Chapter

Patellofemoral Instability

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Abstract

Recurrent patellofemoral instability is a common cause of knee pain and functional disability in adolescent and young adult patients, resulting in loss of time from work and sports. There are numerous factors that contribute to recurrent patellofemoral instability; these factors include tear of the medial patellofemoral ligament (MPFL), weakening or hypoplasia of the vastus medialis obliquus (VMO), trochlear dysplasia, increased tibial tuberosity-trochlear groove (TT-TG) distance (>20 mm), valgus malalignment, increased Q angle, malrotation secondary to internal femoral or external tibial torsion, patella alta, and generalized ligamentous laxity. A detailed history and a thorough physical examination are crucial to clinch an early, accurate diagnosis. Imaging studies play an important role to confirm the clinical diagnosis and also help to identify concomitant intra-articular pathologies. Initially, nonoperative management (including the use of physical therapy, patellar taping or brace) is offered to patients with acute, first-time patellar dislocations and most patients respond well to this mode of treatment. Surgical treatment is indicated for patients who have post-trauma osteochondral fracture or loose body; predisposing anatomical risk factors; recurrent, symptomatic instability; and who have failed an adequate trial of nonoperative management. Surgical treatments include MPFL reconstruction, proximal or distal realignment procedures, and trochleoplasty. Lateral release is often performed in combination with other procedures and seldom performed as an isolated procedure. An individualized case-by-case approach is recommended based on the underlying anatomical risk factors and radiographic abnormality.

Keywords: Knee, Patellofemoral instability, Patellar subluxation or dislocation, Nonoperative management, Surgical treatment, Medial patellofemoral ligament reconstruction, Tibial tuberosity transfer, Trochlear dysplasia, Trochleoplasty

1. Introduction

This chapter is divided into 2 major sections. Section 2 provides a brief overview of acute dislocation of the patella. In Section 3, we discuss the soft tissue and osseous anatomy, clinical presentation and physical examination, radiographic studies, nonoperative management, surgical treatment, and authors' preferred method of medial patellofemoral ligament (MPFL) reconstruction for patients with recurrent patellofemoral instability.

2. Patellofemoral instability: acute dislocation of the patella

Acute dislocation of the patella is an orthopedic disorder of the knee that frequently affects adolescent and young adult population (peak age of 10 to 20 years). Acute patellar dislocation accounts for 2–3% of all knee injuries. It has been reported that there is a 17–49% risk of redislocation following first-time, acute patellar dislocation [1]. The risk increases to 44–71% following a second-time dislocation [2]. Acute traumatic patellar dislocation (with or without associated osteochondral fracture) is the second most frequent cause of traumatic hemarthrosis of the knee, after anterior cruciate ligament tear. The patella usually dislocates laterally, causing ruptures of the MPFL in about 90% of the cases.

2.1 Studies on the natural history of acute dislocation of the patella

Hawkins et al. [1] have reported on the natural history of acute patellar dislocations. The authors of this study reviewed 27 patients who sustained primary dislocations of the patellae. Of these 27 patients, 20 were treated with immobilization and subsequent physical therapy (including nine patients who underwent arthroscopy) and seven with immediate surgical stabilization and lateral release. In this study, the patients with predisposing factors such as patellofemoral malalignment, abnormal patellar configuration, and a history of prior symptoms of patellofemoral instability were more prone to recurrent dislocation and may benefit from operative intervention. These authors noted that at least 30–50% of all patients having sustained a primary patellar dislocation will continue to have symptoms of instability and/or anterior knee pain.

Atkin et al. [3] prospectively studied the characteristics and early recovery of an unselected population of patients who had acute, first-time lateral dislocation of the patella. Seventy-four patients (average age 20 years) met the enrollment criteria. A standardized rehabilitation program was utilized, emphasizing range of motion, muscle strength, and return of function. Patients returned to stressful activities (including sports) as tolerated when they regained a full passive range of motion in the knee, had no joint effusion, and when quadriceps muscle strength was at least 80% as compared with the opposite, non-injured extremity. Sports participation remained significantly reduced throughout the first 6 months after injury, with the greatest limitations in kneeling and squatting. The patients who had acute primary patellar dislocation were young and active, and most injuries occurred during sports.

Fithian et al. [4] published a prospective cohort study to define the epidemiology and natural history of acute dislocation of the patella, and to identify risk factors for subsequent patellofemoral instability episodes. These authors prospectively followed 189 patients for a period of 2 to 5 years. The overall annual risk for a first-time patellar dislocation was 5.8 per 100,000 members, with 61% of injuries occurring during sports. There was an increasingly higher incidence of patellar dislocation in younger and female patients. The annual risk for patients with a previous history of patellar subluxation or dislocation was 3.8 per 100,000 members, with a statistically higher proportion of older and female patients.

2.2 Anatomy

Warren and Marshall [5] have delineated the anatomy of the medial aspect of the knee. These authors dissected 154 fresh human knee joints and found a consistent three-layered pattern with condensations between the tissue planes.

The fibers of MPFL were transversely oriented within layer II, superficial to the joint capsule and deep to the vastus medialis. Since then, various studies have been reported on the anatomy of the MPFL [6–21]. Schottle and associates [22], in their landmark cadaveric study, defined a radiographic point representing the femoral attachment of the MPFL. This was described on a true lateral radiograph of the knee (with both posterior condyles projected in the same plane), as 2 mm anterior to the posterior cortex extension line, 2.5 mm distal to the posterior origin of the medial femoral condyle, and proximal to the level of the posterior-most point of the Blumensaat's line.

In earlier anatomical dissection studies, the MPFL has been defined as a pure ligament spanning from the medial femoral condyle to the medial border of the patella. However, recent advances in the surgical anatomy of the MPFL have revealed that there are fibers that insert onto the deep, undersurface of the quadriceps tendon as well as the patella, thus earning the name "medial patellofemoral complex" to allow for the variability in its anatomy [23]. The medial patellofemoral complex (MPFC) has been more recently identified as a broad, fan-shaped structure with both bony and soft tissue insertions [24, 25]. The MPFC origin is generally accepted to originate within a triangular saddle of bony landmarks on the medial condyle of the femur, formed by the medial gastrocnemius tubercle, the medial femoral epicondyle, and the adductor tubercle [17, 24, 25]. The insertion of the MPFC is more variable; about 57% of its fibers attach to the patella and the remaining 43% attach to the undersurface of the quadriceps tendon [26]. Fulkerson has described this quadriceps portion of the MPFC as the medial quadriceps tendon-femoral ligament (MQTFL) [27]. The length of the MPFL ranges from 45 mm to 64 mm, and its width is slightly greater at its patellar insertion than its femoral origin [11, 13]. The midpoint of the 30.4-mm-wide insertion of the MPFC has been reproducibly found at the junction of the medial border of the quadriceps tendon with the articular surface of the patella [24, 26].

Tanaka [26] undertook a cadaveric study to describe and quantify the variability of the attachments of the MPFL. In his study, 33 cadaveric knees were dissected, and the MPFL was identified from the articular side after anterior reflection of the extensor mechanism and removal of the synovium. The mean width of the MPFL was 10.7 ± 1.8 mm at the femoral origin and 30.4 ± 5.5 mm at the patellar attachment. Tanaka [26] concluded that MPFL fibers vary in their width and percentage of attachments to the patella and quadriceps tendon. Further research is required to identify the appropriate fixation points to recreate the anatomy and isometry of the MPFL during patellar stabilization surgery for patients with patellofemoral instability.

Aframian et al. [17] conducted a systematic review of anatomical dissections and imaging studies to identify the true anatomical origin and insertion of the MPFL. After screening and review of 2045 papers, a total of 67 studies investigating the relevant anatomy were included. The authors found that the origin of the MPFL appears to be from an area rather than a single point (as previously reported) on the medial femoral condyle. The weighted average length of the MPFL was 56 mm with an 'hourglass' shape, fanning out at both ends of the ligament. The MPFL is an hourglass-shaped structure running from a triangular space between the adductor tubercle, medial femoral epicondyle and gastrocnemius tubercle, and inserts onto the superomedial aspect of the patella. **Figure 1** shows the diagram summarizing the femoral and patellar attachment areas of the MPFL. Awareness of anatomy is essential for accurate placement of the graft while performing MPFL reconstruction for patellofemoral instability.

The MPFL has been regarded as the major medial soft tissue stabilizer of the patella (particularly in early knee flexion), originating from the medial femoral

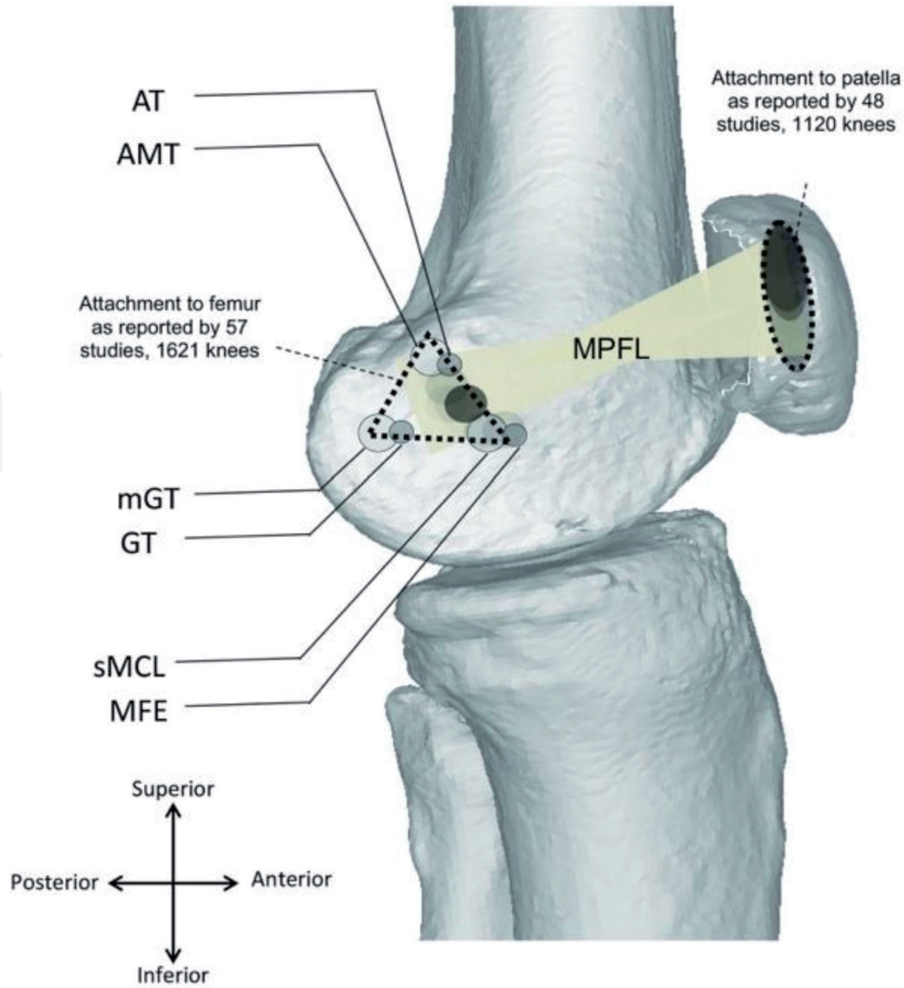

Figure 1.
Diagram summarizing the MPFL attachment areas. Darker shading represents study concordance. AT - adductor tubercle; AMT - adductor magnus tendon; GT - gastrocnemius tubercle; mGT - medial gastrocnemius tendon; sMCL – superficial medial collateral ligament; MFE – medial femoral epicondyle. Reprinted with permission from: Aframian et al. [17]. Copyright © The Author(s) 2016. Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/). No changes we made.

condyle and inserting onto the proximal two-thirds of the medial border of the patella. The MPFL acts as a primary static checkrein to resist lateral translation of the patella, providing approximately 208 N of mean tensile strength before rupture [6, 28, 29]. Conlan et al. [6], based on their landmark cadaveric study of the knees, reported that the MPFL is the major medial soft tissue restraint that prevents lateral displacement of the distal knee-extensor mechanism, contributing an average of 53% of the total force. The patellomeniscal ligament and associated retinacular fibers in the deep capsular layer of the knee (which were previously thought to be functionally unimportant) in the stabilization of the patella, contributed an average of 22% of the total force. The patellotibial band and the medial patellotibial ligament are less important restraints to lateral translation of the patella. The quadriceps functions as a dynamic stabilizer of the patella.

A number of anatomic risk factors have been associated with acute dislocation of the patella (**Table 1**). These risk factors become increasingly important when evaluating patients with recurrent patellofemoral instability.

