particularly true in the older population.

34.8.2 Taping

Taping the patella aims to incrementally displace the patella medially to increase the patellofemoral contact area, and thereby decrease the patellofemoral contact pressure [8]. There is strong evidence in the literature for the short-term pain reduction benefits of patellar taping in the osteoarthritic population. Cushnaghan et al. [5]. found that patellar taping in the medial direction reduced the pain by 25% in patients with both PF and tibiofemoral osteoarthritis. It is perhaps more beneficial to not only reposition the patella with a medial "tilt and glide" tape, but also to unload (shorten) the inflamed fat pad and/or the inflamed pes anserinus bursa with a more vertically oriented tape. Indeed, the pes anserinus bursa can be inflamed in symptomatic osteoarthritic knees because the hamstrings are overactive in their attempt to brace the knee. This is especially true when the quadriceps are weak.

- There remains a roll for activity modification, e.g., avoidance of deep knee bending against resistance.
- Maintenance of an appropriate BMI should be part of any program.
- Pain-free, strengthening exercises are recommended, especially in a closed-chain mode.
- Water exercise offers low-stress strengthening and coordination.

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Current Concepts Regarding Tibial Tubercle Osteotomy

35

My Philosophy and Experience

John P. Fulkerson

Tibial tubercle transfer (TTT) is a powerful way to control patellofemoral mechanical function. Before using TTT, one must understand the fundamental mechanical problem in the patellofemoral joint and determine that transferring the tibial tubercle is the most appropriate way to restore optimal function of the joint. Usually this means that the surgeon wants to provide more balanced tracking of the patella thereby compensating for underlying structural problems that have caused lateral patella instability or overload. When the patella is tracking out of its optimal alignment pattern, it is possible to alter the path of patella movement permanently, by TTT. Often TTT is the most benign PF realignment alternative for the patient, particularly when compared to derotational osteotomy of the femur or tibia. Once the tracking vector is normalized by TTT, peripatellar retinacular structures may be adjusted to provide additional support for the patella. In this author's opinion, retinacular structures (including the medial patellofemoral ligament [MPFL]) should not be used to displace patella tracking, but rather to guide it gently in its proper course of movement, attempting always to balance articular loading optimally. The most common reasons for TTT are:

1. Lateral patella instability related to a lateral tracking vector (high Q-angle or TT-TG)
2. Medial patella instability related to an excessive previous TTT
3. Patella Alta requiring distalization of patella tracking
4. Patella Infera requiring that the patella be moved proximally
5. Patellofemoral articular breakdown requiring transfer of patella tracking onto healthier cartilage
6. In conjunction with articular resurfacing surgery
7. To compensate for trochlear dysplasia related to chronic lateral patella tracking
8. To compensate for tibial or femoral torsional dysplasia

When the patella tracks laterally embryologically and in childhood, the lateral trochlea becomes permanently flattened (dysplastic) developmentally, resulting in patella instability. Corrective restoration of central, stable patella tracking by TTT will yield stable patella function permanently in most cases, but supplemental restoration of dysplastic or damaged medial patella support structures or a lateral trochlear buttress may be needed in some cases. If the TT-TG relationship is restored and the patella tracks centrally, little more is needed in many cases. The art of patellofemoral stabilization surgery is the ability to determine which type of stabilization is most appropriate in each patient, as no one procedure is most appropriate for everyone.

In some patients, lateral tracking causes focal lateral articular overload, such that moving the tibial tubercle medially or anteromedially will also take excessive load off of an overloaded and painful lateral and/or distal patellofemoral articulating surface.

Medial TTT shifts load off of the lateral patella, which is often broken down after years of lateral tracking, and onto the medial patella, whereas *anterior* TTT shifts load off of the *distal* patella in early flexion, by moving the patella contact proximally on the patella. Therefore, anteromedial TTT unloads the lateral patella while transferring articular loading proximally, off of a painful distal patella articular lesion.

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35.1 Decision Making Regarding Alternatives to Tibial Tubercle Transfer

A tibial tubercle transfer is most appropriate to restore an optimal, balanced tracking relationship between the patella and the trochlea. When the lateral patella tracking vector is more seriously out of balance (TT-TG disparity over 20 mm) with secondary lateral trochlea flattening, TTT medially or anteromedially is often the best way to balance patellofemoral articular loading and create stable patellofemoral tracking permanently without focal overload, if properly done. Adding anteriorization by creating an anteromedial TTT takes the load off the distal patella which is often a source of patella articular pain. Correcting Patella Alta by transferring the tibial tubercle distally gets the patella to the trochlea earlier such that the patella will be "captured" appropriately and stabilized by the trochlea.

In patients with longstanding lateral patella tracking, the lateral facet may collapse such that the patient ends up with a painful Ficat "excessive lateral pressure syndrome" In such patients, anteromedial TTT immediately offloads the painful lateral patella breakdown and yields consistently favorable results without arthroplasty. Similarly, when the distal pole of the patella has become damaged by aberrant mechanical function such that the patient has pain upon stepping down with the opposite leg (loading the distal pole of the affected side in early flexion), anteriorization of the tibial tubercle lifts up the distal patella and can completely eliminate this frequent source of pain. Anteromedial TTT also realigns the extensor mechanism while unloading the distal articular pole of the patella.

TTT is often not necessary in patients with patella instability. In cases of less severe malalignment with traumatic disruption of the medial patella stabilizing structure, proximal surgery alone may be indicated, usually after healing of the injured extensor mechanism. Lateral release is best to relieve lateral tightness and tilt. In patients with little dysplasia and minor instability, medial imbrication or advancement of a healed MPFL, often with a lateral release, may be all that is needed to restore functional stability of the patellofemoral joint. This type of surgery, traditionally called "proximal realignment" is not so much realignment as a *restoration* of medial support of the patella. As such, the surgeon must remember that it is likely to fail if there are significant laterally directed forces continuing to act on the patella during motion and function of the patellofemoral joint. Therefore, proximal restoration is sometimes appropriate in conjunction with TTT, in which case early motion starting 10–14 days after surgery, with at least one knee bend a day, is important. When proper tracking is established, such that distorting lateral "malalignment" is no longer present, early motion becomes appropriate, much as in the case of ACL reconstruction

Tendon graft reconstruction of the MPFL is another important patella stabilizing procedure when there is more serious MPFL deficiency, failed MPFL imbrication, and in cases of a deficient MPFL and *a normal* TT-TG relationship.

Whenever MPFL reconstruction is necessary, great care must be taken to *avoid adding load to a distal medial patella articular lesion* (quite common after patella dislocation).. Anteromedial tibial tubercle is advisable in such instability cases when the TT-TG distance exceeds 20 mm and the proximal medial patella is intact.

35.2 Pearls and Principles of Tibial Tubercle Transfer

1. Design the osteotomy specifically for the patient's unique alignment and articular problem
2. Make all cuts perfectly flat
3. Taper osteotomy to anterior tibial cortex distally to avoid a large distal tibial stress-riser
4. Check tracking and patella articulation arthroscopically before final fixation
5. Avoid patella tracking from medial to lateral or the patient may end up with a debilitating medial patella subluxation complication
6. Secure fixation of the transferred tubercle
7. Early (within days of surgery) range of motion
8. Do not overdo anything
9. Be sure indications are correct
10. Protect weight bearing, but progress to full weight bearing by 6 weeks postsurgery

35.3 Conclusions

TTT is a powerful way to reestablish balanced patella tracking or to unload some articular lesions. TTT is best regarded as compensatory for underlying structural imbalances that have resulted in abnormal patella tracking and the problems of instability and articular breakdown that go along with it.

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Isolated Patellofemoral Osteoarthritis: Prosthetic Indications

36

Johan Bellemans and Hilde Vandenneucker

36.1 Introduction

Although prosthetic replacement of the patellofemoral joint seems a logical treatment option for end-stage disease of the patellofemoral joint, it still remains a controversial treatment in the minds of many knee surgeons.

Since the first successful attempt by McKeever in 1955 to replace the patellar surface using a Vitallium shell, and since the results of the first artificial patellotrochlear replacements by Blazina et al. were published in 1979, the enthusiasm of surgeons towards artificial replacement of the patellofemoral joint has gone through ups and downs [9,29].

The results of these implants were initially considered as unpredictable and inconsistent by most surgeons, in contrast to what was observed for total knee replacements. Shortcomings in the available designs, difficulty in obtaining correct implant positioning, and failure to address correctly the underlying pathology were the main reasons for this lack of enthusiasm.

Recently, however, there has been a renewed interest in the use of patellofemoral arthroplasty, and there is a growing tendency to believe that artificial patellofemoral replacement has a well defined place in the treatment of end-stage patellofemoral osteoarthritis.

The recent trend towards less invasive surgery as well as the revival of selective, unicompartmental resurfacing options has aroused the orthopedic industry towards increasing the efforts in designing better and more anatomic patellofemoral prostheses.

In the meantime, a better understanding of patellofemoral physiology and pathology has allowed surgeons to gain a better understanding of how and when patellofemoral arthroplasty should be performed in order to lead to consistent clinical results.

Like any other operation, a successful clinical outcome depends on correct patient selection and indication, as well as surgical technique and postoperative care. In this chapter we address the issue of patient selection and indication, based upon the evidence available in literature. Over the last few years several reports have been published on the results of patellofemoral arthroplasty as well as total knee arthroplasty (TKA) for patellofemoral disease, and based upon these data it is becoming increasingly clear what the exact role is for prosthetic patellofemoral surgery.

A review of the literature shows that all of the published studies on patellofemoral replacement are retrospective in nature, and provide only level 3 or level 4 evidence[1–5,10–12,15,16,18,20,21,24,27,31,34–36] (Table 36.1).

No therapeutic level 1 or level 2 studies have been performed in order to compare patellofemoral replacement to total knee replacement or any other treatment options for patellofemoral pathology.

36.2 Isolated Patellofemoral Arthroplasty

The typical indication for the use of a patellofemoral prosthesis has traditionally been the patient with disabling, isolated end-stage patellofemoral degeneration

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Table 36.1 Literature overview on isolated patellofemoral joint replacement

Series	Implant	Number of cases	Follow-up (years)	Good/excellent results (%)	Revison rate (%)
Blazina et al (1979)	Richards I/II	57	2	NA	35
Arciero et al (1988)	Richards II	25	5.3	85	12
Cartier et al (1990)	Richards II/III	72	4	85	10
Argenson et al (1995)	Autocentric	79	5.5	84	13
Krajca et al (1996)	Richards I/II	16	5.8	88	6
De Cloedt et al (1999)	NA	45	6	NA	18
Tauro et al (2001)	Lubinus	62	7.5	45	28
de Winter et al (2001)	Richards II	26	11	62	19
Smith et al (2002)	Lubinus	45	4	69	19
Kooijman et al (2003)	Richards II	45	15.5	86	25
Board et al (2004)	Lubinus	17	1.5	53	12
Merchant et al (2004)	LCS	15	3.7	93	0
Lonner et al (2004)	Lubinus	30	4	84	33
Lonner et al (2004)	Avon/Nexgen	25	0.5	96	0
Argenson et al (2005)	Autocentric	66	16.2	NA	51
Ackroyd et al (2005)	Avon	306	2	NA	4
Cartier et al (2005)	Richards II/III	79	10	72	13
Leadbetter et al (2006)	Avon	30	2	83	7
Sisto et al (2006)	Kinamatch	25	6	100	0
Ackroyd et al (2007)	Avon	109	5.2	78	17
Gadeyne et al (2008)	Autocentric	43	6	67	24

that has failed to respond to conservative or other surgical treatment options. Usually this means that the patient has full thickness patellofemoral cartilage loss as documented by radiographic, arthroscopic, or other investigation. Usually this also means that this patient is younger than the traditional tibiofemoral osteoarthritis population.

In cases of subtotal patellofemoral cartilage damage without exposed bone, one should always consider more conservative surgical options first (Fig. 36.1). Arthroscopic debridement may be helpful in cases of mechanical symptoms caused by unstable cartilage flaps. Microfracture, mosaicplasty, or even autologous chondrocyte transplantation may have a place in the younger patient with a fresh, posttraumatic lesion. Lateral retinacular release, soft tissue realignment of the extensor mechanism, and/or anteromedialization osteotomy of the tibial tubercle may all help to unload the damaged patellofemoral cartilage.

In cases of erosive full thickness damage these options are however frequently inappropriate or insufficiently effective, requiring further and more drastic care. Patellectomy may be a theoretical option, but it is a mutilating operation and history has taught us that the results are unpredictable both with respect to the subjective as well as functional outcome [17,19,25].

A more conservative approach with excision of just the eroded lateral facet, while leaving the patellar body in situ, may be a better alternative [8,17,28,37,38].

Patellofemoral joint replacement effectively replaces the damaged cartilage layers, and therefore provides a more logical solution for the predominant problem of the patient. This implies that concomitant issues such as underlying patellar malalignment or maltracking should be absent or corrected (Fig. 36.2). Likewise, there should be no evidence of other pathology in the knee such as tibiofemoral arthritis or an inflammatory arthropathy.

Fig. 36.1 The patient with partial thickness lesions or chondromalacia is the wrong indication for patellofemoral arthroplasty. This patient may be a potential candidate for other procedures, such as local trimming or debridement, cartilage restorative procedures, correction of the underlying malalignment, and/or an unloading procedure

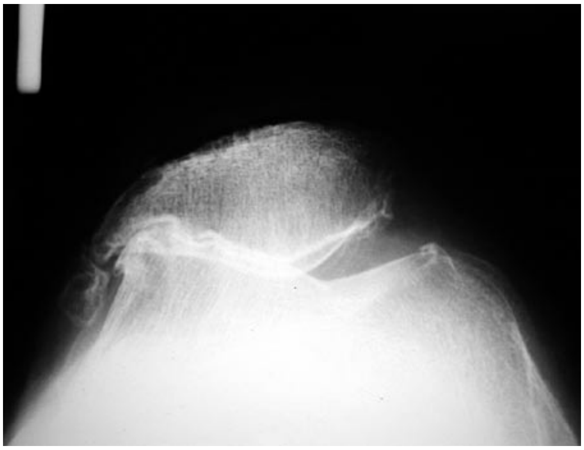

Fig. 36.2 End-stage patellofemoral osteoarthritis with full cartilage loss and lateral maltracking, is a potential indication for isolated patellofemoral replacement, but will require correction of the maltracking intraoperatively. Usually a limited lateral release or facetectomy will be sufficient to obtain this

In view of this, Leadbetter et al. have recently outlined the optimal indications and contraindications for patellofemoral arthroplasty [23,24]. Degenerative osteoarthritis limited to the patellofemoral joint and causing severe symptoms affecting daily activity is the

Table 36.2 Indication criteria for isolated patellofemoral arthroplasty

– Isolated patellofemoral osteoarthritis (documented loss of patellofemoral joint space with osseous deformation)
– Severe patellofemoral symptoms affecting activities of daily life
– Nonresponsive to nonoperative treatment for at least 3–6 months
– Absent patellofemoral malalignment (or corrected intraoperatively)
– Absent tibiofemoral disease
– Neutral tibiofemoral alignment
– No obesity
– No evidence of inflammatory arthritis

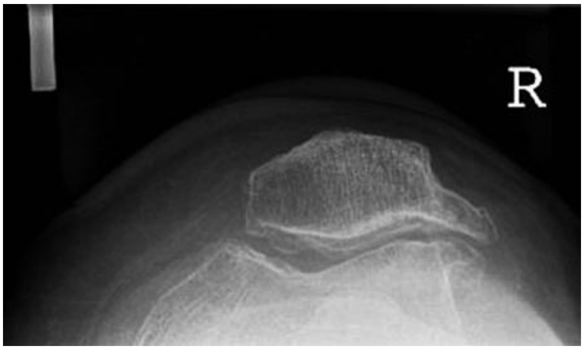

Fig. 36.3 End-stage patellofemoral osteoarthritis after lateral facetectomy 7 years prior to isolated patellofemoral joint replacement

primary indication, at least in cases where a lengthy period of nonoperative treatment has been unsuccessful (Table 36.2).

Posttraumatic osteoarthritis, extensive grade 3 chondrosis affecting the entire trochlea, the medial facet, or proximal half of the patella, and failure of previous extensor unloading surgical procedures are additional indications according to these authors (Fig. 36.3). In their opinion, contraindications to the procedure are the presence of tibiofemoral arthritis, systemic inflammatory arthropathy, Patella Infera, uncorrected patellofemoral malalignment, tibiofemoral malalignment, psychogenic pain, and loss of range of motion greater than 10° [23,24].

Interestingly, factors that are known to be associated with the development of tibiofemoral pathology are indeed associated with inferior results after patellofemoral arthroplasty. Obesity, tibiofemoral malalignment, and limited range of motion fall in this category.

Table 36.3 Contraindications for isolated patellofemoral arthroplasty

– Presence of tibiofemoral disease
– Inflammatory arthropathy
– Uncorrected patellofemoral malalignment or instability
– Tibiofemoral malalignment
– Gross obesity
– Fixed flexion contracture >10°
– Evidence of psychosomatic component/chronic regional pain syndrome

Mechanical malalignment exceeding 3° is therefore in our opinion a relative contraindication to isolated patellofemoral joint replacement, even if the patient is still asymptomatic at the tibiofemoral level (Table 36.3).

In most published series, the most frequent reason for revising a patellofemoral arthroplasty to a total knee replacement has been the progression of the arthritic disease in the femorotibial compartments.

In a recent literature analysis Leadbetter et al. reported an overall average reoperation rate of 24% after patellofemoral joint replacement [24]. Revision to TKA was necessary in 9% (range 5–18%) of the published cases, with progression of osteoarthritis in the remaining compartments as the most important cause. Uncorrected extensor malalignment with patellar maltracking or instability, knee joint stiffness, and patellar component loosening were the other reasons for conversion to total knee replacement.

Recent data available from international knee arthroplasty registries seem to confirm these findings. In the annual 2008 report of the Australian Hip and Knee Arthroplasty registry, 1,057 patellotrochlear replacements were reported, accounting for 0.5% of all knee procedures [6].

Nine different designs were used, with the Avon, LCS, Lubinus, and RBK being the most frequent and accounting for 86% of all procedures. Again, the revision rate was found to be relatively high compared to total or unicondylar knee arthroplasty, with 3.1 revisions per 100 observed component years, and a 5 year cumulative percent revision of 13.8% (versus 12.1% at 7 years for uni's, and 4.3% at 7 years for total knee replacements.

The main reason for revision of patellotrochlear replacements was progression of disease in 24%, pain in 22%, and loosening in 17%. Interesting to note was that the outcome depended on age, with the 5 year cumulative percent revision declining with increasing age. Patients aged less than 55 years at surgery had a 5 year cumulative revision percent of 17%, versus 13% for the age group 55–64, 12% for age 65–74, and only 7% for those over 75 years old. Males had a doubled risk of revision compared to females. Finally, revision rates were highly influenced by the type of prosthesis used [6].

In a recent German, nation-wide survey a total of 195 patellofemoral replacements were reported, accounting for 0.37% of all knee replacements. Again, the main reason for failure was progression of tibiofemoral degeneration of the affected knee [7].

Careful patient selection is therefore crucial and the clinical challenge is to chose the patient with isolated patellofemoral full thickness cartilage wear, absent or correctable malalignment, and absence of risk factors for developing tibiofemoral disease (Fig. 36.4). This is not an easy task, and requires careful clinical and technical investigation [17,19,23,24,26].

While interviewing and examining the patient, it should become clear that the pain is exclusively located in the anterior compartment and secondary to severe wear of the patellofemoral joint. Patellofemoral crepitus, retropatellar pain while squatting or while performing open chain extension against resistance, and pain during retropatellar palpation should be present. Femorotibial joint line tenderness or other signs of femorotibial or meniscal pathology should not be present. Also, other causes of anterior knee pain such as prepatellar bursitis, pes anserinus tendonitis, patellar tendonitis, or referred hip pain should be excluded. Patellar tracking should be closely examined, and maltracking should be corrected preferably before or at the latest during the patellofemoral replacement.

Technical investigations should include standing AP and lateral knee radiographs both in extension and 30° flexion (Rosenberg or schuss view), in order to exclude tibiofemoral degeneration. On the lateral views the presence of Patella Alta or Baja can be noted. A patellar skyline (axial or merchant) view should be taken to document cartilage loss as well as patellar tracking. Standing full leg radiographs may be necessary to rule out tibiofemoral malalignment. CT scan or MRI may be helpful to further document cartilage status and to evaluate the tibiofemoral compartment.

Finally, patellofemoral arthritis can be the first, subtle indication of an otherwise subclinical inflammatory condition, and serum analysis may therefore be warranted in doubtful cases [19].

Based upon all these clinical and technical investigations, one should be able to determine whether the patient fulfills the criteria for isolated patellofemoral replacement as shown in Table 36.2.

Fig. 36.4 Patellofemoral joint replacement in situ

36.3 Total Knee Arthroplasty

Proponents of patellofemoral arthoplasty argue that despite the significant incidence of femorotibial degeneration necessitating revision to TKA, this argument does not justify the systematic use of total knee replacement for the treatment of end-stage patellofemoral disease. In their point of view, TKA is an extreme and overly aggressive treatment for this indication.

Despite this, several studies have been published indicating that TKA is an effective and reliable procedure for the treatment of isolated patellofemoral disease, with very low reoperation or revision rates, contrary to isolated patellofemoral replacements. Although no comparative studies exist, the mere fact that the revision and reoperation rate in published series is definitely lower for total knee replacement compared to published data on patellofemoral joint replacement is a strong argument in favor of TKA.

According to those in favor of TKA, the results after patellofemoral arthroplasty should at least become as good as those after TKA with respect to longevity and pain relief, in order to justify its use as a reasonable treatment option for isolated patellofemoral osteoarthritis.

Several authors have reported on the results after TKA for isolated patellofemoral osteoarthritis [13,14,22,30,32,33] (Table 36.4).

Laskin et al. have reported on 53 patients with an average follow-up of 7.4 years, and noted a better subjective and functional outcome comparing this group with a matched series of patients with tricompartmental osteoarthritis [22]. Meding et al. retrospectively compared the outcomes of 33 TKAs with patellofemoral osteoarthritis with a matched group of primarily tibiofemoral osteoarthritis, and noted similar results for both groups [32]. In their analysis of the literature, they pointed out that of the 167 TKAs performed for the treatment of isolated patellofemoral osteoarthritis,

Table 36.4 Total knee arthroplasty (TKA) performed for isolated patellofemoral osteoarthritis: literature overview

Series	Number of cases	Follow-up (years)	KS score	Revison rate (%)
Dalury et al (1995)	33	5.2	96	0
Laskin et al (1999)	53	7.4	96	0
Parvizi et al (2001)	31	5	89	3
Mont et al (2002)	33	6.8	93	0
Meding et al (2007)	33	6.2	88	0

only one knee was revised and two knees underwent reoperation. Three of the studies reported no revisions or reoperations, and the highest revision rate was 3% (1 of 31 TKAs) (Table 36.4).

In view of these data, TKA can therefore be considered as an acceptable treatment option for the treatment of isolated end-stage patellofemoral disease, and is the treatment of choice if early tibiofemoral degeneration is present, or if risk factors for the development of such tibiofemoral degeneration exist.

36.4 Summary

- The ideal indication for isolated patellofemoral joint replacement is the patient with end-stage patellofemoral osteoarthritis that has been non responsive to prolonged conservative treatment, causing severe problems in activities of daily life.
- Underlying patellar maltracking should not be present or should be corrected during the procedure.
- Total knee replacement should be used if tibiofemoral degeneration or risk factors for developing tibiofemoral degeneration are present.

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Post-operative Management of Surgeries Aimed at Correcting Patellofemoral Instability: Results of an International Surgeon Survey

37

Andrew D. Lynch and Lynn Snyder-Mackler

37.1 Introduction and Justification of the Survey

When possible, the responsible health care practitioner bases intervention on the best available evidence in the peer reviewed literature. Unfortunately, the literature is often insufficient to guide all aspects of treatment. When the literature is lacking for a given condition, treatment must be based on the opinions of experts in the field and on sound biomechanical and biological principles. Unfortunately, despite the prevalence of surgeries aimed at managing recurrent patellofemoral dislocation, high quality research concerning postoperative care is not available. Therefore, we must base our decisions on the recommendation of experts and the biomechanics and dynamics of the patellofemoral joint.

A survey (sample attached) was submitted to surgeons with experience in patellofemoral procedures to procure expert opinion about postoperative management of these surgeries and to provide general rehabilitation guidelines for the rehabilitation professional. Surgeons were asked to answer a number of questions concerning five surgeries:

- Medial patellofemoral ligament reconstruction
- Medial patellofemoral ligament repair with medial imbrication of the quadriceps
- Lateral extensor retinaculum release
- Tibial tubercle osteotomy with screw fixation
- Trochleoplasty

In addition to their opinions on postoperative management, surgeons were also asked to respond to questions about nonoperative management of patellar dislocation.

Surgeons surveyed for these guidelines had an average of 18 years experience in orthopedics, ranging from 3 to 35 years. In addition to performing patellofemoral procedures, these surgeons also performed operations on patients with other knee injuries, shoulder injuries and sports traumatology. They represent a wide range of experience and specialty concerning operative management of knee pain and injury. They were surveyed for their common recommendations in regards to immobilization, range of motion restrictions and exercise progressions. Only responses from surgeons who performed each operation within the last year were included for each procedure.

While the recommendations that follow are based on a "typical" postoperative patient, both the surgeon and the physical therapist must make considerations to the role of the other professional. The interplay of surgery and rehabilitation is described in the theories of rehabilitation modified surgery and procedure modified rehabilitation. The therapist practices procedure modified rehabilitation to ensure that the surgical procedure is not overstressed, with the quality of tissue and fixation dictating the ability of the physical therapist to aggressively advance rehabilitation. The surgeon practices rehabilitation modified surgery to achieve the fixation that will best allow the physical therapist to perform an aggressive rehabilitation program. The interplay of these two practices allows the patient to achieve the best possible outcome after surgery.

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37.2 Immobilization, Bracing, and Weight-Bearing Status

Immobilization after a surgical procedure aims to allow the repaired or reconstructed tissue to heal in the ideal position as well as preventing undue stress to a fragile graft. The extent of immobilization depends on a number of factors, including the quality of the tissue that was operated on and how the biomechanics of the knee joint will stress these sites. For a lateral release, there is no period of immobilization because there was no tissue reconstructed or repaired. Conversely, for procedures involving soft tissue repair without rigid fixation (MPFL reconstruction and medial imbrication) and nonoperative management, soft tissue healing and scarring lead to increased stability respectively, both of which require longer periods of immobilization. Bony surgeries (tibial tubercle osteotomy and trochleoplasty) may also require a period of immobilization to allow for full healing, lasting from 4 to 6 weeks. Despite these biological time frames for healing, some surgeons still do not recommend immobilization, as they consider their surgical fixation to be adequate to withstand the rigors of motion. The results of this survey (Fig. 37.1) demonstrate the variety of opinions on immobilization and lead to the recommendation that each patient be given a recommendation on an individual basis based on the quality of the fixation and the nature of their impairments.

However long the period of immobilization, this should not be absolute immobilization, such as in a typical casting protocol. After a procedure which so closely involves the joint, a period of prolonged immobilization may result in arthrofibrotic changes, limiting the functional range of motion of the knee. These changes will require extensive rehabilitation or manipulation under anesthesia to correct, and will limit function until they are resolved. This can be prevented with early postoperative rehabilitation, which includes gentle mobilization and protected range of motion exercises to preserve joint mobility, while still allowing adequate healing time. With the exception of nonoperative management, the most common recommendation for all procedures is early removal of the immobilizer for physical therapy for range of motion and quadriceps strengthening exercises (Fig. 37.2).

Postoperative bracing is typically the preferred method for immobilization, usually in a straight-leg immobilizer or a hinged long-leg immobilizer. The

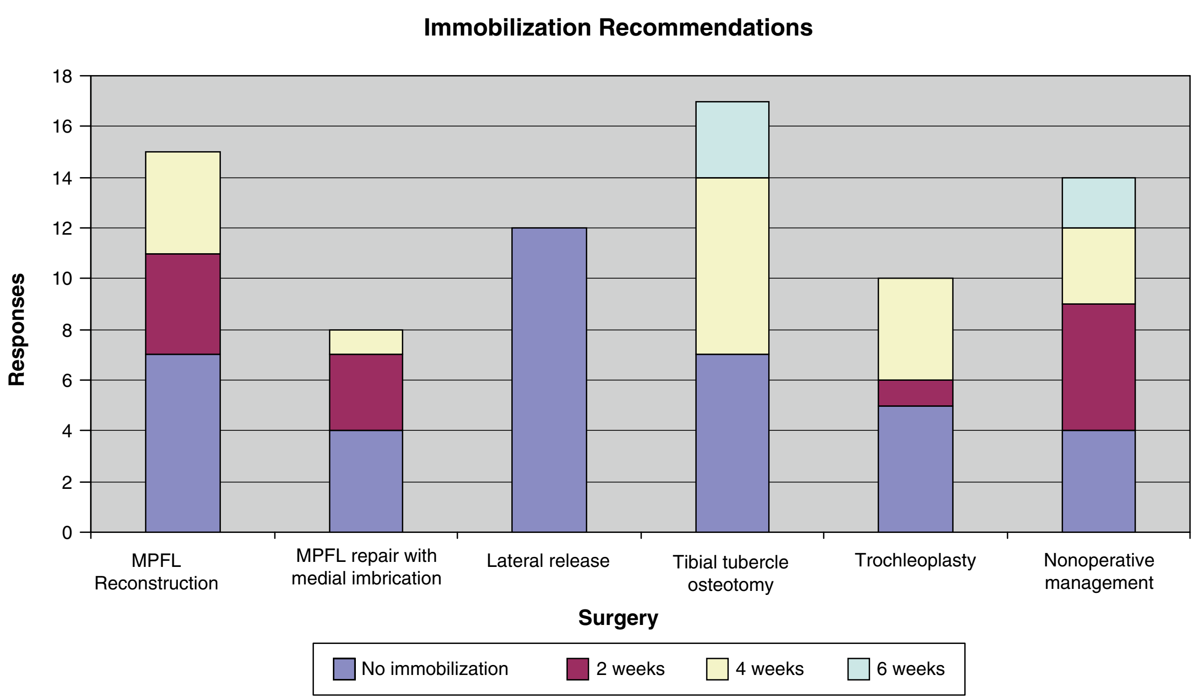

Fig. 37.1 Survey results for recommended immobilization times for each procedure

advantage of a hinged immobilizer is allowing a range of flexion for sitting, while maintaining an exact angle or range of weight bearing, usually prescribed to prevent placing excessive stress on the fixation. Recommendations of limiting flexion to 30°, 60° and 90° were each made for trochleoplasty, although whether these were weight bearing or non-weight bearing was not clarified. Another recommendation was to use a hinged brace that allows the patient's available range, with a gradual progression. Some respondents offered that they prefer to use a simple knee sleeve to maintain the position of the patella without limiting the motion of the patient. Overall, there was no consensus for either brace type or the ideal ranges of motion to allow while wearing a hinged immobilizer.