2.3 Clinical presentation

Most acute patellar dislocations occur during sport. Sporting injuries account for 61–72% of acute patellar dislocations [3, 4]. Acute dislocation of the patella can

1. Genu valgum
2. Increased Q angle
3. Increased femoral anterversion; internal femoral torsion
4. External tibial torsion
5. Lateralized tibial tuberosity
6. Lateral patellar tilt
7. Patella alta
8. Generalized ligamentous laxity
9. Weakening or hypoplasia of the vastus medialis obliquus (VMO)
10. Trochlear dysplasia or hypoplasia
11. Pes planus (Flat foot)

Table 1.
Anatomic Risk Factors Associated with Acute Dislocation of the Patella.

occur either by a direct blow to the knee or indirectly, as the body rotates around a planted foot. The player may sense that "kneecap is out of place", but often the patella will dislocate and spontaneously reduce. If the patella remains dislocated, it may be palpable over the lateral aspect of the femur, and the medial femoral condyle appears prominent. The indirect mechanism of injury is more common than a direct blow. This mechanism is noncontact and occurs with the knee in slight flexion and valgus as the tibia externally rotates relative to the femur. It can occur on a planted foot as the femur and body rotate internally, such as the hind leg of a baseball player swinging hard at a pitch. Alternatively, the free foot can be forced into external rotation, such as a soccer player whose instep kick is met with excessive resistance, or a snow skier whose ski acts as an offending lever arm [30]. Patellar dislocation can occur in various sports, such as American football, soccer, baseball, basketball, ice hockey, gymnastics, wrestling, tennis and golf. **Figure 2** demonstrates the indirect (noncontact) and direct (contact) mechanisms of injury that can result in acute dislocation of the patella.

2.4 Physical examination

Most patients present to the outpatient clinic in the subacute phase after their injury. Physical examination at this stage may be difficult due to presence of pain and swelling. In select cases, aspiration of a tense joint effusion may be required to relieve pain, and to allow better physical examination and radiographic evaluation. The appearance of the joint aspirate may provide important diagnostic clue. Lipohemarthrosis indicates presence of a concomitant osteochondral fracture.

A complete examination of the injured lower extremity should be undertaken. The astute clinician should look for limb malalignment (especially genu valgum), patella alta, and rotational abnormality, such as excessive anteversion of the femoral neck (internal femoral torsion) and external tibial torsion. A comprehensive ligamentous examination of the injured knee should be performed to rule out associated injury to the cruciate and/or collateral ligaments. Joint-line tenderness and a positive McMurray's test may indicate presence of concomitant meniscal injury. Generalized ligamentous hyperlaxity should be noted by examining finger metacarpophalangeal joint hyperextension, thumb-to-forearm apposition, knee hyperextension, and elbow hyperextension. A complete neurovascular examination of the limb should be performed.

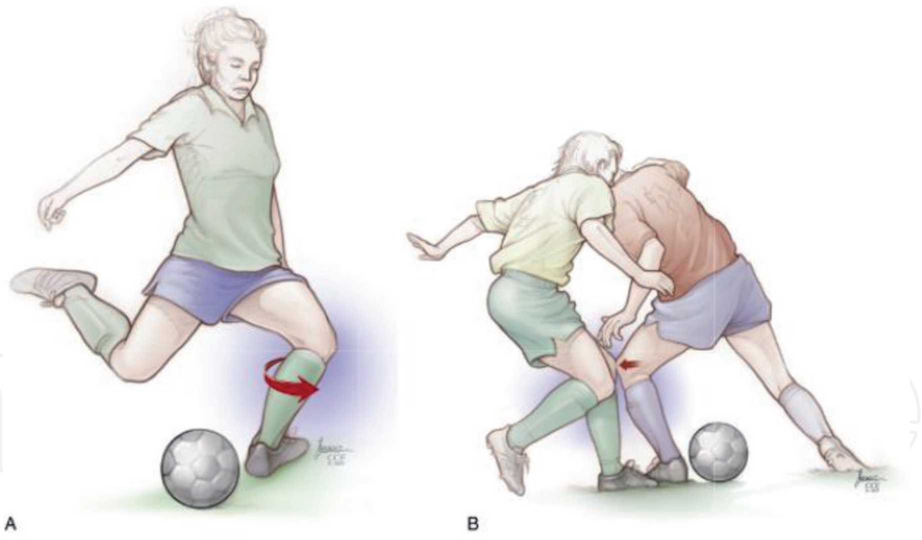

Figure 2.
Mechanisms of acute patellar dislocation: (A) A noncontact dislocation occurs by external rotation of the lower leg relative to the body. (B) Contact injury is caused by a direct blow to the medial aspect of the knee. Adapted from Steiner and Parker [30]. Reprinted with permission of The Cleveland Center for Medical Art & Photography © 2008. All Rights Reserved.

The knee should be specifically palpated for areas of localized, maximal tenderness. There is tenderness along the medial border of the patella and also over the injured or torn medial patellar retinaculum. In some cases, a palpable defect in the medial retinaculum is noted. There may be localized tenderness at the origin, at the insertion, or along the course of the MPFL. Tenderness at the medial border of the patella or along the lateral femoral condyle may suggest osteochondral injury. Tenderness or asymmetry at the distal portion of the vastus medialis obliquus (VMO) may suggest significant disruption of its tendinous insertion. The patellar apprehension test should be performed to determine patellar instability. The apprehension test is performed by applying a laterally directed force along the medial border of the patella with the knee in 20 to 30 degrees of flexion (**Figure 3**). A positive finding occurs when the patient has a sense of pain and impending subluxation or dislocation. In addition to apprehension, there may be increased translation of the patella when compared with the uninjured knee.

2.5 Associated injuries

The most common findings associated with acute dislocation of the patella are chondral and osteochondral injuries. Stefancin and Parker [31] systematically reviewed the literature on patients who had had first-time patellar dislocation. The average age of the patients was 21.5 years. In their compilation of 70 articles, the incidence of osteochondral fracture (confirmed by open surgery, arthroscopy, or MRI) ranged from 0% to 73%, with an overall incidence of 24%. Osteochondral injuries resulting from lateral patellar dislocation have a characteristic pattern; there is an injury to the medial facet of the patella and the lateral femoral condyle. The osteochondral fragments may remain attached, may become loose in the joint, or may be retained in the peripatellar retinacular tissue [30].

2.6 Radiographic studies

The radiographic evaluation of patients with patellar dislocation include plain radiographs and MRI of the knee.

The plain radiograph series of the knee should include standing anterior–posterior view, 45-degree flexion posterior–anterior weight-bearing view (Rosenberg view), lateral view, and axial view. The lateral view provides useful information

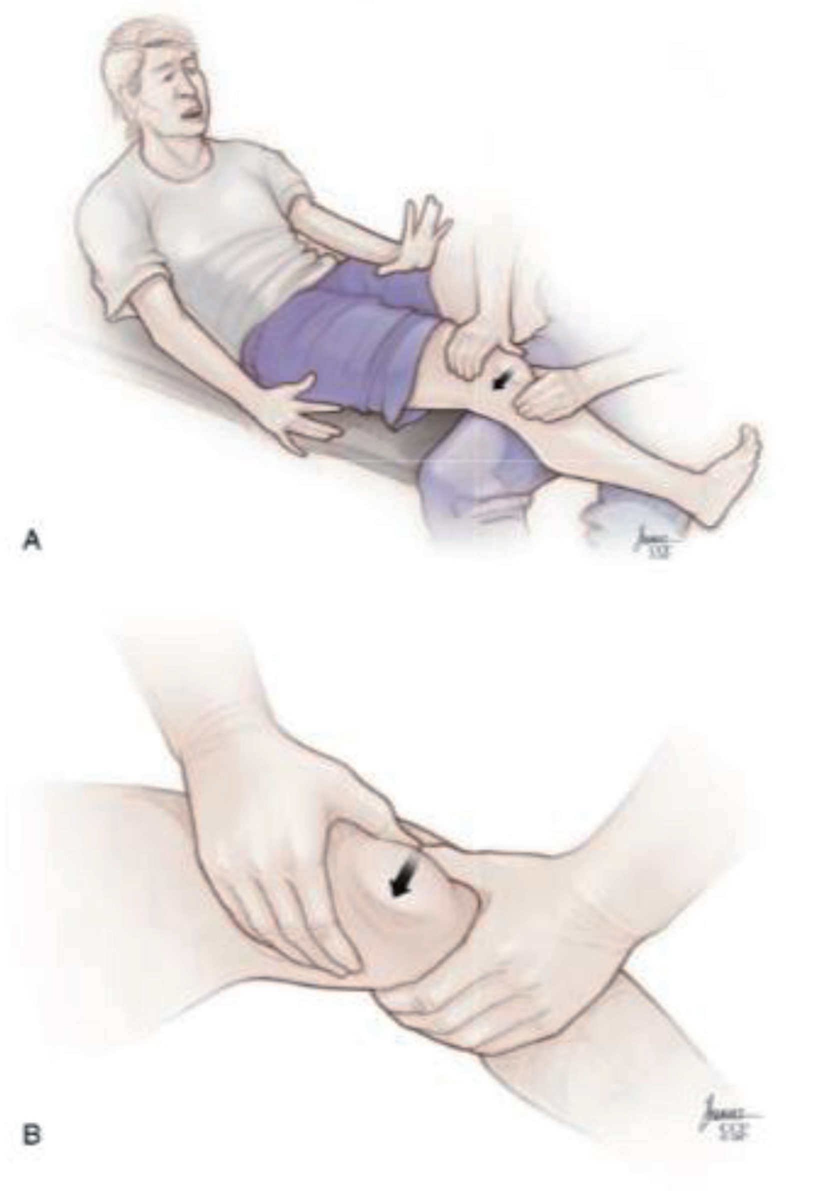

Figure 3.
Patellar apprehension test. The physician applies a lateral force to the medial border of the patella with the knee in 20 to 30 degrees of flexion. The patient experiences a sensation of the patella subluxating or dislocating in an outward (lateral) direction. Adapted from Steiner and Parker [30]. Reprinted with permission of The Cleveland Center for Medical Art & Photography © 2008. All Rights Reserved.

about the patellar height, trochlear depth, and patellar tilt. Patella alta is a known risk factor for patellar dislocation and can be determined on the lateral radiograph by numerous methods. These methods include the Insall-Salvati ratio [32], the modified Insall-Salvati ratio [33], the Blackburne-Peel ratio [34], and the Caton-Deschamps ratio [35]. A brief description of the above-mentioned radiographic measurements is provided under the heading – Assessment of Patellar Height – in Section 3 of this book chapter.

The Blackburne-Peel ratio, which is based on consistent bony landmarks, is the most reproducible and has the most moderate results for classification into patella alta and patella baja. The trochlear depth and patellar tilt can also be determined from the lateral radiograph of the knee. It is worth emphasizing that the lateral view of the knee must be a "true" lateral with the posterior borders of the femoral condyles overlapping for accurate interpretation and analysis of the trochlear depth and patellar tilt. The axial views as described by Merchant and colleagues [36] and Laurin and colleagues [37, 38] are commonly used. The axial view of the patellofemoral joint provides valuable information about any persistent subluxation or dislocation of the patella. In addition to the lateral patellar overhang, the sulcus angle can be determined on the axial view.

MRI has become the imaging modality of choice in the evaluation of patients with acute dislocations of the patella. Various pathologies such as, VMO edema, bone contusion, chondral and osteochondral injury, loose body, medial patellar retinacular injury, MPFL injury, and associated ligamentous and/or meniscal injury can be well visualized on a high-quality MRI study. The MPFL is almost universally disrupted in patients with acute lateral dislocation of the patella. The aforementioned MRI findings following acute dislocation of the patella are useful for the treating physician and allows him/her to formulate a sound treatment plan. Presence of a large osteochondral fragment, loose body, a complete tear of the MPFL, and associated ligamentous or meniscal injury may point the surgeon toward operative intervention [30].

2.7 Nonoperative treatment

Currently, there exists a debate in the orthopedic literature regarding nonoperative versus operative treatment of acute patellar dislocations. Most physicians recommend a more conservative, i.e. nonoperative approach, whereas some recommend immediate repair of the injured medial structures.

Maenpaa and Lehto [39] have reported a long-term study on nonoperative treatment of acute patellar dislocations. In their study, 100 patients were treated nonoperatively for primary acute patellar dislocations, either by plaster cast (N = 60); by posterior splint (N = 17); or by patellar bandage or brace (N = 23) for 2 to 4 weeks, followed by rehabilitation. Follow-up examinations were performed at an average of 13 years (range, 6 to 26 years) after the initial injury. The recurrence rate was 44% overall, yielding 0.17 redislocations per follow-up year; an additional 19% without recurrence had continued symptoms of pain and instability, and required surgery. The mean Kujala score at follow-up was 80, with significantly lower scores in those older than 30 years of age.

In the management of acute patellar dislocations, prospective, randomized controlled studies have shown higher Kujala scores (higher scores indicate better knee function) [40–42] and reduced rate of recurrent patellar dislocation [40–43] after surgical stabilization as compared with nonoperative treatment.

Despite above-mentioned studies, majority of patients with acute lateral dislocation of the patella are initially treated by nonoperative management. Nonoperative treatment is indicated for patients with acute, first-time dislocation of the patella without associated osteochondral fracture or loose bodies. The nonoperative treatment consists of immobilization in a plaster cast or a brace for about 4–6 weeks followed by a period of well-planed, supervised rehabilitation. Immobilization allows for healing of the injured soft tissues on the medial aspect of the knee. Some surgeons recommend early rehabilitation of the knee without immobilization to avoid harmful effects of immobilization (such as quadriceps weakness and wasting, knee stiffness, and chondrolysis). Whether immobilized or not, patients with acute patellar dislocation should expect a prolonged rehabilitation period before return to sport.

2.8 Operative treatment

Operative treatment is indicated for patients who have persistent pain, recurrent instability and diminished knee function, and who have failed a trial of nonoperative management. In our experience, the indications for initial operative treatment include presence of an osteochondral fragment, loose body, a complete tear or avulsion of the MPFL, palpable defects in the vastus medialis insertion, obvious tear in the medial patellar retinaculum, associated ligamentous or meniscal injury, and persistent asymmetric subluxation of the patella.