Presented in Table 37.1 are the recommendations for ceasing the use of a brace. Time based recommendations are the most common, presumably in respect to

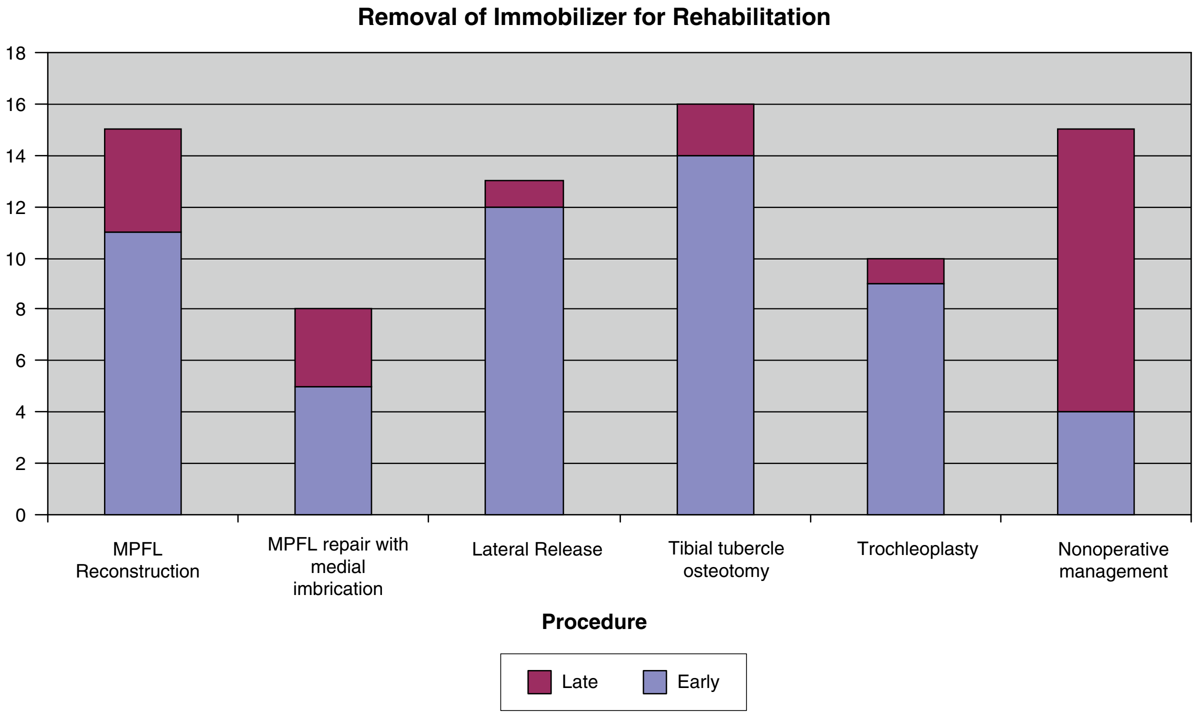

Fig. 37.2 Schedule for immobilizer removal for PT treatment. Early is defined within the first week of surgery. Late is the period of 2–4 weeks post-operative

Table 37.1 Survey results – discharge parameters for post-operative bracing

Answer options	After prescribed time	After gait pattern is normalized	After patient can complete a straight-leg raise without quadriceps lag	As function allows
MPFL reconstruction	8	2	3	0
MPFL repair with medial imbrication	4	1	2	0
Lateral release	3	1	2	0
Tibial tubercle osteotomy	7	1	1	1
Trochleoplasty	7	0	1	0
Nonoperative management	7	1	2	0

biological healing times. The normalization of the gait pattern serves as a functional measure, requiring full active knee extension, similar flexion excursions and normal spatiotemporal characteristics of gait (step length, time, cadence). The ability to complete a straight-leg raise without a quadriceps lag signifies that the quadriceps has regained enough strength to adequately control the knee, potentially reducing the amount of stress placed on the repaired or reconstructed structure. Radiographic evidence of tibial tubercle osteotomy healing signifies the time frame for immobilizer discharge. The most detailed progression of immobilization for nonoperative management calls for a fixed 20° flexion angle for 2 weeks; allowing motion from 20° to 60° of flexion for an additional 2 weeks; and finally 10° to 90° for weeks 5 and 6. This progression keeps the patella engaged in the trochlea early on, followed by a progressive restoration of motion after scar formation has begun (Fig. 37.3).

Weight-bearing recommendations for each procedure can be found in Fig. 37.4. The majority of surgeons surveyed do not recommend limiting the amount of weight born by patients save for self-limiting to increase comfort. A few surgeons recommend limited weight bearing in the first week after surgery; however, the trend is to increase weight bearing by one level each week, with partial weight bearing in most cases by postoperative week 3. When immobilized in extension and bearing weight, the quadriceps are not required to be as active as in a free situation, which results in decreased stress on the surgical site. Increased caution is used with tibial tubercle osteotomies due to the risk of developing a stress reaction at the surgery site, although weight bearing is quickly increased after the early postoperative period.

37.3 Range of Motion

37.3.1 Continuous Passive Motion

Continuous passive motion has been suggested as a method of restoring motion postoperatively and as prophylaxis for a stiff knee. The value is in question in most procedures, although evidence exists to support use in postoperative cartilage surgeries to aide in cartilage nutrition. The results (Table 37.2) of our survey demonstrate this controversy, without a clear consensus in any one of the procedures except for trochleoplasty. As this procedure involves modification of a weight-bearing surface, it may benefit from continuous passive motion to help restore the integrity of that surface. In those that do recommend passive motion, there is not a consensus on the appropriate duration. It would be wise to recommend passive motion only until the patient can achieve 90° of flexion independently, if at all.

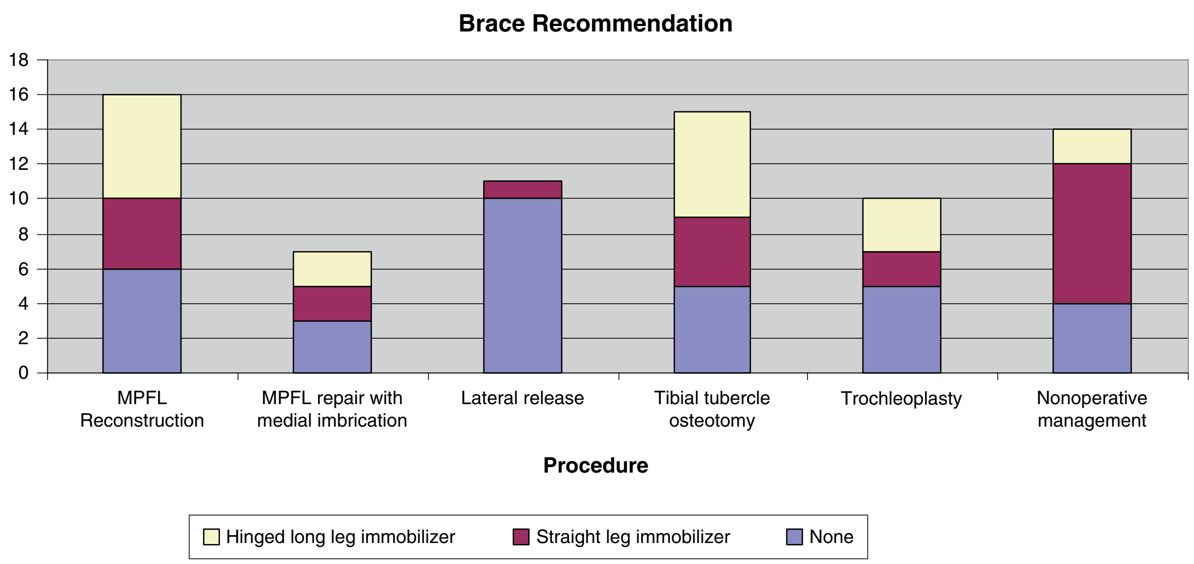

Fig. 37.3 Survey results – Post-operative brace recommendation

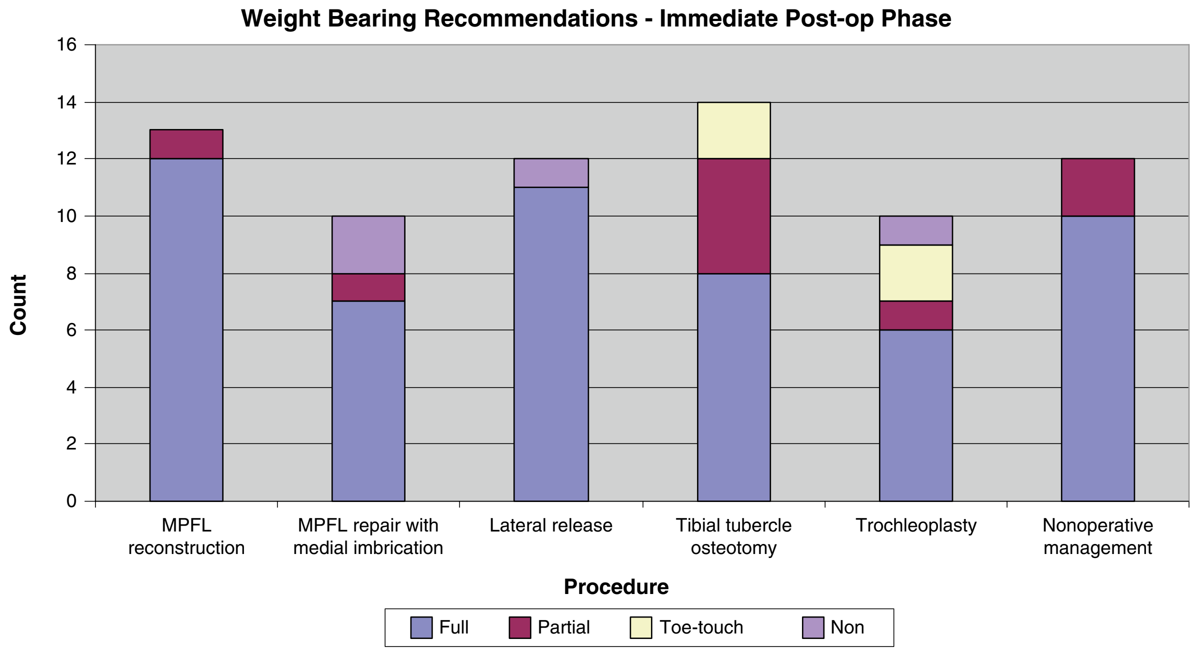

Fig. 37.4 Survey results for weight-bearing status. Categories are defined as follows:
- Full – full weight bearing and weight bearing as tolerated;
- Partial – 50% weight bearing;
- Toe-touch – 25% weight bearing;
- Non – non-weight bearing

Table 37.2 Surgeon recommendations for continuous passive motion

Do you currently recommend CPM?			Duration			
	No	Yes	1 week	2 weeks	3 weeks	4 weeks
MPFL reconstruction	7	7	1	2	0	3
MPFL repair with medial imbrication	6	6	1	2	0	1
Lateral release	8	4	1	1	0	1
Tibial tubercle osteotomy	9	6	0	1	1	2
Trochleoplasty	2	8	0	1	1	3
Nonoperative management	12	3	1	0	1	1

37.3.2 Active and Passive Range of Motion

While in postoperative rehabilitation, the physical therapist aims to restore range of motion, both passively and actively. This motion must be balanced against the integrity of the repair, with some surgeons limiting the range of motion for either active or passive activities. The results of the survey are shown in Table 37.3 (passive) and Table 37.4 (active) with individual surgeon comments following each table.

37.4 Open and Closed Kinetic Chain Quadriceps Exercise

Active use of the quadriceps after surgery needs to be balanced. This powerful muscle, necessary for locomotion and function, tends to shut down after surgeries involving the knee joint, making restoration of quadriceps strength a goal in rehabilitation. However, quadriceps activity causes patellar motion and directly affects at least some of the dynamics of each of these surgical procedures. Balancing the delicate nature of

Table 37.3 Passive range of motion limitations with respondent comments below

Is there any reason to restrict immediate passive range of motion?If so, please comment		
Answer options	Yes	No
Medial patellofemoral ligament reconstruction	4	11
MPFL repair with medial imbrication of the quadriceps	3	5
Lateral extensor retinaculum release	0	12
Tibial tubercle osteotomy with screw fixation	6	9
Trochleoplasty	3	7
Nonoperative management of patellar dislocation	6	9

- Passive range of motion should be limited:
  - In 30° of flexion for 2 weeks in order to have the patella give a compression force to the cartilage
  - Within reason. ROM should progress gradually as the pain diminishes
  - To secure fixation device and assure correct healing
  - To have some retinacular healing before ROM and also like to slow down the patient's progress for same reason
  - As it can provide too much stress on the suture
  - For 15 days, as it is better to avoid passive patellar motion in nonoperative treatment
  - For screw fixation restricted until 100° (for tibial tubercle osteotomy)
  - For MPFL reconstruction because we do not know the exact flexion angle for fixation to obtain an isometric/anatomic placement. Motion can compromise graft fixation
  - With nonoperative management because we want scar formation to reconstruct the medial retinaculum
- Passive range of motion should not be limited:
  - For lateral release to heal in distension
  - If the surgery is adequate there is no reason to restrict, if the surgery is inadequate it should not have been done. There is logic in restricting full extension to reduce MPFL stress, but again if the surgery is adequate, this is not necessary

Table 37.4 Active range of motion limitations with respondent comments below

Is there any reason to restrict immediate active range of motion? If so, please comment		
Answer options	Yes	No
Medial patellofemoral ligament reconstruction	6	9
MPFL repair with medial imbrication of the quadriceps	3	5
Lateral extensor retinaculum release	0	12
Tibial tubercle osteotomy with screw fixation	8	6
Trochleoplasty	3	6
Nonoperative management of patellar dislocation	7	7

- Active range of motion should be limited:
  - To secure fixation device and assure correct soft tissue healing
  - It creates too much stress on the graft (MPFL reconstruction)
  - It creates too much stress on the suture (medial imbrication)
  - It creates too much stress on the osteotomy (tibial tubercle osteotomy)
  - It creates too much shear stress (trochleoplasty)
  - It creates risk of non healing (nonoperative management)
  - If the trochlea is deficient and all the load is placed on the MPFL, then restricting full extension is logical, but in the end if the surgery was adequate, no restriction is necessary, if the surgery was inadequate it should not have been done.

the surgical procedure and the importance of regaining quadriceps strength leads to varying recommendations for when to begin quadriceps strengthening exercises, whether they be in open or closed kinetic chain. The results from the poll of surgeons concerning the timing for beginning quadriceps exercise and the angles which are considered safe are presented in Tables 37.5–37.12.