The surgical procedures include arthroscopy, lateral release, medial retinacular repair, MPFL repair with or without augmentation, realignment procedure, or combination of these surgical techniques. Repair and reconstruction should be undertaken to address identifiable, injured soft tissues on the medial aspect of the knee, whereas release or lengthening of the lateral patellar retinaculum should be performed to restore soft tissue balance of the patellofemoral joint. Realignment procedure is indicated for patients who have a clear underlying anatomic malalignment.

2.8.1 Arthroscopy

Arthroscopy helps to identify and treat the associated intra-articular pathologies, such as chondral and osteochondral injuries; meniscal tears; and ligamentous injuries. Arthroscopy can be performed alone or in combination with open procedures. Minor or small chondral or osteochondral fragments can be excised, and medium-sized or large chondral or osteochondral fragments can be fixed with the use of modern arthroscopic surgical technique, instrumentation, and implants.

2.8.2 Lateral release

We are extremely cautious in advocating an isolated lateral patellar retinaculum release procedure for the treatment of acute lateral dislocation of the patella. In our opinion, arthroscopic lateral release is strictly indicated for patients who have a documented patellar tilt without subluxation. Using a biomechanical cadaveric model, Desio et al. [8] have shown that the intact lateral patellar retinaculum actually prevents lateral displacement of the patella, contributing 10% of the restraining force. Several authors [44–46] have reported recurrent lateral dislocations of the patella, almost exclusively in groups of patients treated by lateral release. Moreover, iatrogenic medial subluxation and dislocation of the patella following lateral release have been reported by several authors [47, 48]. Fithian et al. [49] conducted a scientific survey of the International Patellofemoral Study Group to determine current views regarding lateral patellar release. The survey response rate was 60%. Isolated lateral release was estimated to account for only 1 to 5 surgical cases per respondent per year, or 2% of cases performed annually. The results of the survey showed that only 7% of respondents would consider a lateral release in a first-time lateral patellar dislocation with a tight lateral retinaculum, and 37% would consider a history of lateral patellar dislocation as a contraindication to lateral release procedure. The authors concluded that even among experienced knee surgeons with a special interest in disorders of the patellofemoral joint, isolated lateral release is rarely performed. Strong consensus was found that isolated lateral release should not be undertaken without previous planning in the form of objective clinical indications and preoperative informed consent. Therefore, in view of the above-mentioned findings, we emphasize that lateral release procedure should be used with caution in patients with acute lateral dislocation of the patella.

2.8.3 Medial retinacular repair

Disruption or stretching of the medial patellar retinaculum and MPFL almost always accompanies lateral dislocation of the patella. Hence, the mainstay of early surgical treatment in the acute, first-time patellar dislocation is repair or reefing of the injured medial soft tissue structures, often accompanied by a lateral release procedure.

2.8.4 Medial patellofemoral ligament repair and augmentation

Repair or reefing of the medial retinaculum often does not completely address the medial-sided pathology after acute lateral dislocation of the patella [30]. As mentioned previously, the MPFL is injured in about 90% of patients who sustain acute lateral dislocation of the patella. Therefore, it is logical that patellar stability may be restored by undertaking direct repair of the MPFL with or without augmentation (using a strip of fascia, slip of the medial patellar retinaculum, distal adductor magnus tendon, etc.). However, there is a limited clinical evidence showing the efficacy of such techniques. Going forward, high-quality, prospective randomized clinical studies utilizing a larger population are needed to firmly establish the role of MPFL repair and augmentation in patients with acute lateral dislocation of the patella. In contrast, MPFL reconstruction is a fairly well-established surgical technique and is usually reserved for cases of recurrent patellofemoral instability. A detailed discussion on MPFL reconstruction is provided in Section II of this chapter.

2.9 Rehabilitation

Traditionally and historically, nonoperative treatment has been the mainstay of therapy for patients with acute patellar dislocation. A comprehensive, well-planned supervised rehabilitation program is vital for a successful outcome. The initial goals of rehabilitation are to decrease joint effusion, regain both active and passive range of motion, and advance the weight-bearing status of the extremity. In the next phase, closed kinetic chain exercises, quadriceps strengthening, and proprioceptive exercises are begun. In the last phase of rehabilitation, emphasis is placed on proprioceptive feedback, and functional and sport-specific training [30]. Isokinetic, eccentric, and high-torque exercises can cause high articular cartilage pressures and should be avoided [50]. Core strengthening is emphasized. In addition, gluteal muscle strengthening should be undertaken to improve the external rotators of the hip, thus externally rotating the femur and decreasing the Q-angle. The ultimate goal of rehabilitation is to obtain a pain-free, mobile, stable and functional knee.

The patient is allowed to return to play when the following criteria have been met: Subjectively, there should be no pain, swelling, or sensation of giving-way/instability. Objectively, there should be no joint effusion, no tenderness, a negative patellar apprehension test, and a full, pain-free range of motion in the knee [30]. Quadriceps strength in the affected lower extremity should be at least 80% as compared with the contralateral side. The role and usefulness of patellar bracing and taping in the management of acute patellar dislocation is unclear. Patellofemoral instability symptoms may be reduced in some patients with a patellar cutout brace or patellar taping. Although patellar taping was originally reported to have a high success rate, researchers have been unable to reproduce these results [51]. Patellar bracing and/or taping should be regarded as adjuvants to physical therapy. Patient should be counseled regarding expectations and clinical outcomes of the nonoperative and operative treatment.

2.10 Summary

- There are two distinct groups of patellar dislocations; one group of patients with normal anatomy and a traumatic event, and the other group with predisposing anatomical factors and a history of patellar subluxation or dislocation without a traumatic event [30].

- The MPFL is the main restraint to lateral patellar subluxation/dislocation.
- The MPFL is injured in about 90% of patients who sustain acute lateral dislocation of the patella.
- Lateral patellar dislocation can occur following an indirect mechanism (noncontact injury) wherein the body rotates on a valgus, flexed knee relative to a planted foot, or as a result of a direct blow (contact injury) to the knee.
- A thorough history and a detailed physical examination, supplemented by plain radiographs and MRI, are vital for early, accurate diagnosis.
- The majority of first-time, acute traumatic lateral dislocations of the patella are treated nonoperatively, and this mode of treatment is supported by high-level evidence.
- Surgery is indicated for patients in following situations:
    1. Presence of an osteochondral fracture or major chondral injury.
    2. Substantial disruption of the medial soft tissue patellar stabilizers (medial retinaculum and MPFL).
    3. A persistent laterally subluxed patella.
    4. Recurrent, symptomatic lateral patellar subluxation or dislocation.
    5. Failure of a trial of nonoperative management.
- An organized, supervised rehabilitation program is crucial for optimal recovery and successful clinical outcome.
- Acute patellar dislocations can result in pain, recurrent instability, impairment of knee function, decreased level of sporting activity, and patellofemoral arthritis.
- Patients should be educated and counseled regarding expectations and clinical outcomes of nonoperative and operative treatment.

3. Patellofemoral instability: recurrent dislocation of the patella

Patellar instability by definition is a disorder where the patella pathologically subluxates or dislocates out of the trochlear groove. This most often involves multiple factors, such as acute trauma, chronic ligamentous laxity, connective tissue disorder, anatomical abnormality, or osseous malalignment [50]. Over a period of time, patients with patellar instability can have debilitating pain, limitations in knee function, loss of time from work and/or sports, and long-term arthritis.

Although medial, superior, and intra-articular dislocations of the patellae have been reported, most patellar dislocations are lateral. In clinical practice, lateral patellar subluxations or dislocations are far more common than medial subluxations or dislocations. Medial subluxation of the patella is usually iatrogenic. Medial subluxation may occur as a complication of an extensive lateral release, a lateral release performed for an incorrect indication, overtightening of the medial structures, or blunt or surgical trauma resulting in scarring and inferomedial tethering of the patella [50].

Two mechanisms of acute lateral patellar dislocation have been described: an indirect (noncontact) injury and a direct blow (contact injury) (**Figure 2**). The indirect mechanism is more common and involves the combination of a strong quadriceps contraction, a flexed and valgus knee position, and an internally rotated femur on an externally rotated tibia with the foot planted to the ground [50]. Patients with dislocations due to an indirect mechanism frequently have one or more predisposing anatomical risk factors. These risk factors include genu valgum, increased Q-angle, increased femoral anterversion (internal femoral torsion), external tibial torsion, patella alta, generalized ligamentous laxity, weakening or hypoplasia of the VMO, and trochlear dysplasia or hypoplasia (**Table 1**). Generalized ligamentous laxity is seen in various orthopedic disorders, such as Down syndrome, Ehlers Danlos syndrome, Marfan syndrome, osteogenesis imperfecta, and Morquio-Brailsford syndrome.

3.1 Clinical presentation

A thorough history should be obtained, focusing on the mechanism of injury, the onset and duration of symptoms, any previous history of patellar symptoms, and prior nonoperative or operative treatment. Patients should be asked whether the previous treatment modalities relieved their symptoms. Patients with patellofemoral instability usually present with a history of peripatellar pain, recurrent swelling, crepitus, giving-way or instability, and weakness in the affected extremity. The knee pain may get worse while going down the stair or up the stairs, and during squatting and kneeling. In few cases, the patient may complain of mechanical catching or locking in the knee, and this indicates presence of a loose body (chondral or osteochondral fragment) in the joint. The patient may report that "my kneecap slides, slips, shifts, pops or jumps out of place" or "my kneecap pops or jumps back into place" with certain positions of the knee. Symptoms may occasionally be preceded by a history of traumatic episode but more commonly, the clinical symptoms are insidious in onset.

3.2 Physical examination

A meticulous comprehensive physical examination of the affected extremity as well as the opposite extremity should be performed. The patient should be examined in standing, sitting, and supine positions, while barefoot and dressed in shorts [30]. Gait pattern, obesity, posture and body habitus should be documented [30]. Patients with significant knee pain may demonstrate antalgic gait. A quadriceps avoidance gait (typically seen in patients with anterior cruciate deficiency) with reduced knee flexion in stance phase may be observed in some patients with patellofemoral instability. A Trendelenburg gait with a drop in the contralateral pelvis during stance phase indicates gluteus medius weakness. This change in pelvic obliquity tightens the ipsilateral iliotibial band, causing pain over the lateral aspect of the knee [30].

The skin of the involved extremity should be examined for presence of traumatic scars or surgical incision(s), or evidence of vasomotor dysfunction (such as, alterations in sweating, skin color, and temperature) and trophic changes in the skin, hair, or nails. Any muscle asymmetry of the thigh or calf should be recorded using a measuring tape, by taking circumferential measurements at a standard distance proximal and distal to the knee.

The patient should be evaluated for any physical signs that may serve as prognosticators of patellar instability (**Table 1**). Generalized ligamentous hyperlaxity should be noted by examining finger metacarpophalangeal joint hyperextension, thumb-to-forearm apposition, knee hyperextension, and elbow hyperextension. Abnormalities in femoral anteversion should be measured by observing maximal prone internal and external hip rotation as well as rotation of the leg at the position of maximal prominence of the greater trochanter [52]. Similarly, transmalleolar axis and thigh-foot angle should be used to confirm excessive tibial torsion.

The range of motion and strength in the hip joint should be assessed as some patients with hip disorders may present with a referred knee pain. Examination of the foot should be performed. Some patients with lateral patellar dislocation may have pronation of the foot and hindfoot valgus. A complete neurovascular examination of the limb should be performed.

3.2.1 Sitting examination

The patient should next be examined in the sitting position, with the knees flexed at 90 degrees over the edge of the examination table. The position of the tibial tuberosity should be observed in relation to the center of the patella. Patella alta or baja can be easily observed from the side. The Q-angle (the angle between the quadriceps tendon and the patellar tendon) should be measured with the knee in flexion. Measurements of the Q-angle in full extension may be falsely low in patients with patellar subluxation. The angle is recorded by drawing one line from the anterior superior iliac spine to the center of the patella and another line from the center of the patella to the center of the tibial tuberosity. The mean Q-angle is about 10 degrees in men and 15 degrees in women [50].

Patellofemoral tracking is assessed as the patient sits on the edge of the examination table. The patient is asked to take the knee from flexion into full extension. The term *J sign* refers to an abnormal tracking pattern in which the patella sits lateral to the femoral sulcus in full extension; the movement of the patella appears in the shape of an upside-down *J* as the knee goes from flexion into full extension [30]. Conversely, the patella starts laterally with the knee in extension and makes an abrupt shift medially as it enters the femoral trochlea at about 20 to 30 degrees of knee flexion. The exact cause of the *J sign* is not known; however, factors such as VMO deficiency, underlying osseous morphology and soft tissue imbalance are postulated as causative factors for the occurrence of *J sign*.