The responses gained from this survey show a variety of recommendations for when to begin either form of quadriceps exercise postoperatively for MPFL Reconstruction, ranging anywhere from immediately postoperatively to 6 weeks after surgery. Additionally, no single range (Table 37.7) was identified as optimal for training in either closed or open chain. Unrestricted range was the most frequently identified response, however, as the knee nears extension, the patella becomes increasingly free from the stability of the trochlea, potentially stressing the reconstruction site. Therefore, a medial patellar taping can be employed to attempt to place the reconstruction on slack. This precaution, along with allowing the patient's report of pain or

Table 37.5 Recommendation for beginning **Open Kinetic Chain** exercise

When do you begin open kinetic chain quadriceps exercise?						
Answer options	Immediately	2 weeks	3 weeks	4 weeks	6 weeks	8 weeks
MPFL reconstruction	3	2	3	2	4	0
MPFL repair with medial imbrication	2	2	3	0	1	0
Lateral release	9	1	1	0	1	0
Tibial tubercle osteotomy	2	2	2	2	3	2
Trochleoplasty	1	2	0	1	3	2
Nonoperative management	3	2	2	3	3	1

Table 37.6 Recommendation for beginning **Closed Kinetic Chain** exercise

When do you begin closed kinetic chain quadriceps exercise?					
Answer options	Immediately	2 weeks	3 weeks	4 weeks	6 weeks
MPFL reconstruction	6	3	2	2	0
MPFL repair with medial imbrication	5	2	2	1	0
Lateral release	9	3	0	0	0
Tibial tubercle osteotomy	5	1	2	3	3
Trochleoplasty	4	2	0	1	2
Nonoperative management	5	2	2	2	4

Table 37.7 Quadriceps strengthening recommendations post-MPFL reconstruction

MPFL reconstruction		No exercise	0–30	0–45	30–60	45–90	60–90	90–120	Unrestricted
Weeks 1 and 2	Open chain	4	0	0	2	0	0	0	4
	Closed chain	2	0	1	1	0	0	0	4
Weeks 3 and 4	Open chain	1	0	2	0	0	2	0	1
	Closed chain	0	0	2	0	1	0	0	1
Weeks 5 and 6	Open chain	1	0	0	0	1	0	1	4
	Closed chain	0	0	0	0	1	0	2	2
Weeks 7 and 8	Open chain	0	0	0	0	0	0	0	6
	Closed chain	0	0	0	0	0	0	0	5

Table 37.8 Quadriceps strengthening recommendations post-MPFL repair with medial imbrication of the quadriceps

MPFL repair with imbrication		No exercise	0–30	0–45	30–60	45–90	60–90	90–120	Unrestricted
Weeks 1 and 2	Open chain	5	0	1	0	0	0	0	3
	Closed chain	3	0	1	0	0	0	0	2
Weeks 3 and 4	Open chain	1	0	1	1	1	1	0	1
	Closed chain	0	0	2	0	0	1	0	1
Weeks 5 and 6	Open chain	1	0	0	0	1	1	0	3
	Closed chain	1	0	0	0	1	0	1	2
Weeks 7 and 8	Open chain	1	0	0	0	0	0	0	4
	Closed chain	0	0	0	0	0	0	0	4

Table 37.9 Quadriceps strengthening recommendations post-lateral release

Lateral release		No exercise	0–30	0–45	30–60	45–90	60–90	90–120	Unrestricted
Weeks 1 and 2	Open chain	1	1	1	0	0	0	0	7
	Closed chain	1	1	1	0	0	0	0	5
Weeks 3 and 4	Open chain	1	0	0	0	0	1	0	4
	Closed chain	0	0	2	0	0	0	0	3
Weeks 5 and 6	Open chain	1	0	0	0	0	0	0	4
	Closed chain	0	0	0	0	1	0	0	4
Weeks 7 and 8	Open Chain	1	0	0	0	0	0	0	3
	Closed chain	0	0	0	0	0	0	0	4

Table 37.10 Quadriceps strengthening recommendations post-tibial tubercle osteotomy

Tibial tubercle osteotomy		No exercise	0–30	0–45	30–60	45–90	60–90	90–120	Unrestricted
Weeks 1 and 2	Open chain	4	2	1	1	0	1	0	2
	Closed chain	5	0	0	1	1	0	0	3
Weeks 3 and 4	Open chain	3	1	0	1	0	2	0	2
	Closed chain	3	1	0	0	0	0	0	2
Weeks 5 and 6	Open chain	2	0	1	0	0	2	0	4
	Closed chain	0	1	2	1	0	0	0	2
Weeks 7 and 8	Open chain	1	0	0	0	0	0	1	5
	Closed chain	0	0	0	0	0	1	0	5

apprehension to guide progression, should allow for early quadriceps strengthening without undue stress to the graft.

The medial imbrication of the quadriceps adds an additional layer of complexity to the rehabilitation of this procedure. Medialization of the quadriceps with sutures does not provide a rigid, secure fixation, leading more surgeons to recommend delaying exercise until weeks 3 and 4 postoperatively, although some surgeons still recommend unrestricted exercise early on. Realistically, after an extensive surgery such as this one, the comfort of the patient will dictate the range of

Table 37.11 Quadriceps strengthening recommendations post-trochleoplasty

Trochleoplasty		No exercise	0–30	0–45	30–60	45–90	60–90	90–120	Unrestricted
Weeks 1 and 2	Open chain	3	0	0	2	0	0	0	3
	Closed chain	3	0	0	2	1	0	0	2
Weeks 3 and 4	Open chain	3	0	0	0	0	0	0	3
	Closed chain	2	0	2	0	0	0	0	2
Weeks 5 and 6	Open chain	2	0	1	0	0	0	0	2
	Closed chain	0	1	1	0	1	0	0	1
Weeks 7 and 8	Open chain	1	0	0	0	0	0	0	4
	Closed chain	0	0	1	0	0	0	0	3

Table 37.12 Quadriceps strengthening recommendations for nonoperative management of patellar dislocations

Nonoperative management		No exercise	0–30	0–45	30–60	45–90	60–90	90–120	Unrestricted
Weeks 1 and 2	Open chain	7	1	0	0	0	0	0	1
	Closed chain	5	0	0	0	0	0	0	2
Weeks 3 and 4	Open chain	5	0	1	0	0	0	0	2
	Closed chain	2	0	2	0	0	0	0	2
Weeks 5 and 6	Open chain	2	0	2	0	0	0	0	3
	Closed chain	0	1	0	0	0	0	0	4
Weeks 7 and 8	Open chain	1	0	0	0	1	0	1	3
	Closed chain	0	0	1	0	0	0	0	4

motion in which they will exercise, making the varied recommendations all feasible for performing quadriceps exercise. Again, to assist in the healing of the medial patellofemoral ligament repair, a medial taping is recommended for these patients.

The majority of recommendations are for unrestricted quadriceps strengthening after an isolated lateral release. With no structure being repaired or needing to heal in a shortened position, free range of motion and strengthening are encouraged. Some recommendations even indicated that more motion was better to prevent the lateral structures from healing in a shortened position.

The main concern with quadriceps strengthening after a tibial tubercle osteotomy is placing too much stress on the screws used to secure the osteotomy, potentially causing a fracture or stress reaction. Boney healing typically occurs within 4–6 weeks and this healing is aided by the placement of screws. This leads to most surgeons recommending exercise by week 5, with varied responses before this time frame. It would be wise to recommend limited weight bearing outside of full extension to reduce the load placed on the quadriceps and therefore the fixation. Allowing the patient's symptoms to dictate progression seems to be the most pragmatic solution early on, until radiographic evidence of healing is found.

Trochleoplasties are a relatively new surgery, with very little research available. Surgeons recommend exercise in mid range knee flexion to provide a compressive force on the trochlea from the patella. Exercise is typically prescribed by week 5 but is not totally precluded in the early postoperative phase.

In non-operative management of patellofemoral dislocations, quadriceps strengthening is not typically encouraged until 5 weeks of relative immobilization have been completed due to the desire for scarring of the medial structures to restore some static stability to the patellofemoral joint. After this time, quadriceps strengthening should be carried out in an apprehension free range. The addition of medial patellar taping or a patellar stabilizing orthosis can add to the patient's sense of security. The most challenging positions will be in less than 30° of flexion, as this is when the patella disengages with the trochlea.

37.5 Conclusion

Presented in this chapter are the various recommendations of expert surgeons on the postoperative management of surgeries aimed at correcting patellofemoral instability. As no consensus opinion could be reached for most of the questions asked, ranges and individual responses were presented. When in doubt, consider biological healing time frames and basic biomechanical principles when determining postoperative treatment plans. Patient reports of pain and other symptoms provide a useful guide for directing treatment. Further research is needed to develop the optimal evidence based treatment paradigm.

Appendix

Please Tell Us About Your Experience as an Orthopedic Surgeon

1. How many years have you been practicing as an orthopedic surgeon?
2. Aside from patellofemoral surgeries, what other surgeries do you routinely perform?
3. How many times per year do you perform the following to correct patellar dislocation/subluxation?
   - Medial patellofemoral ligament reconstruction
   - Medial patellofemoral ligament reconstruction with medial imbrication of the quadriceps
   - Lateral retinacular release
   - Tibial tubercle osteotomy with screw fixation
   - Trochleoplasty
4. If you perform tibial tubercle transfers, do you perform them in isolation or with a combined lateral retinacular release?

Please only answer questions based on the surgeries you perform. If you do not perform a listed surgery, please mark N/A or omit an answer.

Please answer the questions about nonoperative management of patellar dislocation.

If you have any additional comments, please add them to the comment fields.

Immobilization and Bracing

1. For each surgery that you perform, how long do you require immobilization?
2. At what point can the immobilization device be removed for physical therapy?
3. What type of postoperative brace do you recommend?
4. When do you discontinue the use of the brace?
5. What weight-bearing restrictions do you place on patients and for how long?
   - Full weight bearing (Full)
   - Weight bearing as tolerated (As Tol)
   - Partial weight bearing (50% body weight) (Partial)
   - Toe-touch weight bearing (25% body weight) (Toe Touch)
   - Non-weight bearing (Non)

Range of Motion

1. Is there any reason to restrict immediate passive range of motion? If so, please comment.
2. Is there any reason to restrict immediate active range of motion? If so, please comment.
3. Do you currently recommend continuous passive motion?

Quadriceps Strengthening

1. When do you begin open kinetic chain quadriceps exercise?
2. Do you limit range of motion for open kinetic chain exercises?
3. When do you begin closed kinetic chain quadriceps exercise?
4. Do you limit range of motion for closed kinetic chain exercises?

Errors and Complications in Patellofemoral Surgery

38

Karl Fredrik Almqvist, Pieter Van-Sintjan, Pieter-Jan De Roo, Peter Verdonk, Rene Verdonk, and Elizabeth Arendt

There are different treatment options to address different patellofemoral problems each with their pearls and pitfalls. When considering a surgical procedure for a patient with anterior knee pain, you have to follow an algorithm to approach the problem and select the best treatment option (Fig. 38.1). In younger patients with isolated patellofemoral arthrosis, replacement of the joint surfaces becomes a serious consideration. As newer prosthesis designs begin to give better results, one must reconsider alternative means of treatment, weighing the advantages and disadvantages. The main surgical options (after basic procedures such as debridement, release and realignment have been tried and have failed) include anterior or anteromedial transfer of the tibial tubercle to shift contact stress and unload the patellofemoral joint, removal of the patella (patellectomy), and articular cartilage resurfacing either by osteochondral transfer or by cartilage cell implantation. Most important, however, the surgeon must be sure to identify any other possible source of pain and treat those first.

Each symptomatic patient undergoing patellofemoral surgery must preoperatively undergo a thorough clinical examination, as well as imaging (conventional x-rays to determine any patellofemoral problems such as Patella Alta/Baja, trochlear dysplasia and patellofemoral osteoarthritis) CT for patellar tilt and a TT-TG measurement to determine any maltracking due to a too lateral or medial patella in relation with the trochlea. If these imaging examinations are not performed preoperatively, the incidence of failure of the patellofemoral surgery is increased. (The radiologist should be aware of the proper imaging of the x-rays for the true lateral view.)

In this chapter, we will discuss the reasons and rates of failure of bony surgery, soft-tissue surgery, cartilage repair and the patellofemoral arthroplasty.

38.1 Bony Surgery

38.1.1 Tibial Tubercle Transposition

The goal of a successful transposition of the tibial tubercle is to remove pressure from an arthritic portion of a joint to achieve symptomatic relief. This also forms

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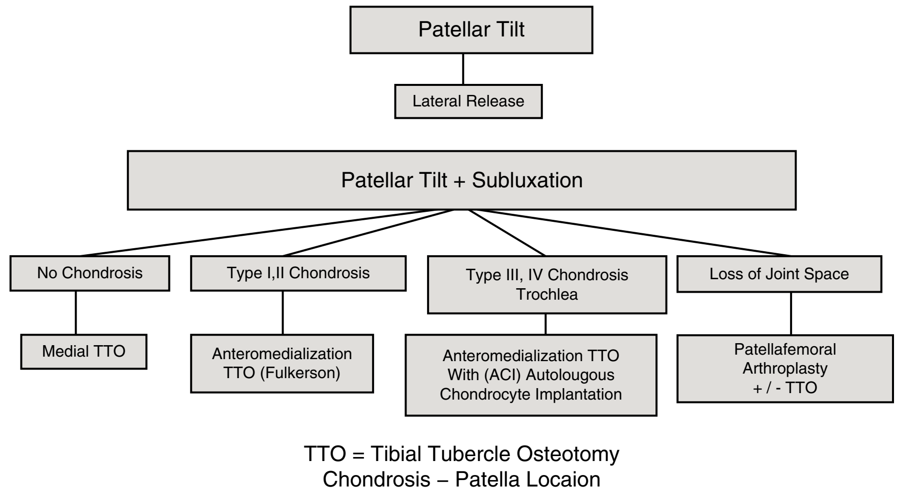

Fig. 38.1 Algorithm to address a patient with patellofemoral disease. Different types of chondrosis according to Fulkerson: *I* inferior pole of the patella, *II* lateral facet, *III* medial facet (frequently associated with trochlear lesions), and *IV* proximal pole (IVa) or panpatellar (IVb).

the basis for other osteotomy-based corrections of patellofemoral malalignment secondary to valgus or rotational deformities, but these are not commonly encountered causes of isolated patellofemoral arthritis.

Realignment of the extensor mechanism has been thought to provide relief because of the restoration of normal alignment and mechanical function and because it unloads a fragmented painful surface of the patellofemoral joint. The older procedures, such as the Maquet and Hauser procedures, did not account for the variability in the normal values of the Q angle or the potential increase in loading of the medial patellar facet (and thus the subsequent possibility of medial tibiofemoral compartment arthritis) caused by overzealous medial transfer of the tibial tubercle [23, 38].

The key principles in successful tibial tubercle transfer for the treatment of patellofemoral arthritis are as follows:

1. Restore or maintain proper balance of the extensor mechanism.
2. Transfer load off a painful, degenerated area onto better cartilage. Transfer the tibial tuberosity medially to unload the lateral aspect of the patella and anteriorly to unload the distal aspect of the patella.
3. Be sure to treat retinacular sources of pain.
4. Perform tibial tubercle transfer in a way that allows early motion and prompt healing.

38.1.1.1 Medialization/Distalization of the Tibial Tubercle

Medialization of the tibial tubercle has been described by Elmslie and Trillat. This procedure is performed when patellar instability and pain is existing, and that preoperative imaging shows an increased lateral displacement of the patella. This situation could be associated with cartilage damage in the lateral patellofemoral joint with subsequent presence of a painful subchondral overpressure. The most common complication when performing the procedure is an overcorrection with subsequently a painful medial patellofemoral joint (Fig. 38.2). This could be avoided by precise preoperative imaging, telling you how many mm the tibial tubercle should be medialized. Other complications present with this bony surgery are breakage of the bony fragment that is medialized, as well as a pseudarthrosis of the osteotomy site. This latter could be diminished by making a manual osteotomy with chisels instead of using a motorized saw.

Next to a too lateral patella, it can also be high-riding (Patella Alta), as diagnosed by conventional imaging criteria. This can give a symptomatic delayed entry of the patella in the trochlear sulcus with knee flexion, necessitating a distalization of the tibial tubercle. When correcting this Patella Alta one should be very cautious not to overcorrect the height resulting in a Patella Infera or Baja with painful initial knee flexion. Complications associated with this procedure are also the ones associated with medialization of the tibial tubercle, e.g., breakage of the bony fragment or pseudarthrosis.