3.2.2 Supine examination

The next stage of the patellofemoral examination consists of evaluation of the patella and related structures. Presence of joint effusion should be noted. The peripatellar soft tissues are carefully palpated. Tenderness over the medial femoral epicondyle region (Bassett's sign) may represent an injury to the MPFL in patients with acute or recurrent dislocations of the patella [53]. Tenderness on palpation of the inferior pole of the patella is often diagnostic of patellar tendinitis, whereas tenderness over the proximal pole of the patella may indicate quadriceps tendinitis. Tenderness within the substance of the distal quadriceps tendon or the proximal patellar tendon is suggestive of diffuse tendinosis. Tenderness along the medial border of the patella may represent injury to the medial patellar retinaculum and the MPFL. The MPFL should be palpated along its entire course from the femoral origin to the patellar insertion. The insertion of VMO should be palpated for tenderness or defect. Tenderness on the lateral border of the patella is often found in patients with excessive lateral pressure syndrome. Tenderness over the lateral femoral condyle is indicative of osteochondral fracture. In patients who have undergone previous surgery, the surgical incision area should be examined for the presence of neuroma. A diagnostic lidocaine injection is helpful to confirm a clinically suspected diagnosis of neuroma. Retinacular tenderness, hypersensitivity to palpation, and decreased patellar mobility are suggestive of Complex Regional Pain Syndrome Type I (previously known as Reflex Sympathetic Dystrophy). Active and passive range of motion in the affected knee should be evaluated and any deficit or asymmetry (as compared with the opposite, normal knee) should be recorded. A resisted straight-leg raise test is performed to rule out disruption of the extensor mechanism (i.e. quadriceps tendon and patellar tendon). The neurological and vascular status of the extremity should be assessed.

3.2.3 Patellar tilt test

Patellar tilt test is used to determine the tightness or integrity of the medial and lateral soft tissue restraints. The test is performed with the knee extended and the quadriceps relaxed. The examiner attempts to raise the patient's lateral patellar facet away from the lateral femoral trochlea. An inability to raise the lateral facet to the horizontal is indicative of lateral retinacular tightness and tethering of the lateral patella.

3.2.4 Patellar glide test

Patellar glide test is performed to assess the integrity of the medial and lateral patellar restraints. Patellar mobility is assessed by attempting to displace the patella medially and laterally. Throughout this portion of the examination, the knee is placed in full extension, with the quadriceps relaxed. The number of quadrants of medial and lateral glide is recorded as lateral and medial patellar pressure are applied. The amount of patellar glide on the affected side should be compared with that on the opposite, asymptomatic side. In a normal knee, the patella cannot be displaced more than half its width in either direction [50].

3.2.5 Patellar apprehension test

The patient lies supine on the examination table. The examiner passively translates the patella laterally with the knee flexed 20 to 30 degrees and the quadriceps relaxed. In a positive test, the patient experiences a feeling of impending subluxation or dislocation of the patella and this is called apprehension [54, 55]. (**Figure 3**). Some patients even make an attempt to hold the examiner's hand to prevent the patella from subluxating or dislocating laterally. Pain usually accompanies the apprehension; however, the latter is considered the major component of a positive test.

3.2.6 Patellar compression test

The patella should be palpated for retropatellar tenderness and crepitus which may suggest an injury to the articular cartilage. Compression of the patella during full range of motion of the knee may reproduce the associated pain. The location of the chondral injury may be estimated on the basis of the knee-flexion angle in which pain is experienced. The patellofemoral contact area moves proximally on the patella as the knee flexion increases. Articular lesions on the distal patella are painful during early knee flexion, whereas proximal patellar lesions are manifested with further knee flexion. Clinically suspected chondral lesions should be confirmed by MRI assessment to help in preoperative planning.

The flexibility of the lower extremity should be evaluated, especially in reference to hamstrings tightness. Excessive tightness of the hamstrings requires greater quadriceps force for knee extension, leading to increased transmission of contact pressure across the patellofemoral joint. Hamstring flexibility is best assessed by measuring the popliteal angle. Gastrocnemius and soleus tightness should also be evaluated. The flexibility of both muscles can be judged by ankle dorsiflexion with the knee extended. With the knee flexed, the gastrocnemius is relaxed, and the soleus is isolated. In both positions, the ankle should dorsiflex 15 to 20 degrees past neutral. Limitation of ankle dorsiflexion causes a compensatory increase in subtalar pronation, thereby increasing internal tibial rotation during gait [30]. The lower extremity should also be examined for iliotibial band tightness and the examination finding should be compared with that in the opposite limb. Iliotibial band tightness is assessed by performing the time-honored Ober's test [56]. With the patient in the lateral decubitus (with the affected extremity on top), the hip and knees are flexed to 90 degrees initially. The examiner then places one hand on the pelvis to stabilize and monitor for movement. The ipsilateral leg is abducted, brought into full extension at the hip and the knee, and then adducted toward the table. Tightness or pain may be elicited. The test is considered positive if the patient's leg does not lower beyond neutral as the examiner lowers it from an abducted and slightly extended position, suggesting shortness of the tensor fascia lata and iliotibial band. A negative test results in the leg returning normally toward the examination table.

3.2.7 Tests for associated meniscal injury

The medial and lateral joint lines should be examined for areas of tenderness. Medial joint line tenderness is suggestive of meniscal tear, arthrosis, or tear of the patellomeniscal ligament along its course to insertion on the anterior horn of the medial meniscus [30]. McMurray's test and Thessaly test are performed to rule out meniscal tear. The Thessaly test [57] is performed as follows: The patient stands on one leg while holding the examiner's hand for support. The examiner instructs the patient to rotate the body and leg internally and externally 3 times with the knee bent at 5 degrees and then at 20 degrees. The test should be first performed on the unaffected side so that the patient can properly perform movement as a practice run before testing the affected knee. The test is considered positive when pain or clicking occurs at the joint line. A locking or catching sensation is also suggestive of meniscal injury.

3.2.8 Tests for associated cruciate and collateral ligament injury

Patellar symptoms may be masked due to presence of concomitant anterior cruciate ligament deficiency; therefore, the Lachman and pivot shift tests should be performed. Posterior cruciate ligament insufficiency has been reported to be associated with patellofemoral arthrosis. Hence, the posterior drawer test is also an essential part of a complete physical examination. Valgus testing to determine the integrity of the medial collateral ligament is important in patients with a patellar dislocation because simultaneous medial collateral ligament and MPFL injuries can occur.

After completion of the physical examination, aspiration of an intra-articular effusion can be done to determine the diagnosis. A hemarthrosis implies a traumatic injury, whereas serosanguinous fluid may indicate an articular cartilage lesion. In patients with acute dislocations of the patella, it is important to examine the aspirate for the presence of fat droplets, which indicate the presence of an associated osteochondral fracture [50].

3.3 Radiographic studies

The radiographic investigations include plain radiographic series, stress radiography (less popular), Computed Tomography (CT) scan, and MRI examination. Recently, dynamic magnetic resonance imaging and 4-dimensional computed tomography have been introduced for better kinematic assessment of the patellofemoral maltracking during extension-flexion motion [58].

3.3.1 Plain radiographs

In all patients with recurrent dislocation of the patella, a complete plain radiographic series, consisting of standing anterior–posterior view, 45-degree flexion posterior–anterior weight-bearing view (Rosenberg view), lateral view, and axial view should be obtained. In patients with clinically diagnosed malalignment of the extremity, an additional full-length, standing alignment radiograph should also be obtained. Plain radiographs are a useful screening tool to rule out gross malalignment and fractures. However, they underestimate the presence of articular surface lesions.

3.3.2 The anteroposterior radiograph

The anteroposterior radiographs of the knee are useful to diagnose malalignment, patellar fracture, bipartite patella, and arthritis. Although patella alta and baja (infera) can be visualized on antero-posterior radiograph, they are best quantified on a 30-degree lateral radiographic view of the knee.

3.3.3 The lateral radiograph

A true lateral radiograph of the knee should be obtained, showing overlap of the distal and posterior cortices of the medial and lateral femoral condyles. The lateral view allows determination of the patellar height and depth of the femoral trochlea. Several measurements have been described to measure patella alta. Controversy exists as to which radiographic measurement is most accurate. When the patella does not engage in the trochlea by 15 to 20 degrees of knee flexion, patella alta may be present.

3.3.4 Assessment of patellar height

The Insall-Salvati [32], modified Insall-Salvati [33], Blackburne-Peel [34], and Caton-Deschamps [35] ratios are commonly used to measure the patellar height. A detailed description of these ratios has been published in standard orthopedic textbooks. The Insall-Salvati [32] index is based on the ratio of the length of the patellar tendon divided by the greatest length of the patella. The normal ratio defined by the authors is 1.0. A ratio of >1.2 indicates patella alta whereas, a ratio of <0.8 denotes patella baja. However, difficulty in determining the exact insertion site of the patellar tendon and abnormal morphology (such as elongated inferior pole of the patella) of the non-articular portion of the patella may falsely alter this ratio. Furthermore, the patellar tendon length varies between sexes in the normal population [59]. In order to eliminate these variables, Grelsamer and Meadows [33] proposed a modified Insall-Salvati ratio. This modified ratio is defined as the distance from the inferior point of the articular surface of the patella to the patellar tendon insertion into the tibial tuberosity, divided by the length of the articular surface of the patella. Using this method, patella alta is defined as a ratio greater than 2.0, a point at which only 3% of controls would be falsely identified as patella alta [33]. Blackburne and Peel [34] reported a ratio that is independent of the length of the patellar tendon. Their index is defined as the ratio of the length of the perpendicular line from the lower end of the articular surface of the patella to the tibial plateau line, divided by the length of the articular surface of the patella. Based on their study, a ratio of 0.8 is considered normal, a ratio of >1.0 indicates patella alta, whereas a ratio of <0.5 denotes patella baja [34]. Caton and Deschamps [35] have also described a ratio to address the difficulty in measuring the length of the patellar tendon. Their ratio is defined as the ratio of the distance from the inferior articular surface of the patella to the anterosuperior border of the tibia, divided by the length of the articular surface of the patella. Based on the Caton-Deschamp index, a ratio of >1.2 indicates patella alta and < 0.6 indicates patella baja. Seil et al. [60] recommended the Blackburne and Peel ratio to measure the patellar height because it showed the most intermediate classification results and the lowest interobserver variability.

3.3.5 Assessment of trochlear morphology

The morphology of the trochlea should be carefully assessed on a true lateral view of the knee as trochlear dysplasia is a known risk factor for recurrent patellar instability. On the true lateral radiograph, three anterior lines are visualized: the most anterior line is a projection of the medial femoral condyle, the middle line is a projection of the lateral femoral condyle, and the remaining line is a projection of the floor of the trochlea. Dejour et al. [61] have evaluated trochlear morphology and reported two separate measures in a radiographic study of the factors of patellar instability; First measure is the trochlear bump and the second is trochlear depth. The trochlear bump is defined as the distance between the projection of the anterior femoral cortex and the projection of the trochlea, which can be anterior positive or posterior negative. The trochlear bump was greater than +3 mm in 85% of patients with objective patellar instability [61]. The trochlear depth is defined as the depth of the trochlea along a line 15 degrees from the perpendicular to the tangent of the posterior femoral cortex. A depth of less than 4 mm was found in 85% of patients with objective patellar instability and in only 3% of controls [61].

One should also look for supratrochlear spur, crossing sign and double contour sign on the lateral radiograph of the knee. The supratrochlear spur is a global prominence of the trochlea. The crossing sign represents an abnormally elevated floor of the trochlear groove rising above the top of the wall of one of the femoral condyles. On the lateral radiograph of the knee, trochlear dysplasia is defined by the crossing sign [62] which refers to the crossing over of the trochlear floor condensation with the condensation of the most prominent aspect of the lateral trochlea and is found in 96% of the population with a history of true dislocation but in only 3% of healthy controls [61, 63]. The double contour sign is a radiographic line that represents the hypoplastic medial facet on the lateral view [64, 65].

Radiographically, trochlear dysplasia is defined by a sulcus angle of greater than 145 degrees as seen on axial radiographic views of the patellofemoral joint [66, 67]. Dejour and colleagues [67, 68] have classified trochlear dysplasia into 4 types as shown in **Figure 4**.

- In type A dysplasia, there is a crossing sign on the lateral radiographs and the trochlear groove is symmetric but shallower than normal, with a sulcus angle greater than 145° on axial images.

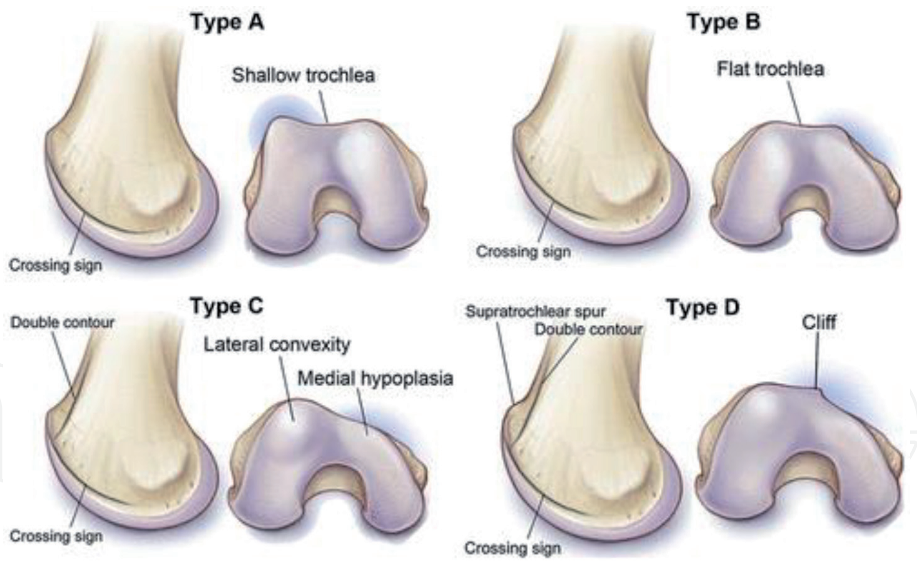

Figure 4.
Dejour classifications of trochlear dysplasia. Type A: Crossing sign, trochlear morphology preserved (fairly shallow trochlea, >145°). Type B: Crossing sign, supratrochlear spur, flat or convex trochlea. Type C: Crossing sign, double contour (projection on the lateral view of the hypoplastic medial facet). Type D: Crossing sign, supratrochlear spur, double contour, asymmetry of trochlear facets, vertical link between the medial and the lateral facet (cliff pattern). Reprinted with permission from: Onor et al. [69].