Patella Baja is most often seen after several knee surgeries or a direct trauma (Fig. 38.3). It is also seen when a tibial tubercle transposition is performed in a skeletally immature patient. In Patella Baja it has been reported that an open release of the captured infrapatellar fat pad followed by mobilization could be indicated. If the length of the patellar tendon is not decreased, with a

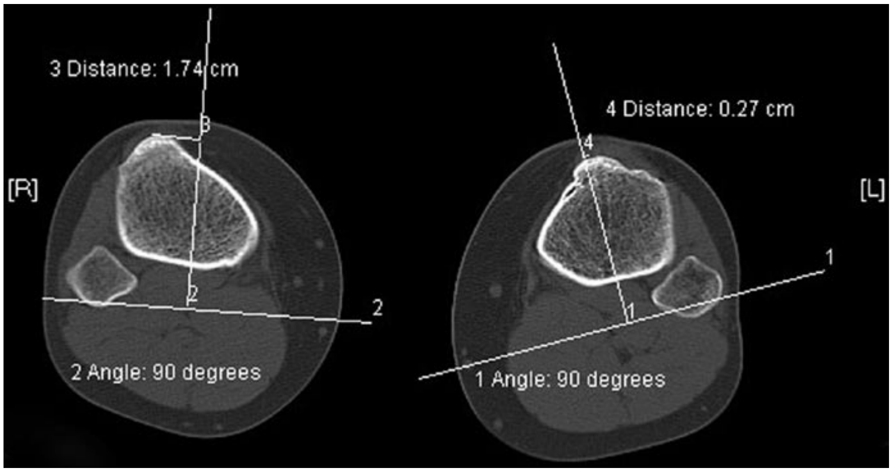

Fig. 38.2 Overcorrection after a medialization of the tuberositas tibia (TT-TG 0.27 cm) with a painful medial patellofemoral joint

Fig. 38.3 Postsurgical induced Patella Baja after a tuberositas tibia transposition

Patella Baja, a proximalization of the tibial tubercle could be indicated.

Conclusion: The most common error when performing a medialization and/or a distalization of the tibial tubercle is an overcorrection. This leads respectively to a painful medial patellofemoral joint and to a Patella Baja with painful initial knee flexion which may also be reduced. A correction of this overcorrection is advised with normalization of the patellofemoral indices.

38.1.1.2 Anteromedial Tibial Tubercle Transfer

Results from anteromedial tibial tubercle transfer have been very good [22, 24, 25, 30, 36]. Results after anteromedial tibial tubercle transfer are best when there are distal or lateral, or both, facet patellar articular lesions; it is less good when there are proximal (direct impact, blunt injury) and medial facet lesions. Arthroscopy of the patellofemoral joint before performing the osteotomy will help determine the most appropriate approach to realignment, such that normal tracking may be restored without adding load to a lesion [5, 26, 55]. Straight anteriorization of the tibial tubercle as provided by the Maquet procedure has yielded less favorable results, [8, 12, 40] with numerous problems reported [34]. This procedure, accordingly, is not frequently chosen today.

The versatility, stable fixation, early motion, and lower morbidity of an oblique osteotomy and anteromedial tibial tubercle transfer approach to patellar decompression and realignment make this appealing, particularly when there are distal and lateral articular lesions [5, 55]. In a long-term follow-up study, Buuck and Fulkerson found that increased activity and return to sports was possible in most patients after anteromedial tibial tubercle transfer [18].

Blood loss is minimal with this type of surgery, incisional pain is less severe than that following knee arthroplasty (since the incision is pretibial instead of peripatellar), and immediate motion is possible (and encouraged). Skin problems and compartment syndrome have not been noted following transfer of the tibial tubercle through a flat, oblique osteotomy. Osteotomies are less desirable in patients who smoke, are grossly obese, or are diabetic, but they are attractive for younger patients for whom longevity is expected.

A more recent study has shown that tibial fracture is more likely if the tibial osteotomy creates a distal stress-riser [54]. In other words, technical precision is of great importance in achieving an optimal result. Of course, transferring load onto healthy articular cartilage and off diseased, painful cartilage is the goal of this type of surgery. When patellofemoral changes are diffuse, as in a crush injury or following patellar fracture, patellofemoral replacement may become necessary. In general, however, anteromedial transfer of the tibial tubercle is the best option in a young patient with distal and/or lateral patellar articular lesions, even when there is bone on bone laterally.

Straight anteriorization of the tibial tubercle is an alternative to patellofemoral replacement. This procedure has been used infrequently because of the deformity created by excessive anteriorization of the tibial tubercle and the concern about skin necrosis, nonunion, and compartment syndrome. The idea behind this technique is to diminish load on a defective or arthritic patella. Results with straight anteriorization procedure were compromised by complications of skin necrosis and compartment syndrome [8, 59]. The tendency with such surgery, which involves placing a bone block behind the elevated tibial tubercle, is to anteriorize too much, sometimes with disastrous results. Alternatively, one may create an oblique osteotomy deep to the tibial tubercle to shift the tibial tubercle in an anteromedial direction, achieving realignment (which frequently is necessary in patients with excessive lateral pressure and resulting arthrosis) and anteriorization [10, 18, 22, 30, 57].

By creating a steep osteotomy angled from the medial patellar tendon and directing an osteotomy posterolaterally under direct vision while retracting the tibialis anterior muscle, it has been possible to achieve 15–18 mm of tibial tubercle anteriorization with minimal medialization. Skin slough, compartment syndrome, and nonunion are rare when the procedure is done properly and is fixed securely with screws. This alternative, although creating some prominence of the tibial tubercle, gives consistent relief of pain and improved function to patients who have a lateral facet patellar arthrosis with or without distal articular lesions. One may do a straight medial tibial tubercle transfer to realign the patella and weaken the tibia less, but fail to gain the benefit of patellofemoral decompression, which often is helpful in patients with patellofemoral arthrosis. Oblique osteotomy of the tibia does weaken this area, [62] so full weight bearing should be avoided for 6 weeks postoperatively. The concept behind this technique is to shift contact from the lateral and distal aspect of the patella onto intact proximal and medial articular cartilage.

Unfortunately, when a crush configuration exists, results are not as good with any anteriorizing procedure, because anteriorization moves the patella onto the crushed proximal cartilage which portends a less good result, based on the findings of Pidoriano et al. [52]. In other words, when a patient has, for example, fallen directly onto a knee or driven it into a dashboard, the more proximal patella is articulating at the time of impact because of the knee flexion in most such injuries. There frequently is injury also on the articulating medial and lateral femoral condyles with such impacts. Patients with this configuration of articular lesions tend not to do as well in our experience with anteriorizing procedures of the tibial tubercle presumably because contact stresses of the patella are shifted to more proximal patellar articular cartilage earlier in the flexion arc when the tibial tubercle is anteriorized. This is the same region that typically has been crushed. Anterior tibial tubercle transfer actually may put damaged proximal patellar cartilage into the functional day-to-day contact area of the patellofemoral joint. Tibial tubercle anteriorization by any method, including anteromedial tibial tubercle transfer, is less likely to render a satisfactory result when there has been a crush or dashboard type of injury. Therefore, this approach is not recommended in such patients [5].

Conclusion: The most common error when performing an anteromedialization of the tibial tubercle is also an overcorrection. This may lead to a medial patellofemoral joint with overpressure and pain. A correction of this overcorrection should be recommended when symptomatic for the patient.

38.2 Soft Tissue

38.2.1 MPFL

The prevention of recurrent patellar dislocation or subluxation is one of the main considerations for undertaking this operation [11]. This outcome postoperatively is mostly the standard in the literature. Nomura and Inoue and Cossey and Paterson stated that none of their patients reported recurrent patellar dislocation or subluxation postoperatively, whilst Nomura et al. and Drez et al. each reported one patient in each of their samples (24 and 15 respectively) who presented with a redislocation or subluxation when followed-up. Deie et al. reported that four patients presented at follow-up with patellar subluxations postoperatively [14, 16, 28, 47, 48].

A number of papers subjectively assessed patient satisfaction of this. Drez et al. and Schottle et al. used the same four questions to determine subjective response. Drez et al. reported that ten subjects reported excellent results, three good results and one patient reported a poor outcome. Similarly Schottle et al. recorded eight patients had excellent scores, five patients with a good outcome and two patients with fair results. Both Steiner et al. and Gomes et al. asked whether their patients were satisfied with their outcome. Steiner et al. found that 33 patients were satisfied with their outcome, and would have the operation again. Gomes et al. reported that 13 patients were satisfied with their outcome, whilst two were not [47, 60, 61].

Postoperative complications are noted rarely. Nomura and Inoue [48] acknowledged that no postoperative complications were noted in their sample. Postoperative knee stiffness was a complication acknowledged in Drez et al.'s [16] paper, with one patient developing arthrofibrosis and one developing a wound dehiscence. Nomura et al. [48] reported that one of their subjects developed a postoperative haemoarthrosis. A minor wound infection postoperatively was reported in one patient by Nomura et al. [47] and Cossey and Paterson [14] Steiner et al. presented a patient who had a postoperative haematoma, and one patient who presented with graft advancement. Finally, pain caused by implants was a complication noted by Nomura et al. in 11 patients (41%) with pain from the staple fixation site, Steiner et al. reported one patient complained of pain from a screw at the medial epicondyle, and Cossey and Paterson reported one patient had pain from a tibial tuberosity transfer screw; both screws were removed [14, 47].

In a recent paper by M. Thaunat et al. [65] two painful situations following MPFL reconstruction were described: the MPFL too tight in flexion causing anterior knee pain and reduced flexion, and the MPFL too tight in extension causing an extensor lag. In the first situation the femoral attachment was too proximal to the recommended femoral insertion (Fig. 38.4), and in the second situation the MPFL had been tightened too tight in extension. A percutaneous release resolved the disturbed and painful situation in the two situations.

Conclusion: A painful patellofemoral joint may be induced by an overtensioning of the MPFL or by a malpositioning of the femoral insertion of the MPFL. A transcutaneous section of the MPFL has been

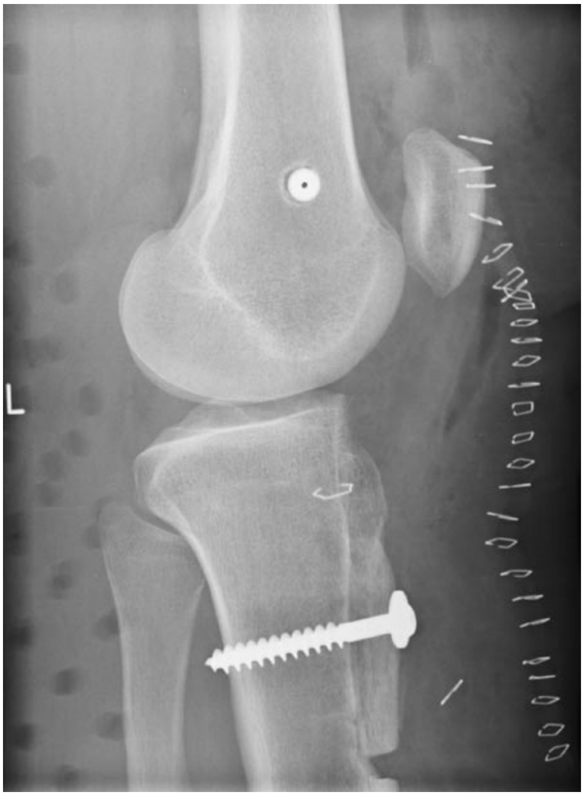

Fig. 38.4 A too proximal femoral fixation of the MPFL. The patient also had a tibial tubercle osteotomy with a distalization of the patella for a Patella Alta, though a gap is still seen at the distal part of the osteotomy

described with reduction and even eliminating the pain.

38.2.2 Lateral Release

During the 1980s, lateral retinacular release was well accepted as a primary surgical procedure for patients with resistant patellofemoral pain [21, 40]. Indications at that time were often ill-defined, and the main topic of discussion was whether to shave loose fragments of cartilage from the patella or trochlea. Since then, indications have been refined considerably, and we now recognize that lateral release is most appropriate for patients with a tight lateral retinaculum associated with rotational (tilt) malalignment of the patella [36, 55].

This mechanical configuration is often associated with an excessive lateral pressure syndrome, originally described by Ficat et al. [53]. In patients for whom non-operative treatment fails to relieve patellofemoral pain, pain relief may be obtained after lateral retinacular release as long as there is a good mechanical reason for doing the procedure. Proper preoperative evaluation followed by careful arthroscopy will determine whether lateral release is appropriate [27].

Hemarthrosis is the most common postoperative complication, but it is likely that the incidence of hemarthrosis has diminished with improved arthroscopic hemostasis techniques. Lateral release does nothing mechanically for a patella that is normally aligned. Overzealous or inappropriate lateral release can cause medial patellar subluxation, a particularly debilitating problem [31, 33]. Thus, lateral release should be used only for specific mechanical indications, and the extent of release should be limited to accomplish only the desired mechanical goal. In most patients, maintaining some vastus lateralis obliquus muscle support on the lateral side [19] is generally advisable and will help to reduce the complication of medial patellar subluxation. Fithian and Meier [19] recently emphasized the importance of restoring the medial patellofemoral ligament. Sallay et al., [58] however, pointed out that patients may experience pain after medial patellofemoral ligament reconstruction. The question that the surgeon should ask is whether any surgical procedure is likely to increase loading of a painful or potentially painful articular lesion. Myers et al. [46] have pointed out that proximal realignment does not work well in patients with patellofemoral pain and should be reserved for patients who have sustained a dislocation and require stabilization.

It is important not to "overdo" any medial repair procedure. Most often, these procedures are accompanied by a lateral release. Because early motion is so important in patients with patellofemoral disorders, any medial reconstruction should be secure enough to allow daily motion of the knee postoperatively. A modified program in which the patient removes the knee immobilizer once a day for 5 min to simply flex the knee 90° a single cycle daily during the first 5–6 weeks after surgery has been very helpful and has virtually eliminated postoperative stiffness problems after routine patellofemoral surgery. Of course, the repair must be secure enough to allow this.

Conclusion: An overzealous or inappropriate lateral release can cause medial patellar subluxation, a particularly debilitating problem. The lateral retinaculum should be reconstructed in these cases.

38.3 Autologous Cartilage Transplantation

Failure of autologous cartilage transplantation can be defined as a partial or full failure regardless of clinical outcome. Partial or full failure can be evidenced by delamination or detachment of the graft from the adjacent cartilage and subchondral bone as seen at arthroscopy or on magnetic resonance imaging, or as evidenced by fibrous or fibrocartilage repair.

The topic of cartilage treatment in the patellofemoral joint will be discussed in another chapter.

38.4 Patellofemoral Arthroplasty

Patellofemoral arthoplasty is going through a recent resurgence in interest with various new designs being introduced for general orthopedic use. Until recently, the clinical results of these prostheses were not considered predictable enough to allow widespread usage with success rates varying from 42% to 88%. Observed shortcomings in design features were perceived as a common problem. However, in the past 5 years, new devices with more accurate anatomic design that attempt to mimic patellofemoral joint function have been introduced. The typical indication for the use of PFA is in a younger patient who suffers disabling isolated arthritis or degeneration of the patellofemoral compartment with minimal or no malalignment who would otherwise consider undergoing a patellectomy because of the severity of the symptoms [13].

There are different reasons why a patellofemoral prosthesis fails. Disease progression in the tibiofemoral compartment is the most common prosthetic unrelated cause for revision. Other common reasons are component malposition, extensor malalignment with prosthetic instability, mechanical prosthetic-related symptoms and prosthetic type. Less commonly cited are persistent pain, patella fracture and loosening of the patella component, subluxation, polyethylene wear or overstuffing. Overall revision rates ranges between 5% and 28% [66].

Disease progression is the most common prosthetic unrelated cause for revision after PFA, but the current literature is lacking in regards to identifying preoperatively the "knee at risk." Few authors use commonly accepted radiologic scoring criteria such as those designed by Kellgren and Lawrence or Ahlback. Body weight and BMI as a measure of obesity is not recorded in any study. Obesity is a strong risk factor for knee arthritic progression [20]. In addition, the effect of obesity and body mass index (BMI > 30) have been associated with higher perioperative complication rates and reduced prosthetic survivorship in unicompartmental and total knee arthroplasty [3, 15, 42].

Prosthetic-related failures in these series frequently had recurrent patellofemoral instability. Often, this was related to surgical prosthetic malalignment or technical error especially in rotation of the femoral component that led to patellar subluxations, dislocations, or anterior knee pain. In contradistinction to unicompartmental arthroplasty [42], failures caused by loosening, especially of the femoral component, is uncommon in PFA. This was not true of uncemented components [4, 6].

Patella Alta poses the risk of impingement in early flexion of the patella component on the upper flange of the femoral prosthesis. This particularly was a common cause of residual clicks and catching sensations in the Lubinus and earlier designs with a high lateral profile to the femoral component. Argenson et al. [4] tried to compensate for this issue by insetting the femoral prosthesis more deeply which has the disadvantage of creating a femoral notch. Patella Infera can result from infrapatellar scarring after previous patellofemoral surgical treatment such as distal realignment or tibial tubercle osteotomy. This condition can aggravate further the known contact discrepancy of the prosthetic components in full flexion as first noted by Blazina et al. [6]. At more than about 90° flexion, the patella prosthetic polyethylene articulates with the native femoral condyle articular cartilage [63]. This occurs with current prosthetic design also, and remains an unresolved issue that may contribute to the incidence of reported persistent effusions after PFA. In another design driven issue, Tauro et al. noted that the Lubinus prosthesis did not conform to the altered anatomy of chronic lateral patellofemoral arthritis with lateral femoral wear. This necessitated the unusual measure of using the contralateral femoral prosthesis in approximately 1⁄2 the cases. This experience has led to an abandonment of the Lubinus prosthesis in favor of newer designs [1, 7, 41, 64].

Age limitations have not been defined for patellofemoral arthroplasty. This is largely because a relatively few number of younger patients in most series has skewed the total population. In the literature, cumulative average age of patients is more than 55 years. As yet, these statistics do not provide conclusive evidence in support of present claims of advantages of PFA over total knee arthroplasty in patients younger than 40 years [13, 56]. Nevertheless, the youngest patient noted to receive a PFA was 19 years old in two series and 22 years old in another [6, 29, 32]. No author has called attention to age as a contributing factor to failure. Merchant noted eight patients aged 30–45 years with an average knee activity score postoperatively of 83% [19]. There has been a cohort of patients younger than 55 years that did well at 5 years minimum follow-up [13]. Other factors documented to affect the outcome of knee arthroplasty surgery adversely are patients being treated under workman's compensation and loss of motion preoperatively [9, 43]. With regard to workman's compensation, similar experience is reported with PFA [3, 35].

The incidence of antecedent procedures was reported as high as 195 in 85 patients in one series and was characteristic of this population of patients with patellofemoral degenerative disease [29]. This history of multiple operations may have in part contributed to the high average of 17.6% postoperative manipulation and arthrofibrotic debridements.

Limitations in the literature are the relatively small number of studies and limited data available. The lack of reliable radiologic grading leaves questions as to defining the "isolated" patellofemoral treatment group. This definition is even more obscure in the patients with grade 3 chondrosis. Follow-up was hindered in most studies by significant loss to follow-up [6, 29, 35, 37]. Reported results may be biased by the use of older technology; however, all but one (Richards I) of the prostheses used in the studies are still in clinical use. There have been no Level I or matched Level II cohort studies offering a comparison of patellofemoral arthroplasty versus total knee replacement (Table 38.1).

As importantly, there are no prospective, comparative, randomized outcome studies of PFA versus other commonly advocated operative treatments for patellofemoral degenerative disease in the younger patient.

Patellofemoral arthroplasty remains an emerging technology in which the most recent results remain promising. For this reason, it is still considered a viable salvage procedure [1, 13, 17, 56]. However, the patient population most suited for this operation is not well defined. The recognized limitations of PFA mandate resorting to total knee replacement when required for knee malalignment, if comorbid risk factors for arthritic progression are prominent, and for overall balancing of the joint. Total knee replacement remains a reasonable option for isolated patellofemoral disease in all age groups and is the most proven option in the older patient [2, 13, 39, 44, 45, 49–51]. Careful adherence to established selection criteria for knee arthroplasty in general and to those established to date for patellofemoral arthroplasty offers the best opportunity for a successful outcome.

Overzealous or inappropriate lateral release can cause medial patellar subluxation, a particularly debilitating problem.

Conclusion: As in all knee joint replacements an endorotation of the femoral prosthetic component and an overstuffing of the patella should be avoided, and if not a reintervention with correction of this can be performed. Any ligamentous overtensioning of the patella should as well always be kept in mind during this kind of surgery.

Table 38.1 Additional factors that may adversely affect patellofemoral arthroplasty outcome

1. Multiple antecedent procedures or extensive soft-tissue trauma associated with residual quadriceps atrophy
2. History of previous arthrofibrosis in the same joint or other operative site
3. Ligamentous tibiofemoral instability
4. A knee that is post-meniscectomy
5. Chondrocalcinosis
6. High patient activity or bent knee use
7. Age younger than 40 years
8. Unrealistic patient expectations
9. A surgeon with lack of experience in arthroplasty or extensor mechanism realignment
10. Obesity (BMI > 30)
11. Patella Alta
12. Primary osteoarthritis
13. Male gender

38.5 Summary

- Primary patellofemoral surgery should be performed by an experienced surgeon.
- It requires careful preoperative planning.
- Overcorrection and pain and disability in the knee joint still happen.
- These second procedures require an exact preoperative determination by imaging to assure the expected normalization of the PF joint.

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39 Trochleoplasty for Symptomatic Trochlear Dysplasia in the Skeletally Immature Patient with Review of Fetal Anatomy

Jean-Luc Jouve, Yann Glard and Sébastien Parratte

Mechanical objective patellar instability may be related to an abnormal patellar course into the trochlear groove and this may be due to trochlear dysplasia [3,4]. D. Dejour classified the trochlear dysplasia into four stages according to the shape of the trochlea [3]. In this classification, the B grade is defined as a flat trochlea. We have the conviction that a flat trochlea should be considered as a genetically determined and inherited condition.

The lower extremity of the femur in human beings is characterized by an anterior groove in which the patella is held during motion. This groove separates the two lips of the trochlea. The lateral trochlear lip is more developed than the medial lip, creating an asymmetrical groove. An asymmetrical patellar groove with a protruding lateral side associated with an oblique femur is a specific mark of bipedal locomotion [6–9]. Some authors have published series comparing femurs in apes and humans. Apes present a wide and symmetrical groove on their distal femur, associated with a flat patella. In apes, the femoral shaft is vertical, showing no obliquity. There is no lateral dislocation stress applied to the patella during contraction of the quadriceps. In such mechanical conditions, there is no need for patellar containment in a deep groove, and no need for special lateral strengthening of the container.

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Tardieu and Dupont [7,8] have pointed out that femoral obliquity is acquired with the process of learning to walk and has no genetic determinism. It is an epigenetic feature. During hominid evolution, the protrusion of the lateral trochlear lip was probably acquired in response to femoral obliquity. We believe that it may have been selected and is genetically assimilated. Some studies have suggested that the shape of the lower extremity of the femur is determined early in development, long before standing and walking. Vries [10] described the fotal patella and showed that its morphology is comparable with that in adults from 16 weeks. Walmsley [11] described a patellar groove in the embryo, with the lateral trochlear lip more elevated than the medial lip. Gray & Gardner [5] showed that joint surfaces of the femoropatellar articulation are well shaped before both parts become properly fixed together. Doskocil [3] published the first series looking at the anatomy of the femoropatellar groove in the embryo. He established that the patellar groove is asymmetrical, with a lateral lip that is larger than the medial lip. However, this was a subjective observation, without any biometric data. Wanner published a biometric evaluation of the patellar groove in adults [13]. The biometry was achieved as shown in Fig. 39.1

In 2005, we conducted an anatomical study of the trochlear groove in human fetuses using the same protocol [4]. α, θL, and θM were remarkably stable through our series and are also very close to the angles measured in adults. There was no correlation between angles α, θL and θM and age, whereas lengths A, B, C, D, and E (see Fig. 39.1 for definition of these measurements) were strongly correlated with age (because of growth). There was no difference between Wanner's results and our series regarding angles α, θL, and θM. These results support the findings of Gray and Gardner (1950) and those of Doskocil (1985), who pointed out

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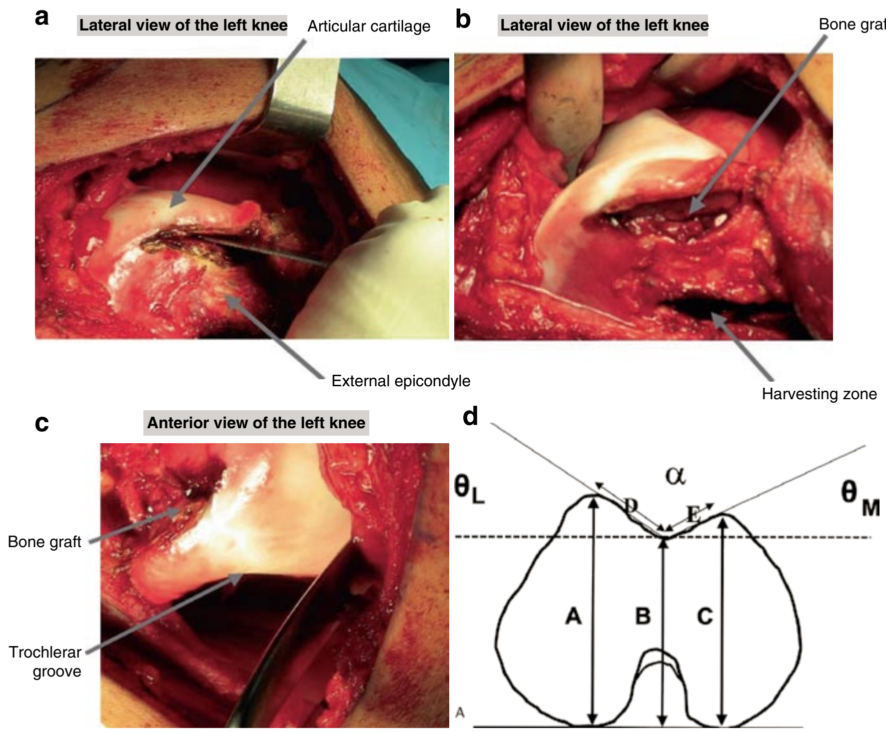

Fig. 39.1 Inferior view of the lower femoral epiphysis. (**a**) Lateral view of the left knee – articular cartilage and external epicondyle. (**b**) Lateral view of the left knee – bone graft. (**c**) Anterior view of the left knee (**d**) A maximum altitude of the lateral margin of the patellar groove (mm); B minimum altitude of the lowest point of the groove (mm); C maximum altitude of the medial margin of the patellar groove (mm); D width of the lateral side of the anterior patellar groove (mm); E width of the medial side of the anterior patellar groove (mm); θL angle formed by a line passing through the point of maximum lateral altitude and the lowest point of the groove and the horizontal; θM angle formed by a line passing through the point of maximum medial altitude and the lowest point of the groove and the horizontal; α angle of patellar groove, enclosed by the medial and the lateral aspect

that the joint surface morphology of the knee is determined very early during *in-utero* life.

Some fetuses in our series presented with a flat trochlea (angle α wide open), while most fetuses presented with a "normal" trochlea. We hypothesize that fetuses presenting with a flat trochlea would grow as adults with trochlear dysplasia. This is why we have the conviction that a flat trochlea should be considered as a genetically determined and inherited condition.

When true dislocation does occur during the childhood, the term "objective patellar dislocation" can be used. To restore the anatomy and preserve the knee from iterative dislocation that can lead to arthritis, several procedure have been proposed [3, 4]. Historically, Albee has been the first to propose in 1915 a bony procedure to modify the shape of the traclea: he described a lateral wedge augmentation of the trochlea [1]. Decades later, Masse [6] proposed a deepening trochleoplasty to improve the patellar stability and restore the trochlear course. All these procedures have been described in adults. In fact, there is a high risk to destroy the distal femoral growth plate in the kids when performing a trochlear deepening [2]. This procedure is therefore not recommended in growing children.

Unfortunately isolated medialization osteotomy is most of the time unable to prevent recurrent dislocation in cases of a flat trochlea. This is why in cases of objective patellar instability with a flat trochlea we perform an Albee lateral wedge augmentation trochleoplasty (modified in order to avoid any damage to the distal femoral physis).

39.1 Surgical Procedure

The patient is draped in the supine position under general anesthesia. A soft augment is placed under the homolateral buttock to facilitate the knee approach. A tourniquet is used. An antero-lateral approach is performed from the lateral side of the anterior tibial tuberosity distally to the lateral cortex of the femur proximally, at the level of the proximal pole of the patella. An associated medialization of the anterior tibial tuberosity is performed in all cases, associated with a distalization if needed. In kids with open anterior tuberosity physe, the medialization is performed according to the Grammont technique. A lateral patellar retinaculum resection is performed in every case.

The lateral wedge augmentation trochleoplasty is performed according to the Albee technique [1]. During the first step of the procedure a triangular shaped cortico-spongious graft is harvested from the lateral cortex of the femur after periosteal elevation. The long side of the triangle should be equal to the length of the trochlea and the short side is about 1 cm long. The second step is the trochlear osteotomy. Using a sharp osteotome, the osteotomy is performed 5 mm below the articular surface and up to the growth plate on the lateral aspect of the trochlea. Slightly and progressively, the lateral wedge is elevated using the osteotome, taking care not to create any fracture into the trochlear groove (Fig. 39.1a). The last step is the impaction of the graft into the osteotomy site. The short side of the triangle is impacted proximally and the top of the triangle distally. The graft is impacted press-fit to ensure its stability (Fig. 39.1b and c). Soft tissue closing in layers is then performed and a drain is left in place for 2 days. A cast is applied for 30 days. Passive range of motion physiotherapy is performed after cast removal at 1 month. Full weight bearing as well as active physiotherapy is authorized after 45 days and sport return started at 2 months.

39.1.1 Evaluation of the Results of Lateral Wedge Augmentation Trochleoplasty for Symptomatic Trochlear Dysplasia in the Skeletally Immature Patient

We retrospectively analyzed the results of the lateral wedge augmentation trochleoplasty for objective instability in the skeletally immature patient with trochlear dysplasia. We performed a retrospective study including 12 knees in 11 children (five girls and six boys) operated on by the same surgeon in our department between November 2000 and June 2004. Every kid had a history of at least one episode of patellar dislocation. Every patient had a lateral wedge augmentation trochleoplasty using an autograft and a patellar tendon medialization. Mean age in the series was 14 years old (min 12/max 17). All of the patients included had a Grade B dysplasia according to the Dejour classification (flat trochlea). Pre- and postoperatively, clinical and radiological (x-ray and CT scan) analyses were performed by an independent observer. The mean follow-up was 58 months (min 48 months/max 82). At final follow-up, none of the patients had sustained a new episode of dislocation. All patients were satisfied or very satisfied after the procedure. Ninety-five percent of the patients came back to the same activity level or higher. According to the CT-scan analysis, the trochlear angle improved from 159° to 129° (p = 0.002), the trochlear slope from 12.5° to 29° (p = 0.002), the ratio comparing the external wedge to the medial wedge improved from 1.08 to 1.26 (p = 0.003) and the high of the external condyle from 1.06 to 1.21 (p = 0.002). We did not observe any growth plate fusion.