- In Type B dysplasia, there is a crossing sign as well as a supratrochlear spur on lateral radiographs, with a flat or convex trochlea on axial images.

- In Type C dysplasia, there is a crossing sign and a double contour sign on lateral radiographs, with lateral facet convexity and medial facet hypoplasia on axial images.

- In Type D dysplasia, there is a crossing sign, supratrochlear spur, and a double contour sign on lateral radiographs. There is asymmetry of the trochlear facets with medial facet hypoplasia. There is a vertical slope demonstrating the so-called "cliff pattern" on axial images because of asymmetry of the lateral and medial trochlear facets.

The Dejour classification is widely referred to in the literature and currently considered the gold standard for the description of trochlear dysplasia.

3.3.6 The Axial Radiograph

The axial views as described by Merchant and colleagues [36] and Laurin and colleagues [37, 38] are commonly used for the evaluation of the patellofemoral joint. The axial view is helpful for diagnosing lateral patellar tilt and also provides valuable information about any persistent subluxation or dislocation of the patella. The sulcus angle can be measured on the axial view. Tangential osteochondral fracture of the medial facet of the patella or osteochondral fracture of the lateral femoral condyle may be visualized on an axial radiograph.

3.3.7 Stress Radiographs

Stress radiography is widely practiced in Europe and less commonly utilized in USA. Stress radiographs are helpful in identifying patients with patellofemoral instability. Measurements on stress radiographs are more reliable predictors of lateral, medial, and multidirectional patellar instability than measurements made on static radiographs [50]. Moreover, they can provide useful objective information when evaluating the results of different treatment regimens. Patients who are unable to relax the extensor mechanism due to pain or who have bilateral symptoms are not candidates for stress radiography [50].

3.3.8 Computed Tomography

Computed tomography (CT) has been shown to be more accurate in detecting patellar malalignment than conventional axial radiography [70]. Among the advantages of CT over plain radiography are that there is no image overlap or distortion and that there are precise reference points for reliable measurements [50]. The conventional axial radiographs cannot assess the patellofemoral joint with the knee in full extension, whereas the cross-sectional nature of the CT scan allows the patellofemoral joint to be evaluated in such position and enhances detection of early lateral subluxation of the patella (within 0 to 30 degrees of knee flexion). Examination of the knee in extension is crucial because most patellar instability occur in the first 30 degrees of knee flexion, before the patella is constrained by the trochlea [30]. Measurements of congruence angle, lateral patellofemoral angle, patellar tilt, TT-TG distance, and rotational abnormalities of the femur and tibia have been studied extensively using a CT scan.

3.3.9 Tibial Tuberosity-Trochlear Groove (TT-TG) Distance

Computed Tomography scan can help in identifying lateralization of the tibial tuberosity, as measured by the TT-TG distance. An axial CT image demonstrating the femoral trochlear groove is superimposed on an axial image of the tibial tuberosity. A line is drawn on this superimposed image along the posterior margins of the femoral condyles. Two lines are then drawn perpendicular to this line, one bisecting the femoral trochlear groove and the other bisecting the anterior aspect of the tibial tuberosity. The distance between these two lines determines the extent of lateralization of the tibial tuberosity. A normal TT-TG distance is around 9 mm. A TT-TG distance >20 mm is considered abnormal. Values greater than 9 mm have been shown to identify patients with patellofemoral malalignment with a sensitivity of 85% and specificity of 95% [71].

3.3.10 Magnetic resonance imaging

Magnetic resonance imaging (MRI) combines the accuracy of osseous measurements made on CT scan with the ability to visualize the soft tissues. Furthermore, MR imaging can detect pathologies such as, articular cartilage lesion of the patella and/or the femoral condyle. Advantages of the MRI include ability to obtain images in multiple planes, better soft tissue resolution, and no risk of exposure to radiation. Sallay et al. [72] have reported the pathoanatomic features of patellar dislocations using MRI. The location of the injury was confirmed by surgical exploration. In their study, MRI revealed effusion in all 23 patients (100%), tears of the femoral attachment of the MPFL in 20 patients (87%), increased signal intensity and retraction of the vastus medialis muscle in 18 patients (78%), a bone bruise in the lateral femoral condyle in 20 (87%), and a bone bruise in the medial patella in 7 (30%). Arthroscopic examination revealed osteochondral lesions involving the patella and the lateral femoral condyle in 68% of cases. Open surgical exploration revealed tears of the MPFL off the femur in 15 of 16 patients (94%). Sallay et al. [72] also noted that the location of the bone bruise on the lateral femoral condyle was slightly anterior and superior to the typical bone bruise seen after an acute anterior cruciate

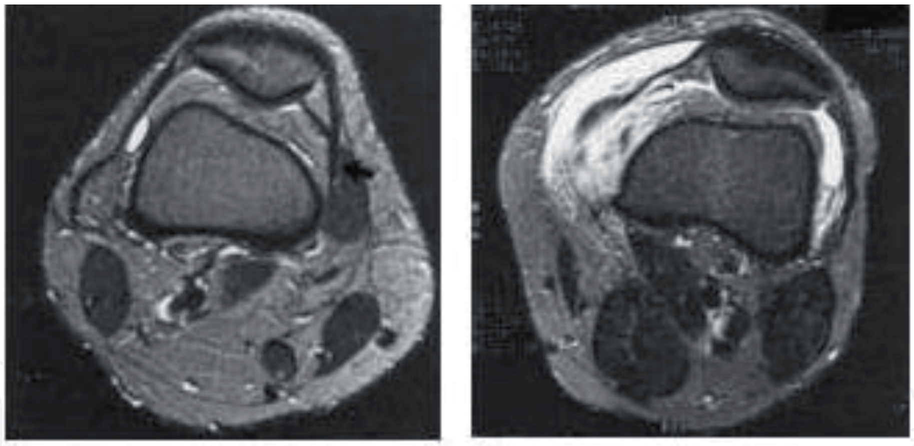

Figure 5.
(A). Axial MR image of the knee showing a normal MPFL. (B). Axial MR image of the knee demonstrating an avulsion of the MPFL from its femoral attachment. Reprinted with permission from Boden et al. [50].

ligament injury. An axial MRI image of the knee showing an avulsion of the MPFL from its femoral attachment is shown in **Figure 5**.

Injury to the VMO, which lies superficial to the MPFL, frequently presents as edema, hemorrhage, and/or elevation of the muscle away from the medial femoral condyle [73, 74]. Approximately 50–80% of injured MPFLs are disrupted at their femoral origin [73–75].

4. Principles of treatment of patellofemoral instability

4.1 Nonoperative treatment

Based on our extensive clinical experience (level V evidence), we have found that nonoperative treatment of chronic patellar dislocations (treated initially by a period of brief immobilization followed by rehabilitation) has produced less satisfactory or even dismal results, with nearly half of patients having recurrent dislocations or continued knee symptoms. Steiner and Parker [30] have also reported less satisfactory clinical outcomes following nonoperative treatment of patients with chronic patellofemoral instability. We believe that immobilization for patients with recurrent episodes of patellar dislocation may be used in the short-term for patient comfort; however, it is of little benefit in the long-term. A trial of rehabilitation may be offered to a patient who experiences only occasional dislocation and displays no obvious predisposing anatomic or radiographic abnormalities [30]. Rehabilitation may be augmented by the use of a patellar brace or orthosis if tolerated by the patient. On the other hand, patients who have predisposing anatomical risk factors (**Table 1**) or those who experience recurrent patellar dislocation with activities of daily living will likely require operative treatment.

4.2 Operative treatment

Operative treatment for patients with recurrent patellar instability should be directed at the underlying causative pathoanatomy that can be determined by careful history-taking, meticulous physical examination, and pertinent radiographic studies. We emphasize an individualized treatment approach rather “one-size-fits-all” approach. Surgical intervention should be based on clear understanding of the underlying pathoanatomic risk factor(s) and radiographic abnormality as shown below:

1. Reconstruction of the MPFL is indicated for patients with recurrent instability, with or without trochlear dysplasia, who have a normal TT-TG distance and a normal patellar height.

2. Distal realignment procedures should be performed for patients who have an increased TT-TG distance (>20 mm) or patella alta.

3. A standard medialization of the tibial tuberosity can be performed if there is a normal patellar height and trochlear anatomy, and an increased TT-TG distance (>20 mm). Distalization of the tuberosity can be added if there is concomitant patella alta, and anteromedialization of the tuberosity is performed if there is lateral and/or distal patellar facet chondrosis.

4. Patients with moderate-to-severe trochlear dyslpasia can be treated by trochleoplasty.

5. Corrective derotation osteotomy may be required for patients with rotational (torsional) abnormality of the femur or tibia.

Patients with recurrent patellofemoral instability often have multiple anatomical and/or radiographic risk factors. In such a scenario, a combination of above-mentioned surgical procedures is necessary to restore patellar stability.

4.2.1 Arthroscopic assessment

A thorough arthroscopic evaluation of the knee joint should be performed. The articular surfaces of the patella and femoral trochlea should be assessed. The extent and type of chondral lesion are determined by probing the articular surface. Large, unstable chondral lesions should be fixed, whereas the small fragments are excised. The superomedial portal is particularly useful in evaluating patellar tracking and patellar tilt [76]. The lateral facet should align with the trochlea by 20 to 25 degrees of knee flexion and the mid-patellar ridge should align with the trochlea by 35 to 40 degrees of knee flexion. Any lateral overhang of the patella should be documented while the patella is engaging the femoral trochlea. Evidence of patellar tilt should be noted.

4.2.2 Lateral retinacular release

In our opinion, isolated lateral release has a very limited role in the management of patellofemoral instability. This procedure may be combined (when indicated) with other procedures such as MPFL reconstruction or distal realignment. Lateral release is effective in reducing patellar tilt. It is important to keep in mind that excessive or unindicated lateral release procedure can result in iatrogenic medial subluxation or dislocation of the patella.

4.2.3 Proximal realignment procedures

The goal of proximal realignment surgery is to reestablish a dynamic balance of forces around the patella. In 1979, Insall and associates described the "tube" realignment procedure for the treatment of chondromalacia patellae [77]. The procedure consists of release of the medial and lateral retinacular tissue, which are sewn together over the quadriceps proximal to the patella. Since then, modifications of this procedure involving a lateral release, with a lateral and 1-cm distal advancement of the vastus medialis, have been described in the treatment of patellar dislocation.

4.2.4 Distal realignment procedures

Historically numerous surgical procedures (such as Roux-Goldthwait procedure, Hauser procedure, Elmslie-Trillat procedure – to name a few) for restoring patellofemoral stability have been described. Few of these reconstructive techniques are still popular in some parts of the word. The Hauser technique has fallen out of favor because of high incidence of patellofemoral arthritis at long-term follow-up. The Elmslie-Trillat procedure allows medialization without posterior transfer of the tibial tuberosity in combination with lateral release and medial capsular reefing. Carney and associates [78] have reported the long-term outcome of the Roux-Elmslie-Trillat procedure for patellar instability. In their study, 18 patients who underwent the Roux-Elmslie-Trillat procedure for dislocation or subluxation of the patella were identified from a group previously evaluated at a mean follow-up of 3 years. The prevalence of recurrent subluxation or dislocation in patients with patellofemoral malalignment who underwent the Roux-Elmslie-Trillat procedure was similar (7%) at 3 and 26 years' of follow-up. Fifty-four percent of the patients rated their affected knee as good or excellent at 26 years' of follow-up. The long-term functional status of the affected knee in patients who underwent the Roux-Elmslie-Trillat procedure declined.

Anteromedial tibial tuberosity transfer has been described by Fulkerson [79, 80]. In this procedure, an osteotomy of variable obliquity is made. Such an osteotomy allows the degree of anterior and medial transfer of the tibial tuberosity that can be independently adjusted to address the patient's individual pathology. The Fulkerson procedure (anteromedial tibial tuberosity transfer) corrects the Q-angle with medialization of the tibial tuberosity and unloads the patellofemoral joint with anteriorization of the tibial tuberosity. A hinge of bone is maintained intact at the distal aspect of the tuberosity to facilitate healing. After the tibial tuberosity has been transferred anteriorly and medially, the bone pedicle is locked into position with two cortical screws. Molina and associates [81] have showed that the most predictable way of increasing contact area and decreasing patellofemoral stress is transfer of the tibial tuberosity 1 cm anteriorly and 0.5 to 1 cm medially.

The indications for anteromedial tibial tuberosity transfer are:

1. Patients with recurrent patellar instability who have an increased TT-TG distance (>20 mm).

2. Patients with patellofemoral malalignment who have degenerative changes in the distal and lateral articular surface of the patella.