39.2 Guidelines for Physicians

Objective patellar instability usually required a surgical treatment and the preoperative individual analysis of these factors is a key point to properly adapt the treatment [2].

According to Dejour and Walch [4], the four factors leading to patellar instability include:

- Trochlear dysplasia
- Distance between the anterior tibial tuberosity and the trochlear groove
- Patella Alta
- Patellar tilt

Four types of trochlear dysplasia have been described in the Dejour classification and the type B is defined by a flat trochlea [3]. The trochlea is flat when there is a hypoplasia of the external wedge. Since anatomical factors are genetically determined and will not spontaneously improve over growth, a correction during childhood seems logical in young patient having recurrent dislocations.

Bony procedures have been described in adults to treat objective patellar instability but not for children. In adults, the most popular trochleoplasty is trochlear deepening [2]. But in growing children, there is a high risk to destroy the distal femoral growth plate in the skeletally immature patients when performing a trochlear deepening. This procedure is therefore not recommended in growing children. On the other hand, isolated medialization osteotomy is most of the time unable to prevent dislocation in case of flat trochlea.

The lateral wedge augmentation trochleoplasty for objective instability in the skeletally immature patient with trochlear dysplasia represents a logical and efficient solution. Clinical and radiological results that we reported in the previously exposed study are encouraging and no growth plate lesion was observed. In very limited patient with recurrent patellar dislocation, this solution can be considered without waiting for the patient to become skeletally mature.

Lateral wedge augmentation trochleoplasty for objective instability in the skeletally immature patient with grade B trochlear dysplasia may improve functional results and prevent from recurrent dislocations.

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Patellofemoral Disorders in the Skeletally Immature Patients

40

Vojtech Havlas

40.1 Overuse Conditions of Patella

40.1.1 Osgood-Schlatter Disease

40.1.1.1 Nature of the Disease

Osgood-Schlatter disease is described as a traction-induced inflammation of the patellar tendon and adjacent cartilage of the tibial tubercle growth plate due to repetitive tensile microtrauma [5, 12, 17, 21, 24, 26, 29, 31]. It is characterized by pain and swelling over the tibial tubercle. The pain is aggravated by sport activities. The disorder usually manifests in early adolescence, between ages 10 and 15, and is more common in boys than in girls. The disorder usually resolves with skeletal maturity in most children. In an occasional patient an ossicle developing in the area of insertion of the patellar tendon may become symptomatic in adult age [12, 21, 24, 31].

The etiology is controversial, but the condition clearly is exacerbated by exercise. In one study of 389 adolescent athletes, 21% reported Osgood-Schlatter disease in those actively participating in sports as compared with only 4.5% of nonparticipants. Approximately 50% of patients relate a history of precipitating trauma [7].

Histologic studies suggest a traumatic etiology for Osgood-Schlatter disease [7, 12, 17]. Bone growth is faster than soft-tissue growth, which may result in muscle tendon tightness across the joint and loss of flexibility [12]. Chronic microtrauma to the tibial tuberosity secondary to overuse of the quadriceps muscle is a leading theory of the etiology. During periods of rapid growth, stress from contraction of the quadriceps is transmitted through the patellar tendon onto a small portion of the partially developed tibial tuberosity. This may result in a partial avulsion fracture through the ossification center [7, 12]. Eventually, secondary heterotopic bone formation occurs in the tendon near its insertion, producing a visible lump. In some studies approximately 25% of patients appear to have bilateral lesions [29].

40.1.1.2 Clinical Finding and Diagnostics

The clinical examination will demonstrate swelling and localized tenderness over the tibial tubercle and the distal portion of the patellar tendon. There is often enlargement of the tubercle, which is firm on palpation. Patients usually describe pain on activity and are tender with active resisted knee extension.

Plain AP and lateral radiographs are usually the only diagnostic studies necessary. The lateral radiograph shows fragmentary ossification of the tibial tubercle (Fig. 40.1), which can be a normal variant. In late cases ossicles may form on the under surface of the patellar tendon just as it reaches the tubercle [24, 27].

MRI may assist in diagnosis of an atypical presentation. It may eventually play a role in staging of the disease and prognosticating the clinical course, however, its role in diagnosis, prognostication, and management is currently limited [5, 17, 24, 27]

40.1.1.3 Treatment Options

The treatment should be conservative in most cases: modification of activities, use of NSAIDs, and a knee

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Fig. 40.1 Lateral knee radiograph of 12-year-old girl with Osgood-Schlatter disease demonstrating fragmentation of tibial tuberosity

pad to control discomfort. In severe cases a knee immobilizer may be used for a few weeks to relieve inflammation. Often quadriceps and hamstring flexibility exercises are prescribed. The resolution is usually slow, often requiring 12–18 months. Local steroid injections are not recommended because of case reports of complications, primarily related to subcutaneous atrophy and risk of patellar tendon rupture [7, 15, 17, 21, 29].

Approximately 90% of cases do well with nonoperative treatment. Refractory cases unresponsive to conservative treatment with persistent, disabling symptoms should be considered for possible surgical intervention after skeletal maturity [7, 15, 21, 26]. Variations of surgical treatment include drilling of the tibial tubercle, excision of the tibial tubercle, longitudinal incision in the patellar tendon, excision of the un-united ossicle and free cartilaginous pieces (tibial sequestrectomy), insertion of bone pegs, and/or a combination of any of these procedures [7, 15, 17, 26, 31].

Prominence of the tubercle has been described as the major complication after surgical management [7, 15, 26, 33, 35]. There are authors reporting pinning of the tibial tuberosity (Guzzanti et al., as per verbal communication), however, there is a lag of evidence in the literature on the technique and the result evaluation. It has been documented that surgical management of skeletally immature patients can result in early closure of the tibial tubercle and development of severe genu recurvatum [26, 29, 31], therefore one has to be careful and take a patients age into consideration when indicating for surgery.

40.1.2 Sinding–Larsen–Johansson Syndrome

40.1.2.1 Nature of the Disease

Sinding–Larsen–Johansson syndrome/disease is an overuse traction apophysitis of the distal pole of the patella clinically characterized by pain and tenderness over the inferior pole of the patella which may by accompanied by radiographic fragmentation of the bone [7, 15, 32, 35, 36].

The etiology of Sinding–Larsen–Johansson syndrome (SLJS) appears to be a traction tendinitis with de novo calcification in the proximal attachment of the patellar tendon [7, 32]. SLJS is caused by repetitive microtrauma at the insertion point of the proximal patellar tendon onto the lower patellar pole. The lesion is felt to be due to a traction phenomenon in which contusion or tendinosis in the proximal attachment of the patellar tendon can be followed by calcification and ossification, or in which minor patellar fracture or partial avulsion produces one or more distinct ossification sites. SLJS is classified by some among the aseptic necroses of bone [32, 35, 36]. This condition is most common in adolescents (prevalent in boys) from age 10–14 years who participate in jumping sports. SLJS is the children's equivalent of patellar tendinosis (jumper's knee) seen in adults [7].

40.1.2.2 Clinical Finding and Diagnosis

The most common clinical symptoms include pain and tenderness over the inferior pole of patella precipitated by overstraining or trauma and limping. Patient has slightly swollen, warm, and tender bump just below the kneecap, describes pain with activity, especially when straightening the leg against force (such as with stair climbing, jumping, deep knee bends, or weight-lifting) or following an extended period of vigorous exercise. In more severe cases, pain during less vigorous activity can be seen [7, 15, 35, 36].

The diagnosis is usually made from clinical examination and plain radiographs, which may demonstrate calcification at the inferior pole of the patella [27]. There are four radiographic stages of the disease described: Stage I – normal finding, Stage II – irregular calcification at the inferior pole of patella, Stage III – coalescence of the calcification, Stage IV – calcification incorporated into the patella [7, 35]. Ultrasound scan can give valuable information about the involvement of bone, cartilage and patellar tendon: the lower pole of the patella is often irregular, fragmented, with chondral changes and thickening at the insertion of the patellar tendon. Ultrasonography is also suitable for periodic follow-up over the course of the disease. Typical MR image findings include thickening of the tendon with increased signal intensity on T1- and T2-weighted images [7, 35]. Occasionally features of Osgood-Schlatter disease can be found in the same knee [15].

40.1.2.3 Treatment Options

Treatment of skeletally immature patients with SLJS is symptomatic. Initial treatment consists of ice (cryotherapy) to relieve pain, stretching and strengthening exercises, and modification of activities. Kneeling, jumping, squatting, stair climbing, and running on the affected knee should be avoided. The exercises can all be carried out at home for acute cases. Chronic cases often require a referral to a physiotherapist or athletic trainer for further evaluation and treatment [7, 15, 32, 35, 36]. A patellar band (brace between the kneecap and tibial tubercle on top of the patellar tendon) may help relieve symptoms. Sometimes modification of activities is recommended to the patient. The natural duration of the disease lasts approximately 3–12 months [7, 15].

Surgical treatment including debridement, drilling of the distal pole of patella, tendon excision, and resection of the involved pole or microtenotomy is considered rarely in skeletally immature patients [7, 35, 36].

40.2 Patello-femoral Instability in Immature Patients

40.2.1 Congenital Dislocation of the Patella

40.2.1.1 Nature of the Disease

Congenital dislocation of the patella (CDP) is an uncommon but well-recognized orthopedic condition that can have various clinical presentations [9, 14, 19, 20, 28]. The patella develops normally as a sesamoid bone of the femur. CDP is considered to result from failure of internal rotation of the myotome that forms the femur, the quadriceps muscle, and the extensor mechanism. This failure normally occurs toward the eighth to tenth week of embryonic development [28, 37]. CDP usually manifests immediately after birth with genu valgum, flexion contracture, and external rotation of the tibia along with a hypoplastic patella [20, 28]. In some cases, however, diagnosis may be delayed until early childhood. In less severe cases, function may be impaired only minimally and the diagnosis can be delayed further, until late childhood, adolescence, or even adulthood [20]. This delay may lead to premature degenerative changes and severe impairment of joint function [14, 20]. Early diagnosis is important as it enables timely management, which permits improved development of the knee joint, thus reducing or avoiding the onset of late sequelae.

CDP is often associated with genetic syndromes with increased joint and connective tissue laxity [14]. Syndromes that show an increased incidence of CDP include Down syndrome [14, 20], Larsen's syndrome [14], arthrogryposis [14, 20], nail-patella syndrome [14, 20], Rubinstein–Taybi syndrome [14, 20, 28], Ellis-van Creveld syndrome [14, 20], diastrophic dysplasia, and other [28]. Most of these cases are noticed soon after birth.

40.2.1.2 Clinical Finding and Diagnostics

Congenital dislocation of the patella presents with a spectrum of severity. The most severe forms have significant knee flexion contractures that make the diagnosis evident in infancy. However, more mildly affected individuals may not present until school age, when relative quadriceps weakness begins to cause initial functional problems. The most common clinical features are genu valgum, flexion contracture, and external rotation of the tibia with a hypoplastic patella [9, 14, 19, 20, 28].

There is a relative paucity of literature focusing on the imaging findings for CDP, especially those where the clinical presentation is not clear from birth [27, 28, 33, 35].

Fig. 40.2 Anteroposterior knee radiograph of congenital dislocation of patella in 29-month-old boy demonstrating genu valgum and decreased height of lateral femoral condyle and lateral tibial epiphysis

Traditionally, patellar dislocation has been diagnosed through radiography [20, 27, 28]. In older children and in adolescents, anteroposterior radiographs can show the size and the position of the patella, although these are better illustrated in the lateral and skyline projections. In infants and toddlers (until about 3 years of age), absence of the normal, unossified, or partly ossified patella and associated soft-tissue changes can pass unnoticed if the diagnosis of CDP is not considered. Anteroposterior views can show the degree of the lateral femoral condyle hypoplasia, the severity of joint space narrowing, and the relative position of the tibia in relation to the femur (Fig. 40.2). The size and position of the patella, however, are better assessed in the lateral and skyline projections [28]. On a lateral view of the knee, one has to search carefully for the unossified patellar cartilage anterior to the knee. Absence of the soft tissues comprising the extensor mechanism and of the patella from its normal location can lead to a diagnosis in young children in whom the patella is not yet completely ossified (Fig. 40.3).

Fig. 40.3 Lateral knee radiograph of congenital dislocation of patella in 2.5-year-old boy with small and fragmented ossification center of patella

Fig. 40.4 Skyline radiograph of congenital dislocation of patella in 2.5-year-old boy with small, fragmented, and dislocated patella

Skyline views show the location, shape, and size of the patella (Fig. 40.4), the condition of the intercondylar sulcus, and the degree of lateral femoral condyle dysplasia [14, 20, 28]. However, in most cases of CDP, ossification is delayed, making radiographic diagnosis more difficult [28].

When suspected, CDP can be diagnosed easily by sonography of both knees. The high resolution for soft-tissue, cartilaginous, and bony structures of the immature skeleton makes sonography the technique of choice for initial evaluation of neonates or infants with genu valgum and flexion contracture [28]. In older children, once ossification of the patella has commenced, radiography becomes more useful. CT can illustrate bone details accurately, when required. MRI is valuable for visualizing bone, soft tissue, and muscular changes and for assessing the developing patella and articular cartilage. MRI best illustrates the overall anatomic relationships of the involved structures of the extensor mechanism and therefore should be considered as a part of any preoperative assessment and planning [28].

40.2.1.3 Treatment Options

Congenital dislocation of the patella usually requires early surgical reconstruction, reducing the dislocation and realigning the quadriceps mechanism, usually late in the first year of age [9, 14, 19, 20, 30, 36]. Surgical intervention should aim for realigning the abnormal muscular and bony constitution of the knee extensor mechanism. Most authors document good results using a combination of extensive lateral release, medial plication, V-Y quadriceps lengthening, medial transfer of the lateral patella tendon, with or without the need for posterior release of the knee [9, 14, 19, 20, 30, 36]. Serial casting and/or bracing is recommended before the surgery in an attempt to initially improve the flexion contracture of the knee [36]. Other procedures, such as semitendinosus tendon transfer or tenodesis might need to be considered in combination with the above to achieve better stability with flexion in older children. Some authors consider extensive subperiostal elevation of the extensor mechanism from the distal femur an essential part of the surgical correction and document good results using this technique [36].

40.2.2 Developmental (Habitual) Dislocation of the Patella

Most authors distinguish between two separate entities – congenital versus developmental dislocation, according to patient age and severity of symptoms at presentation. Congenital (or persistent) dislocation of the patella is present at birth, is permanent and irreducible, and is associated with a flexion contracture [14, 20, 28]. Developmental dislocation usually manifests when the child begins to walk, because of knee instability that is worse if the condition is bilateral [14, 20]. At times, this type may be well tolerated and is diagnosed only in late childhood when a knee deformity is noticed in an otherwise asymptomatic child.

40.2.2.1 Clinical Finding and Diagnostics

In the developmental form, in contrast to the congenital form, the dislocation is not permanent and is reducible. The patella is located stably in the femoral groove when the knee is flexed but tends to drift laterally as the knee extends. This drifting usually happens in full extension, and the patella relocates during flexion. Predispositions involve Patella Alta, a hypoplastic lateral femoral condyle, shallow patellar groove, and an extensive femoral neck antetorsion that are usually all evident on radiographic imaging [28].

Another specific form of patellar dislocation that manifests in knee flexion resulting from quadriceps shortening was described in children treated by multiple injections into the vastus lateralis for neonatal infection [7, 28]. In these children, progressive quadriceps contracture and loss of the full range of knee flexion usually develops later on. On knee flexion the patella tends to gradually sublux and dislocate laterally.

40.2.2.2 Treatment Options

Surgical treatment usually involves lateral retinacular release in combination with medial advancements and/or distal realignments, where indicated. Knee rotational malalignment and all additional dysplastic changes should be addressed at the time of surgical management. Distal femoral rotational osteotomy is often considered in the treatment cycle [7, 14, 20, 28].

40.2.3 Acute Dislocation of the Patella

Acute dislocation of the patella occurs most frequently in adolescence and is less common in early childhood [1, 2, 7, 10, 11, 15, 16, 23, 33, 35]. In comparison to adult patients patella dislocation in children is usually related to anatomic features that make the patella less stable. These are represented mainly by a shallow femoral groove, valgus and rotational knee malalignment, or ligamentous laxity. Individuals with lax ligaments may be more likely to dislocate but less likely to sustain osteochondral fractures. However, in most cases an acute injury is reported. Girls are more often affected than boys [7, 15, 33, 35].

40.2.3.1 Clinical Finding and Diagnostics

Most patellar dislocations are reduced spontaneously or shortly after they occur and therefore diagnosis is not always easy. Mechanism of injury usually involves a twisting event. After reduction, the residual findings include diffuse parapatellar tenderness and a positive apprehension test (Fairbank's sign) [1, 2, 7, 10, 16, 33]. The medial capsule, medial retinacle and medial patellofemoral ligament may have been stretched or torn; the tenderness may extend to the medial femoral epicondyle. Medially, there may be a palpable defect from avulsion of the vastus medialis insertion into the patella. Hemarthrosis result from a capsular tear or a current osteochondral fracture or ACL sprain. Post reduction radiographs should be inspected for evidence of osteochondral fragments, bony fragments seen along the medial patellar margin often are not free in the joint, but rather result from avulsion of the vastus medialis insertion. A Merchant view may demonstrate significant residual maltracking. CT or MRI may be considered if there is any doubt about the complex diagnosis [27].

40.2.3.2 Treatment Options

The natural history of acute patellar dislocation in children is such that approximately 1/6 develop recurrent dislocation, 2/6 will have some minor residual patellofemoral symptoms and 3/6 will remain asymptomatic [7]. The incidence of redislocation after nonoperative treatment diminishes considerably with advancing age. Cash and Hugston [10] found 60% incidence among patients aged 11–14, 30% incidence among patients aged 19–28 and few in the group over 28. Indications for acute surgery in skeletally immature patients involve associated osteochondral fracture from the lateral femoral condyle or patellar surface and significant avulsion of the vastus medialis requiring primary repair. Medial retinaculum rupture is considered to be a relative indication for surgical treatment of acute patellar dislocation [7]. Early repair or advancement of the vastus medialis, with or without distal realignment procedures are sometimes indicated, however, it has been described that any reconstructive procedure (more than an arthroscopy) immediately following an acute knee injury with hemarthrosis can precipitate an acute fibrosis reaction, therefore careful indication for surgery with a clear reason to operate always needs to be addressed when dealing with pediatric patients [7, 10, 33].

40.2.4 Recurrent (Chronic) Dislocation of the Patella

Although the risk of ongoing patellofemoral instability increases with each subsequent dislocation, many patients are successfully managed without surgery. Patients usually present with acute traumatic dislocation with subsequent recurrent instability, often based on underlying dysplasia with minimal injury that precipitates the episodes of instability [7].

40.2.4.1 Clinical Finding and Diagnostics

For unknown reasons adolescent girls are the most frequently affected. This may be related to the fact that the adolescent female pelvis becomes wider and there can be a great degree of valgus at the knee, resulting in a laterally directed force of the patella, however there is no clear evidence for this [7]. Pain is the most frequent symptom and is usually poorly localized to the parapatellar area. Patients may have an increased Q angle with generalized ligamentous laxity and a positive "patellar apprehension test" (Fairbank's sign). The pain is usually aggravated by running, jumping, cutting, and stair climbing. Swelling is a common complaint but is rarely accompanied by objective findings [3, 4, 6, 8, 13, 22, 33]. The patella can be seen to track laterally before entering the intercondylar notch of the femur, especially when the examiner drops the leg just as the knee is beginning to flex. This is described as the "J" sign, as the patella alters its course from lateral to medial in order to enter the notch. Generalized ligamentous laxity may be present. X-ray appearance may be consistent with tilting or subluxation of the patella on tangential views with 30° of knee flexion (Merchant view) which has been reported to be a confirmatory finding [27].

40.2.4.2 Treatment Options

The first line of treatment in skeletally immature patients is conservative focusing on relieving symptoms by reduction of activities, use of NSAIDs, eventually with the use of a patellar stabilizing orthosis and a structured physiotherapy program involving muscle stretching and strengthening with an emphasis on the vastus medialis obliquus.

Surgical treatment is usually considered only after a prolonged rehabilitation program without success. There is a selection of procedures and the decision to treat recurrent patellar instability must be individualized [3, 4, 7, 8]. The degree of instability and disability should be weighed against the risks and benefits. Age is another factor to be considered when planning for surgery. Tibial tubercle transfers are generally contraindicated if the physes are still open. Lateral retinacular release is routinely combined with medial advancements and/or distal realignments, where indicated. When the decision to operate is made all underlying pathologies (malalignment, dysplastic changes, fractures, soft-tissue injury) should be addressed at the same time. A variety of techniques for medial patellofemoral ligament reefing (vastus medialis obliquus advancement) have been described, but the fundamental elements include a combination of lateral release and medial plication. Patients with an excessive Q angle can benefit from a bony distal realignment procedures like Elmslie-Trillat, Maquet, or Fulkerson when they reach adolescent age (growth plate closure) [3, 4, 7, 8, 13, 33]. For skeletally immature patients with open physis the Galleazzi procedure (transferring the proximal end of the semitendinosus to the inferomedial pole of the patella, leaving the distal end of the semitendinosis attached to the tibia) would be the treatment of choice [8, 33]. There have been reported 81% very good results with this procedure [3]. Alternatively the Roux-Goldthwait procedure (splitting of the patellar tendon and transferring the lateral half beneath the medial site) can be used, although complications like rotational tilt and physeal tethering anteriorly have been reported, therefore this procedure would not be the first choice [18, 33].

All surgical treatment options require adequate rehabilitation to restore the knee motion and maximize dynamic stability from quadriceps [7, 8].

40.3 Patellar Fractures in Pediatric Patients

40.3.1 Patella Sleeve Fracture

Patella sleeve fracture is an uncommon injury unique to skeletally immature patients consisting of an avulsion of a portion of the articular surface. This type of fracture is usually caused by acute injury (e.g., forceful contraction of the quadriceps tendon against the flexed knee), when the lower pole of the patella, together with a significant sleeve of articular cartilage, is pulled off the remaining body of the patella [7, 25, 34, 35]. This can happen during the course of running, jumping, and kicking. It is a typical injury of the take-off leg.

A sleeve fracture may involve the superior, inferior, medial, or lateral aspect of the patella. When it involves the inferior pole usually a portion of the patellar bone and retinaculum and a large portion of articular cartilage are displaced inferiorly such that the larger, superior fragment is high compared with the contra lateral side [7, 8, 25].

40.3.1.1 Clinical Finding and Diagnostics

The clinical picture at presentation usually includes a palpable defect at the affected patella pole and an inability to fully extend the knee. Pain, hematoma and pain on movements are the main clinical indicators of patellar sleeve fractures [34].

Diagnosis can be difficult, as sometimes there is little or no bone noted in the separated fragment seen on the lateral view x-ray [7, 34, 35]. Contra lateral films allow one to compare the position of the patella (the patella on the injured site will be more proximal). MRI or CT may be needed for correct diagnosis of patellar sleeve fractures [27]. Recognition of this pathology is very important, as part of the articular surface of the patella is usually displaced with the fragment. Without treatment, an extensor lag will remain with a possible development of non union. A patella sleeve fracture should not be confused with Sinding–Johansson–Larsen disease [32], which is a chronic overuse injury to the distal pole of the patella.

40.3.1.2 Treatment

Open reduction, repair of the retinaculum, rigid internal fixation of the fragment and cast immobilization for 4–6 weeks are usually required. If there is little bone present, it is a bit like sewing two rope ends together. In this case absorbable suture materials are recommended [7, 34, 35].

40.3.2 Marginal Fracture of Patella

The lower or proximal pole of the patella can be avulsed during the course of running, jumping, kicking, occasionally on the background of preexisting degeneration or inflammatory changes (Sinding–Larsen–Johansson syndrome) [32], or rarely as a result of a direct trauma [7, 25, 34, 35]. Treatment of marginal fractures of the patella is similar to treatment of a bipartite patella. If the fragment does not displace conservative measures are considered [7, 34]. In case of displacement open revision and osteosynthesis is an option. Occasionally, arthroscopic or open fragment removal can be considered depending on the locality and size of the avulsed part of patella [7, 8, 34].

40.3.3 Transverse Fracture of Patella

This type of patellar injury is relatively uncommon in children with open physis. It is more frequent in adolescent age and the clinical presentation, diagnosis and treatment do not differ from those in adults [7, 34].

40.4 Chapter Summary

- The patello-femoral joint can be affected by various conditions at any age.
- The patello-femoral affection can be caused by an inherited condition or by pathology gained during the growth of an individual as a result of repetitive (over)load, sport related activity, or trauma.
- A selective approach to individual pathologies must be considered when approaching the skeletally immature (pediatric) patient.

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Dictionary

Abnormal Tracking

During active or passive motion of the knee the patella dislocates in terminal extension and relocates in early flexion. The patella begins lateral to the trochlea and moves suddenly medially to enter the trochlea. It is a sign of patellofemoral dysplasia. The angle of flexion when the patella relocates should be documented. It has also been termed "J tracking."

Apprehension Sign

The examiner pushes the patella laterally with the knee in full extension, the sign is positive if the patient expresses fear by stopping the movement or by a verbal expression. It is the only pathognomonic sign of an objective dislocation. (Historically it was also named Smillie's or Fairbanks sign).

Arthritis (Isolated Patellofemoral Arthritis)

Alteration of the patellofemoral joint using the Iwano classification. Tibio-femoral joint line is normal on the weight bearing AP view at 45° degree flexion.

Chondromalacia

An anatomo-pathological observation that could be made either by arthroscopic examination, direct eye examination at the time of open surgery, or via magnetic resonance imaging or arthro-tc. It is not a diagnosis.

Episodic Patellar Dislocation

See patellofemoral disorders classification

Excessive Lateral Hyperpressure Syndrome

Lateral retinacular tightness that results in a pain syndrome that is felt to be due to lateral facet overload, tissue tightness and imbalance, or both. See lateral retinaculum tightness.

Hyperlaxity

Could be related to articular laxity (ligaments, capsule) and/or muscular laxity or stiffness.

J Sign

This is a physical exam sign that signifies excessive lateral and superior patella translation when the kneecap is subjected to a strong quadriceps pull in full extension. It is a combined result of a flattened trochlea and unbalanced soft tissue structures. It used to be named Quadriceps pull test.

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J Tracking

See Abnormal Tracking

Lateral Retinaculum

A constellation of several soft tissue layers, including iliotibial band and its deep fibers of the lateral patellofemoral ligament. The lateral patellofemoral ligament may be a misnomer as these fibers insert into the deep layers of the iliotibial band at the intermuscular septum and do not have a direct insertion to the femur itself. (Please see Chapter 16).

Lateral Retinacular Tightness

This can be defined by a decrease in medial patella glide test and also the patella tilt test. A patella tilt test less than neutral position (one cannot bring the lateral patella border to the level of the horizon) is a sign of lateral tightness. A medial glide test less than 2 quadrants, or 6 mm, is felt to be a sign of lateral tightness. The inter and intra variability of these measurements have not been studied.

Malalignment of the Patellofemoral Joint

It can be discussed as physical exam signs that exceed the upper limits of normal (increased Q angle, increased torsional measurements including anteversion and external tibial torsion). It can be used to describe radiographic signs (excessive lateral tilt and translation, excessive TT-TG, patellar dysplasia, trochlear dysplasia) or excessive anteversion or external tibial torsion as measured by a rotational study (CT or MRI). It is most commonly used to describe malpositioning between the patella and femur due to *coronal plane* positioning.

Medial Retinaculum

Medial retinaculum is divided into the medial patellofemoral ligament and the medial tibial ligament (see chapter on MPFL).

Objective Patellar Instability

Better termed Objective Patellar Dislocation. Refers to a classification patients that have had at least one lateral patella dislocation event (see Patellofemoral Disorders Classification).

Patella Alta/Infera

Patella Alta and Patella Infera describes the position of the patella in the sagittal plane. There are several measurements performed on imaging that objectively define the patella's position in the sagittal plane. Patella Infera is a more proper term that Patella Baja, indicating the sagittal position of the patella is lower than normal population. The patella height has always to be quantified by an index (Please see Chapter 7).

Patellofemoral Disorders Classification

Objective Patellar Dislocation (OPD)

Patients who had at least one documented dislocation, have one of the four principal instability factors (trochlear dysplasia, excessive TT-TG, Patella Alta, excessive patellar tilt).

Potential Patellar Dislocaters (PPD)

Patients who had no dislocation and may have pain, but have one of more of the anatomical abnormalities associated with lateral patella dislocations (trochlear dysplasia, excessive TT-TG, Patella Alta, excessive patellar tilt).

Patellar Painful Syndrome (PPS)

Patients who have pain did not have a patella dislocation, and have NO anatomical PF abnormalities (trochlear dysplasia, excessive TT-TG, Patella Alta, excessive patellar tilt).

Patellar Dysplasia

Use Wiberg classification.

Patella Glide Test

A physical exam test to objectify the amount of tightness or laxity in the patella retinacular structures. Excessive glide suggests reduced restraint while reduced glide suggests tightness of the retinaculum. The degree of knee flexion to perform this test is not standardized in the literature. It is also named the "Quadrant" Test.

Patellar Instability

When one is referring to lateral patella dislocation, the more precise term "dislocation" should be used rather than instability.

Patella Tilt Test

Evaluates the tightness or laxity of the patella retinacular structures. The examiner pushes the medial patellar border in an attempt to elevate the lateral edge of the patella upwards. Elevation of the lateral patella to neutral or less than the level of the horizon represents a tight lateral retinaculum. Greater than 20° of elevation is considered excessive. Twenty degree of elevation is approximately about the width of an average finger. The degree of knee flexion to perform this test is not standardized in the literature. It used to be named Medial patella tilt test.

Potential Patellar Instability

Refer to Patellofemoral Disorders Classification.

Q Angle

A physical exam measurement of lateral quadriceps vector force. It represents a line from the anterior superior iliac spine to the center of the patella. A second line is then drawn from the center of the patella to the tibial tubercle. The angle of these intersecting lines is the Q angle. The degree of knee flexion to perform this test is not standardized in the literature.

Patella Subluxation

This refers to a dynamic pattern of patella movement. It is not a diagnosis. It should not be used to define patella position on imaging; lateral translation is a more precise term.

Tibial Tubercle Trochlear Groove Distance (TT/TG)

An objective measurement to assess the distance between the midpoint of the trochlea and the tibial tubercle. This objective measurement is most consistently described in the literature on axial CT images. More recently, axial MRI images have been used in a similar fashion. Please see Chapter 35 for more information.

Trochlear Dysplasia

Presence of crossing sign: use classification in Four Grade (A, B, C, D) (see chapter on X-ray Analysis)

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