The contraindications for anteromedial tibial tuberosity transfer are:

1. Patients who have a normal TT-TG distance.

2. Presence of significant chondrosis affecting the proximal and/or medial facet of the patella.

3. Skeletally immature patients with patellar subluxation or dislocation.

4. Relative contraindications include smoking and severe osteoporosis.

The tibial tuberosity transfer procedure should not be performed in skeletally immature patients (who have open growth plates) with recurrent patellar instability due to the risk of premature closure of the physis and subsequent development of genu recurvatum.

Complications of anteromedial tibial tuberosity transfer include skin slough, hematoma, wound infection, compartment syndrome, knee stiffness, persistent knee pain, delayed union or non-union at the osteotomy site, symptomatic hardware, hardware failure (loosening, migration or breakage of the hardware), risk of proximal tibial facture, and progressive chondral deterioration.

Fracture of the proximal part of the tibia or of the tibial tuberosity after anteromedial tibial tuberosity transfer has been reported by several authors [82–84]. In order to prevent the occurrence of such a complication, various preventive measures have been suggested; these strategies include avoidance of step cuts [82], an osteotomy of at least 5 cm in length and 0.75 cm in thickness to avoid fracture of the tibial tuberosity [82], protected weight-bearing for six to eight weeks in a hinged knee brace, and advancement to full weight-bearing only when the osteotomy site has fully healed radiographically [83–85].

Stetson et al. [83] reviewed the records of 234 patients who underwent anteromedialization of the tibial tubercle with oblique osteotomy. In their series, six patients (2.6%) had fractures of the proximal tibia postoperatively, within 13 weeks of the Fulkerson osteotomy. All fractures occurred after a change in the postoperative physical therapy regimen from partial weight-bearing to immediate full weight-bearing. Given this increase in fracture incidence, a more conservative postoperative physical therapy regimen was recommended. The authors concluded that patients should be non-weight-bearing initially, advanced gradually to partial weight-bearing, and allowed full weight-bearing only after the osteotomy site shows radiographic evidence of complete healing.

Cosgarea et al. [85], in their biomechanical study, performed oblique and flat osteotomies on 13 pairs of fresh-frozen cadaveric knees. The knees were then tested to failure on a materials testing system by exerting a load through the quadriceps tendon at a rate of 1000 N/sec to simulate a stumble injury. The authors found that the failure mechanism for flat osteotomies was more likely to be a tubercle "shingle" fracture, while oblique osteotomies more frequently failed through a tibial fracture or fixation failure in the posterior tibial cortex. These authors recommended flat osteotomy for patients with isolated recurrent patellar instability and an oblique osteotomy in patients who have concomitant patellofemoral pain or degenerative changes in the articular cartilage. In cases where an oblique osteotomy is used, the authors recommended postoperative brace protection and restricted weight-bearing until the osteotomy site heals.

4.2.5 Trochleoplasty

Different surgical techniques have been developed to correct the pathologic trochlear morphology seen in patients with recurrent patellofemoral instability. These techniques include deepening of a shallow or flat trochlear groove (trochleoplasty), elevation of the anterior portion of the femoral condyles (trochlear osteotomy), and/or removal of a prominent trochlear bump. Numerous variations in these techniques and retrospective case series of their results have been reported. However, there are no prospective, randomized controlled studies in the literature that support the use of these techniques [30]. Trochleoplasty is more popular in Europe. There are concerns about possible irreversible damage to the articular cartilage and subchondral bone of the femoral trochlea, and these concerns have limited the use of trochleoplasty in the United States.

Trochleoplasty is a complex, challenging and technically demanding surgical procedure. Several authors have reported their experience with the use of trochleoplasty in the management of trochlear dysplasia in patients with patellofemoral instability [67, 68, 86–95]. Indications for a sulcus-deepening trochleoplasty include abnormal patellar tracking with a *J-sign*, usually manifested by a TT-TG distance of greater than 10 to 20 mm, and/or a dome-shaped trochlea noted on a perfect lateral radiograph of the knee with overlap of the posterior femoral condyles, and radiographic evidence of trochlear dysplasia in a patient with recurrent patellofemoral instability [89]. In a trochleoplasty procedure, a strip of cortical bone around the edge of the trochlea is elevated and the cancellous bone of the trochlea is exposed. The new trochlear sulcus is then created, proximal and about 3 to 6 degrees lateral to the previous sulcus, by removing the cancellous bone. Next, the trochlear bone shell is impacted into the new sulcus and fixed with two small staples. Alternatively, the bone shell can be secured using resorbable sutures [87, 90]. Early postoperative complications include arthrofibrosis and bothersome patellofemoral crepitus. Meticulous surgical technique in combination with postoperative continuous passive motion (CPM) are vital for maintaining range of motion of the knee and to ensure optimal clinical outcome.

Von Knoch et al. [90] reported the clinical and radiological outcome of trochleoplasty for recurrent patellar dislocation in association with trochlear dysplasia. Thirty-eight consecutive patients (45 knees) were treated by trochleoplasty, medial reefing, with or without reconstruction of the MPFL. The patients were reviewed at a mean follow-up of 8.3 years (range, 4 to 14 years). A total of 33 knees were available for radiological assessment. None of the patients had recurrence of dislocation after trochleoplasty. Preoperatively, patellofemoral pain was present in 35 knees. Postoperatively, 15 (43%) of 35 knees had worsening of the patellofemoral pain. The most recent Kujala score averaged 95 points (range, 80 to 100 points). The depth of the trochlea increased and the trochlear boss height was reduced. Although trochleoplasty was effective in preventing future patellar dislocations, it did not halt the progression of patellofemoral arthritis. At latest follow-up, ten (30%) of the 33 knees had osteoarthritic changes in the patellofemoral compartment.

Rouanet et al. [95] reported the long-term results of sulcus deepening trochleoplasty for patellofemoral instability. In their study, 34 cases were reviewed after a mean follow-up of 15 years (range, 12 to 19 years). No recurrent objective instability was observed. Seven knees had additional surgery after a mean follow-up of 7 years. Furthermore, 7 cases required conversion to total knee arthroplasty because of progression of osteoarthritis. Overall, there was an improvement in the knee function postoperatively. Patients were satisfied in 65% of the cases. At the time of the final follow-up, osteoarthritis was present in 33/34 cases. The authors concluded that the sulcus deepening trochleoplasty corrects patellofemoral instability in patients with severe trochlear dysplasia and the long-term functional outcome is better in this group. However, it does not prevent patellofemoral osteoarthritis. The sulcus deepening trochleoplasty procedure should be limited to patients who have severe trochlear dysplasia in conjunction with supratrochlear spurs, and this procedure should be combined with other surgical techniques to realign the extensor mechanism of the knee.

In conclusion, we believe that trochleoplasty has a limited but important role in the management of patients with recurrent patellofemoral instability with concurrent moderate-to-severe trochlear dysplasia. In such cases, trochleoplasty should be undertaken in combination with other surgical procedures, such as MPFL reconstruction or distal realignment procedure.

4.2.6 Medial Patellofemoral Ligament (MPFL) Reconstruction

Various authors have reported that the MPFL is universally disrupted in patients with lateral patellar dislocation and that its integrity is of primary importance to maintain stability of the patella [6, 8, 9, 72, 75, 96]. Hence, it is important to undertake reconstruction of MPFL (when indicated) in patients with recurrent patellofemoral instability to restore the patellofemoral biomechanics and kinematics. Medial patellofemoral ligament reconstruction has become one of the most common and widely used procedures to regain stability in patients with recurrent lateral dislocation of the patella. Recent studies have demonstrated low recurrence rates, improved patient-reported outcome measures, and a high rate of return to sports. Reconstruction of the MPFL is typically indicated for patients with recurrent patellofemoral instability, with or without trochlear dysplasia, who have a normal TT-TG distance and a normal patellar height. The procedure may be performed with concomitant procedures, such as distalization of the tibial tuberosity in a patient with patella alta, or trochleoplasty in a patient with high-grade trochlear dysplasia.

Numerous surgical techniques have been reported for reconstruction of the MPFL. A detailed description of all available techniques is beyond the scope of this chapter. The MPFL reconstruction can be performed using various sources of graft material, such as the medial retinaculum [97], adductor magnus tendon [98–102], patellar tendon [103, 104], quadriceps tendon [105–115], and most commonly, hamstring tendon (gracilis or semitendinosus tendon) [116–136]. In general, about 80–96% good to excellent results following isolated MPFL reconstruction have been reported.

Over the years, various methods of fixation of the tendon graft have been reported; these methods of fixation include staples, spiked washers, sutures, bone tunnels, interference screws, and bone anchors [30]. It is worth noting that variation in the location and length of the graft can greatly alter the compressive forces at the medial aspect of the patellofemoral joint [30].

4.3 At What Knee Flexion Angle the Graft Should be Fixed?

There is still no clear consensus of opinion regarding the ideal knee flexion angle at which the tendon graft should be fixed during MPFL reconstruction. Most authors prefer to fix the graft with the knee at 30 to 60 degrees of flexion. Patel et al. [137] conducted a systematic review to determine the effect of knee flexion angle during graft fixation on outcomes and complications following MPFL reconstruction. Of the 3399 studies, 17 studies satisfied the inclusion criteria. A total of 556 patients with a mean age of 24 years underwent MPFL reconstructions, with 458 patients in the 0° to 30° fixation group and 98 in the 45° to 90° fixation group. The authors concluded that the knee flexion angle during MPFL graft fixation ranges from 20° to 90°. Graft fixation at both low and high knee flexion angles during MPFL reconstruction showed excellent patient-reported outcomes and low patellar redislocation rates overall, with no clear differences between the 2 groups based on the available data.

4.4 Use of Autograft versus Allograft for MPFL Reconstruction

Kumar et al. [138] completed a retrospective chart review on patients younger than 18 years of age who underwent MPFL reconstruction for recurrent instability after failed nonoperative management. The patients were divided into autograft or allograft hamstring cohorts for comparison. Primary outcome measures were return to normal activity, incidence of redislocation/subluxation, pain, stiffness, Kujala scores, and other complications. After criteria were applied, there were 59 adolescents (38 girls and 21 boys; mean ± SD age of 15.2 ± 1.7 years). Allograft was used in 36 patients and the autograft in 23. The patients were reviewed at a mean follow-up of 4.1 ± 1.9 years (allograft, 3.3 ± 1.1 years; autograft, 5.7 ± 2.1 years;

$P \leq 0.001$). The authors identified no significant differences in return to activity, pain score changes, and incidences of failure between patients undergoing MPFL reconstruction with allograft versus autograft. Although teenagers with surviving autograft MPFL reconstruction reported statistically higher Kujala scores, the mean score difference of 5 points was not clinically significant. It appears that using allograft tendon instead of autograft tissue for MPFL reconstruction in this teenage population does not adversely affect the long-term outcomes.

The choice of autograft or allograft for MPFL reconstruction is based on surgeon and/or patient preference. A thorough preoperative counseling should be undertaken, and advantages and disadvantages of each graft source should be discussed with the patient before choosing the tendon graft for MPFL reconstruction.

4.5 Single-Bundle or Double-Bundle MPFL Reconstruction?

Singhal et al. [139] carried out a meta-analysis of studies reporting outcomes of MPFL reconstruction using hamstring tendon autograft in a double-bundle configuration and patellar fixation via mediolateral patellar tunnels. The primary outcome examined was the postoperative Kujala score. The authors identified 320 MPFL reconstructions in nine relevant articles. The combined mean postoperative Kujala score was 92 using a fixed effects model and 89 using random effect modeling. The reported rate of complications with MPFL reconstruction was 12.5% (40 of 320), with stiffness of the knee being the most common. The authors concluded that high-quality evidence in assessing double-bundle MPFL reconstruction is lacking. The current literature consists of a mixture of prospective and retrospective case series. High-quality, prospective randomized controlled trials are needed before definitive conclusions can be drawn regarding the superiority of one form of surgical technique over the other.

Kang et al. [140] performed a systematic review of the single-bundle (SB) and double-bundle (DB) MPFL reconstruction procedures using the hamstring tendon autografts, and compared the clinical outcomes including the Kujala score, postoperative apprehension, recurrent subluxation or dislocation, and complications. Thirty-one articles were included, involving 1063 patients (1116 knees). Two hundred and forty-four patients (254 knees) underwent SB reconstruction, whereas 819 patients (862 knees) underwent DB reconstruction. The pooled mean values of Kujala score improvement were similar in both groups. The SB group had a significantly greater rate of postoperative apprehension (8%) than the DB group (4%). There were no significant differences between the SB and DB groups in the rates of recurrent subluxation or dislocation and complications. The authors concluded that the DB procedure for isolated MPFL reconstruction demonstrates similar outcomes as compared to the SB technique regarding improvement of knee function, recurrent subluxation or dislocation, and complications. The SB technique may have a greater risk of postoperative apprehension, whereas the DB technique may cause more stiffness.

4.6 Outcomes of MPFL Reconstruction in Skeletally Immature Patients

Shamrock et al. [141] performed a systematic review and meta-analysis of the literature to evaluate the outcomes and complications of MPFL reconstruction in skeletally immature patients. Seven studies that entailed 132 MPFL reconstructions (126 patients) met the inclusion criteria. There were 73 females (58% of the cohort) and the mean age was 13 years (range, 6 to 17 years). Mean postoperative follow-up was 4.8 years (range, 1.4 to 10 years). Autograft was used for all reconstructions, with gracilis tendon (61%) being the most common. Methods of femoral fixation included interference screw (39%), suture anchor (39%), and soft tissue pulley around the medial collateral ligament or adductor tendon (22%). Pooled Kujala scores improved from 59 to 85 after MPFL reconstruction. The total reported complication rate was 25% and included 5 redislocations (4%) and 15 subluxation events (11%). No cases of premature physeal closure were noted. Neither autograft choice nor the method of femoral fixation influenced recurrent instability or overall complication rates. These findings suggest that MPFL reconstruction in skeletally immature patients is a viable and reasonable treatment option, with significant improvement in patient-reported outcomes and redislocation event rates of less than 5% at nearly 5-year follow-up. Further high-quality research should be undertaken to determine optimal surgical technique and graft options.

4.7 Return to Play

Few studies have reported on return to play after patellar stabilization in patients with patellofemoral instability [142–145].

Schneider and associates [142] performed a systematic review and meta-analysis to evaluate the outcomes of isolated MPFL reconstruction for the treatment of recurrent patellofemoral instability. Fourteen articles met the inclusion criteria and were included in this review. The mean age of the patients was 24 years. The mean postoperative Tegner score was 5.7 and the pooled estimated mean postoperative Kujala score was 86. Eighty-four per cent of the patients returned to sports after surgery. The pooled total risk of recurrent instability after surgery was 1%, with a positive apprehension sign risk of 4% and a reoperation risk of 3%. The authors concluded that a high percentage of young patients return to sports after isolated MPFL reconstruction for chronic patellar instability, with short-term results demonstrating a low incidence of recurrent instability, postoperative apprehension, and reoperations.

Sherman and colleagues [143] evaluated the existing literature regarding return to play (RTP) and return to prior performance (RPP) following patellar stabilization surgery. These authors found that there is a lack of validation and universal adoption of standardized RTP guidelines. The best available studies to date would suggest high RTP rates (84–100%), average RPP rates (33–77%), and a highly variable timeframe (3 to 12 months) for return to sport. Sherman et al. [143] concluded that the best available data on RTP and RPP following patellofemoral instability is based on lower quality of evidence studies, expert opinion, and published societal guidelines.

Manjunath et al. [144] performed a systematic review to determine both the rate and timing of return to play after MPFL reconstruction, and the rate of further patellar instability. Their review found 27 studies including 1278 patients meeting the inclusion criteria. The majority of patients were women (58%), and the total group had a mean age of 22 years. The mean follow-up was 39 months. The overall rate of return to play was 85% (with 68% returning to the same level of play). The average time to return to play was 7 months postoperatively. The rate of recurrent instability events following reconstruction was 5%.

Platt et al. [145] undertook a systematic review and meta-analysis to evaluate return to sport after MPFL reconstruction for patellar instability. Twenty-three articles met the inclusion criteria after full-text review. A total of 930 patients were analyzed, including 786 athletes. The overall mean age of the patients was 21 years. Women represented 61% of all patients. The mean follow-up was 3 years (range, 0.8 to 8.5 years). The return to sport rate was 93%. Patients returned to or surpassed their preoperative level of activity in 71% of cases. An osteotomy was performed in 11% of the athletes. Return to sport did not differ significantly in patients undergoing MPFL reconstruction without osteotomy versus those receiving additional osteotomy. Patients returned to sport at a mean of 6.7 months (range, 3 to 6 months) postoperatively. The overall complication rate was 9%. The most common complication was recurrence of instability.

We emphasize that the treating surgeon should counsel their patients preoperatively regarding their expectations and outcomes of treatment. Based on abovementioned studies, a high rate of return to sport after MPFL reconstruction surgery is expected. In our experience, most athletes return to play around 6 to 8 months after undergoing MPFL reconstruction.

4.8 Complications of MPFL Reconstruction

Postoperative complications following MPFL reconstruction include subcutaneous hematoma, wound infection, dehiscence, seroma after graft harvest, persistent pain, knee stiffness, flexion contracture, recurrent instability, patellar fracture, and deep vein thrombosis. The cause of recurrent patellar instability may be technically inadequate MPFL reconstruction or failure to address other concomitant pathology. Persistent pain may be caused by the over-constrained MPFL, unaddressed chondral defect in the patellofemoral compartment, or patellar fracture.

Shah and associates [146] performed a systematic review to determine the rate of complications associated with MPFL reconstruction. A total of 164 complications occurred in 629 knees (26%). These complications included wound infection, knee pain, restriction of knee flexion, recurrent patellar instability, and patellar fracture. Twenty-six patients returned to the operating room for additional procedures.

Parikh and colleagues [147] have reported the early complications (<3 years) of MPFL reconstruction in young patients. A total of 179 knees underwent MPFL reconstruction during the study period. There were 38 complications (16%) in 29 knees. The major complications included recurrent lateral patellar instability, knee motion stiffness with flexion deficits, patellar fractures, and patellofemoral arthrosis/pain. In their series, 18 of 38 (47%) complications were secondary to technical factors and were considered preventable. Female gender and bilateral MPFL reconstructions were risk factors associated with postoperative complications. Patients should be counseled preoperatively on the risk of potential complications that may occur after MPFL reconstruction.

Common fixation techniques for MPFL reconstruction at the patella include transosseous bone tunnels [148, 149], suture anchors [122, 150, 151], and interference screws [152–154]. It has been reported that the patellar tunnel techniques present a higher risk of postoperative patellar fractures, particularly for those that pass completely through the patella [146, 147, 155–159]. In view of the high risk of patellar fracture with the use of transosseous tunnel technique, the suture anchor fixation was introduced [154, 160]. Suture anchors provide a stable fixation and are gaining increasing popularity. Good to excellent results have been reported with the use of suture anchors for fixation of the tendon graft in MPFL reconstruction [122, 150].

4.9 Authors' Preferred Treatment of MPFL Reconstruction

In order to eliminate the risk of patellar fracture (that may occur using the patellar tunnel technique), the senior author of this paper (AJS), prefer to use suture anchors to fix the tendon graft to the medial border of the patella. Kurowicki et al. [130] have reported the Patella Footprint Technique of MPFL reconstruction. In our opinion, this surgical technique provides a safe, reliable and reproducible method of restoring patellofemoral stability. The Patella Footprint Technique minimizes the stress risers in the patella by using suture anchor fixation that creates a ligamentous footprint instead of tendon healing into a bony socket in the patella.

4.10 The Authors' Operative Technique of Medial Patellofemoral Ligament Reconstruction using the Patella Footprint Technique

4.10.1 Step 1: Patient Preparation and Diagnostic Arthroscopy

The patient is placed in the supine position. Using a surgical marking pen, the skin incisions and anatomical landmarks (i.e. the medial two-thirds of the patellar border, the pes anserinus, adductor tubercle, and medial femoral epicondyle) are marked as shown in **Figure 6**. After the induction of general anesthesia, the patient is examined for range of motion and the presence of 4-quadrant translation of the patella with minimal force applied. After performing the examination under anesthesia, the patient is prepped and draped in a sterile fashion. Using standard anterolateral and anteromedial portals, diagnostic arthroscopy of the affected knee is undertaken. Arthroscopic chondroplasty is performed if the patient has significant chondromalacia of the patellofemoral joint.

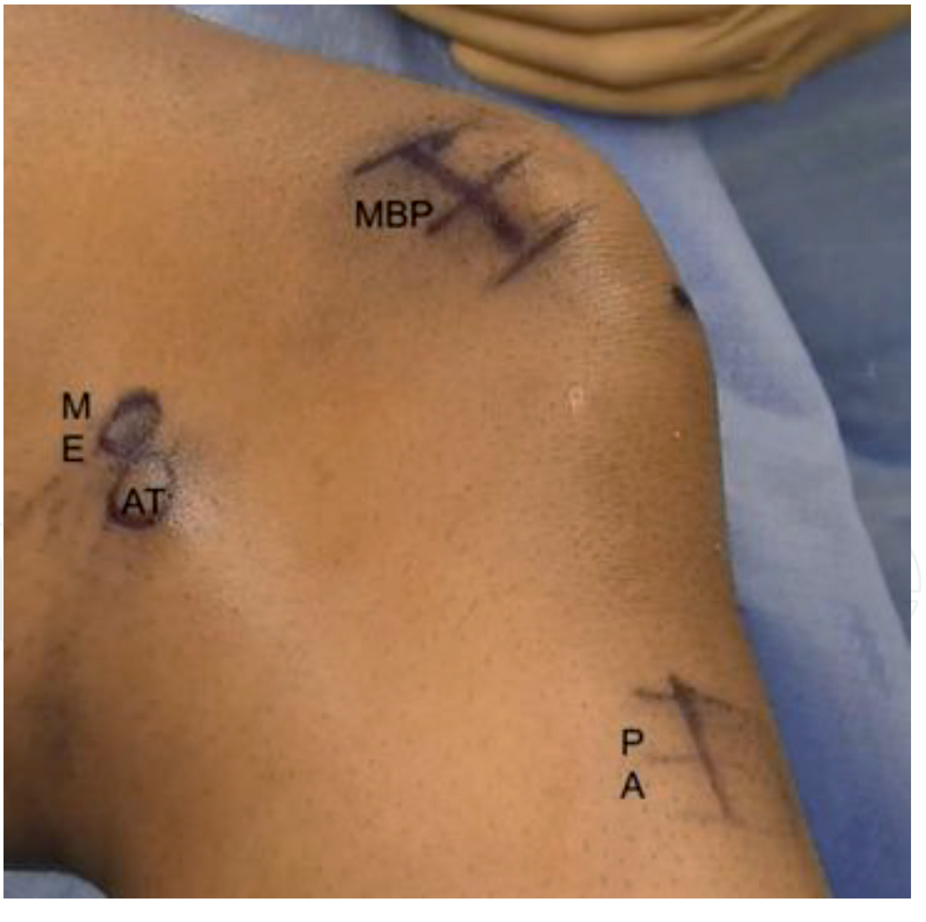

Figure 6.
Patient is placed in the supine position with the left knee in 45° of flexion providing an anteromedial view of the knee. Using a surgical marking pen, the anatomical landmarks are drawn. First, the medial border of the patella (MBP) is palpated and the proximal two-thirds is marked. The pes anserinus (PA) is marked at the anteromedial border of the proximal tibia. On the medial aspect of the knee, the adductor tubercle (AT) can be palpated just distal to the medial femoral epicondyle (ME). Proper identification of these anatomical landmarks is essential to performing this MPFL reconstruction with relative ease. Reproduced with permission from: Kurowicki et al. [130].

4.10.2 Step 2: Graft Harvesting and Preparation

A longitudinal incision is made over the pes anserinus, and dissection carried out down to the level of the sartorial fascia. The sartorial fascia is identified and incised proximal to and in line with the gracilis tendon. The gracilis tendon is bluntly dissected off of the sartorial fascia, and brought out of the wound using a hemostat (**Figure 7A** and **B**).

The open hamstring stripping device (Stryker Orthopedics, Mahwah, NJ) is used to harvest a gracilis tendon autograft, maintaining the distal attachment during the harvesting process. Once harvested, the gracilis tendon is detached sharply at its insertion taking care to avoid damage to the semitendinosus tendon. The muscle belly is removed from the gracilis tendon using a periosteal elevator. A whip stitch is applied to the distal end of the gracilis tendon using a No. 2 orthocord suture (DePuy Mitek, Warsaw, IN). The gracilis tendon graft is placed in a moist lap sponge while attention is now turned to the placement of suture anchors in the medial border of the patella.

4.10.3 Step 3: Medial Patellar Dissection With Suture Anchor Placement and Bone Debridement

Next, a longitudinal incision is made over the medial border of the patella, and dissection is carried out down to the level of the capsule. A longitudinal arthrotomy is performed just medial to the patellar tendon. The proximal-third of the medial aspect of the patella is debrided with a rongeur down to a base of bleeding bone, creating a footprint for insertion of the gracilis tendon graft. Two GRYPHON suture anchors (DePuy Mitek) are placed in the medial aspect of the patella: the first suture anchor at the junction of the proximal-third and middle-third of the medial border of the patella, and the second suture anchor, 5 mm to 10 mm proximal to the first (**Figure 8**).

4.10.4 Step 4: Soft Tissue Tunneling

Using the adductor tubercle and the medial femoral epicondyle as anatomical reference points, a blunt instrument is used to develop an intra-articular, extrasynovial plane, tunneling toward the anatomic insertion of the MPFL on the femur (**Figure 9**).

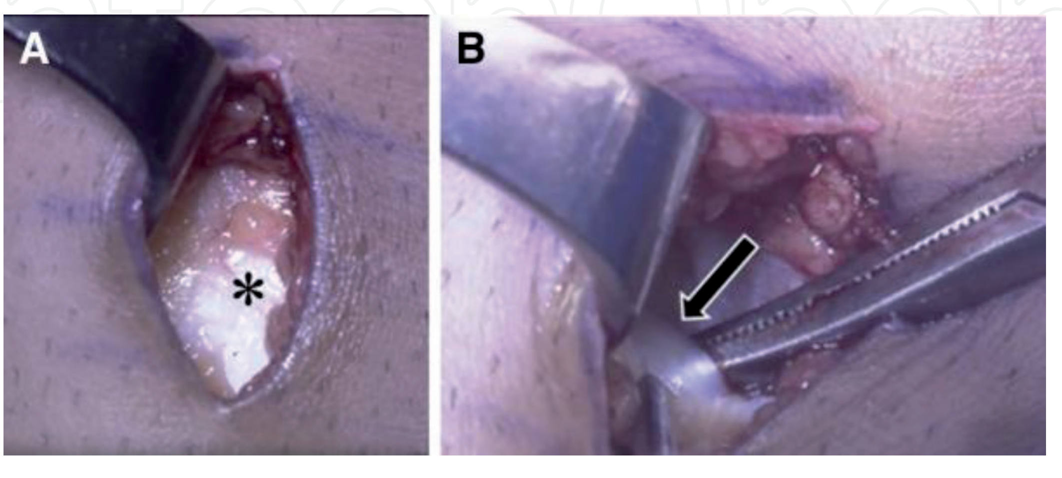

Figure 7.
With the patient in the supine position and the left knee flexed at 45°, a longitudinal incision is made over the pes anserinus and dissection is performed down to the level of the sartorial fascia, indicated by the asterisk (*) in Figure A. The sartorial fascia is then incised proximally and in line with the gracilis tendon (the arrow denotes the gracilis tendon in Figure B). Blunt dissection of the sartorial fascia off of the gracilis tendon is performed. Reproduced with permission from: Kurowicki et al. [130].

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Figure 8.
With the patient in the supine position and the left knee flexed at 45°, a longitudinal incision is made over the medial aspect of the patella just medial to the border. Dissection is carried out down to the level of the capsule, and a longitudinal arthrotomy is performed just medial to the patellar border. The proximal-third of the medial aspect of the patella is debrided with a rongeur down to a base of bleeding bone, creating a footprint for graft insertion. The asterisks (*) indicate the placement of 2 GRYPHON suture anchors (DePuy Mitek) approximately 5 mm to 10 mm from each other. Reproduced with permission from: Kurowicki et al. [130].

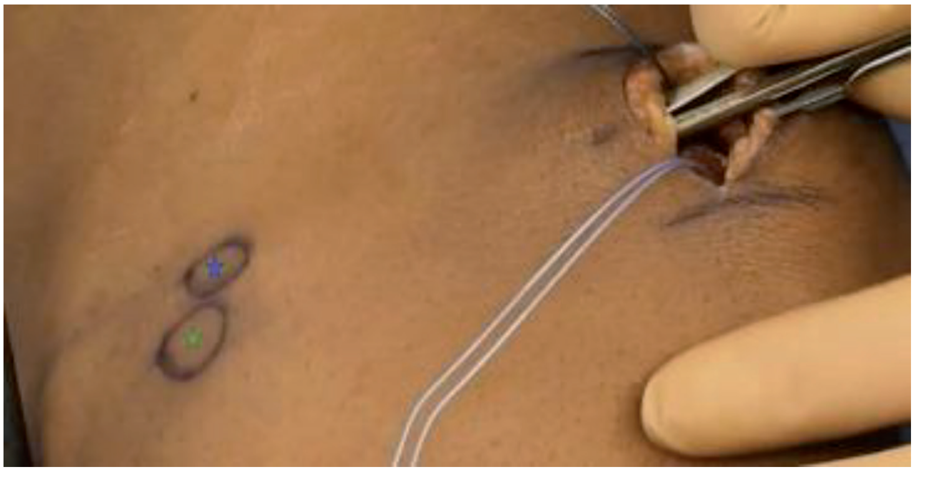

Figure 9.
Formation of an intra-articular, extrasynovial plane for tunneling toward the anatomic insertion of the MPFL on the femur using a blunt instrument with the patient positioned supine and the left knee flexed at 45°. The blue star represents the medial femoral epicondyle, and the green star represents the adductor tubercle. The anatomic origin of the MPFL on the femur can be found in the saddle area between the proximal-posterior to the medial epicondyle and distal-anterior to the adductor tubercle. Reproduced with permission from: Kurowicki et al. [130].

4.10.5 Step 5: Femoral Tunnel Formation, Graft Preparation, and Femoral Graft Fixation

An incision is made over the site of anatomic origin of the MPFL on the femur. A guidewire is placed to approximately 30 mm of depth at the anatomic attachment of the MPFL on the femur, which can be identified in the saddle area proximal-posterior to the medial epicondyle and distal-anterior to the adductor tubercle (Kruckeberg et al. 2018). The femur is drilled and the drill hole is tapped. One end of the whip stitch applied to the gracilis tendon autograft is loaded through a 7 mm × 23 mm MILAGRO interference screw (DePuy Mitek) with the assistance of the CHIA PERCPASSER suture passer (DePuy Mitek). The tendon graft is then pushed into the drill hole with a pickup or a freer, and the screw is advanced until flush with the cortex of the femur (**Figure 10A** and **B**). A free needle is used to sew

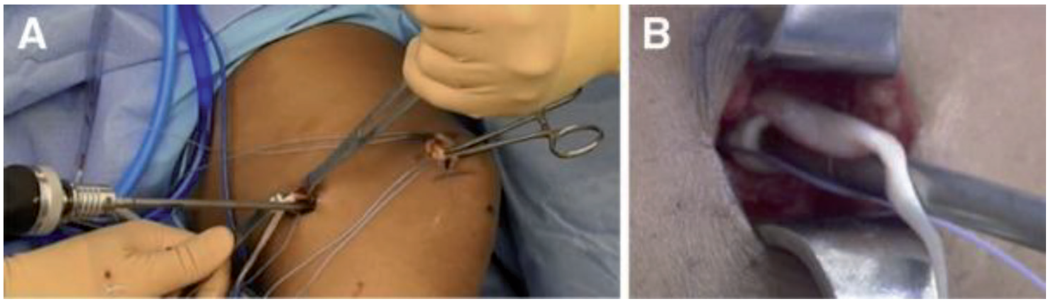

Figure 10.
(A) With the patient supine and the left knee in 45° of flexion, an incision is made over the saddle area proximal-posterior to the medial epicondyle and distal-anterior to the adductor tubercle on the femur. A guidewire is placed to approximately 30 mm of depth, the femur is drilled, and the drill hole is taped. One end of the whip stitch applied to the gracilis tendon autograft is loaded through a 7 mm × 23 mm interference screw (DePuy Mitek) and the tendon is dunked into the drill hole. (B) The screw is advanced until flush with the cortex of the femur. Reproduced with permission from: Kurowicki et al. [130].

the unused end of the suture through the graft, and it is tied to the end that was previously passed through the suture anchor.

4.10.6 Step 6: Deliver the Graft Through the Soft Tissue Tunnel and Tension the Graft

The gracilis tendon graft is now passed through the intra-articular, extrasynovial plane using a hemostat (**Figure 11**). With the knee held in 45° of flexion, the graft is marked where it aligns with the more distal suture anchor, and then from there the distance between the 2 suture anchors is marked off on the graft.

4.10.7 Step 7: Secure Distal and Then Proximal End of the Graft to the Patella

A free needle is used to whip stitch the graft to the appropriate suture anchor at each level. The unused end of the graft is pulled to take up the slack, bringing the

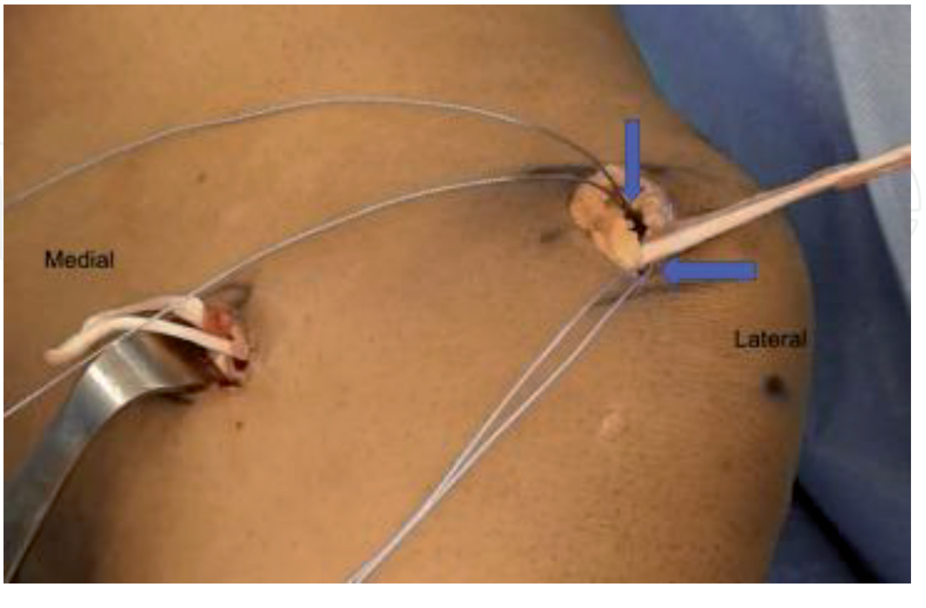

Figure 11.
The patient is in the supine position, the left knee flexed to 45°, when the gracilis tendon autograft is passed from the femoral fixed side through the intra-articular, extrasynovial plane using a hemostat and exiting out the opening at the medial border of the patella. Once the graft is passed, with the knee held in 45° of flexion, the graft is marked where it aligns with the more distal suture anchor, and then from there the distance between the 2 suture anchors is marked off on the graft. Arrows denote the location of 2 suture anchors. Reproduced with permission from: Kurowicki et al. [130].

Figure 12.
The patient is supine with the knee in 45° of flexion and a free needle is used to whip stitch the graft to the appropriate suture anchor at each level. The unused end of the graft is pulled to take up the slack, bringing the graft down to the bone and suture anchor. The knots are subsequently tied, starting with the distal anchor and then the proximal anchor, and the excess graft is cut off. The blue star denotes excess graft. Reproduced with permission from: Kurowicki et al. [130].

graft down to the bone and anchor. The knots are subsequently tied, starting with the distal anchor and then the excess graft is cut off (**Figure 12**).

4.10.8 Step 8: Evaluate Graft Tensioning

The knee is taken through a range of motion to confirm that the graft is not overtensioned. Translation of the patella is confirmed to be less than 2 quadrants.

4.10.9 Step 9. Wound Closure

The capsule is repaired in a "pants-over-vest" fashion with a No. 2 orthocord suture (DePuy Mitek). The skin incision is closed with a subcuticular vicryl suture followed by a running monocryl.

4.11 Postoperative rehabilitation protocol

Postoperatively, the patient is weight bearing as tolerated with the brace in 0° to 30° of flexion for the first week, progressing to 60° of flexion by week 2 and 90° of flexion by week 4. With the assistance of a physical therapist, the patient

Pearls	Pitfalls
1. Proper tunnel and footprint position	1. Malposition leads to anisometric graft placement
2. Avoid graft overtensioning by marking in 45° of knee flexion	2. Postoperative pain and stiffness due to overtensioned graft
3. Address concomitant pathology when needed; consider tibial tuberosity transfer if the TT-TG# distance is >20 mm, or consider osteochondritis dissecans repair for a full-thickness chondral defect	3. Recurrence of dislocation due to unaddressed pathology or recurrent pain due to chondral defect in the patella

#TT-TG, tibial tuberosity-trochlear groove.
**Adapted from Kurowicki et al. [130].*

Table 2.
*Pearls and pitfalls of patellar footprint technique of MPFL reconstruction.**

Advantages
1. Anatomic interference femoral screw allows for proper graft isometry and promotes osseous ingrowth
2. Use of two bioresorbable suture anchors on the patella creates a ligamentous footprint to decrease the propagation of patellar stress risers
3. Gracilis tendon provides a stronger construct compared with the native MPFL while limiting hamstring morbidity
4. ensioning in 45° of knee flexion allows for some bony restraint by trochlea yet prevents overtensioning of the graft
5. L-configuration diminishes patellar rotation
Disadvantages
1. Interference screw fixation on the patellar side provides a biomechanically stronger fixation as compared with the suture anchor fixation [154]
Adapted from Kurowicki et al. [130].

Table 3.
*Advantages and disadvantages of patellar footprint technique of MPFL reconstruction.**

undertakes quadriceps strengthening (especially, the VMO) exercises for the first 6 weeks. At more than 6 weeks postoperatively, if patients have achieved a near-full range of motion and can maintain a strong quadriceps contraction, discontinuation of the brace is acceptable. **Table 2** highlights the pearls and pitfalls of the Patella Footprint Technique of MPFL reconstruction. **Table 3** outlines the advantages and disadvantages of our described operative technique. The surgical technique described in this chapter provides an easy to replicate anatomical MPFL reconstruction with suture anchor patellar fixation. However, future studies are warranted comparing the outcomes between different fixation options, as well as evaluating long-term clinical outcomes.

5. Discussion

Patellofemoral instability typically affects the young and athletically active patient population. Most physicians recommend an initial trial of nonoperative management for patients who present with first-time patellar dislocation, without intra-articular osteochondral fragments, severe injury to the medial patellar soft tissue stabilizers, and significant patellofemoral malalignment or dysplasia. One of the challenges around nonoperative management of patellar dislocation is the complexity of interventions offered and the various rehabilitation regimens that are practiced in different institutions. Numerous physical therapy protocols have been described. The goals of physical therapy are to decrease pain, restore the range of motion of the knee, strengthen the quadriceps musculature, address the deficiencies in the trunk, hip or foot biomechanics that may predispose to patellar instability, improve the joint function, enhance the quality of life, and increase patient satisfaction. Unfortunately, there are little data or validated, objective evidence to determine which nonoperative treatment regimen is best for the management of patients with acute patellar dislocation.

We are aware that some physicians recommend nonoperative management as the first-line treatment for patients with chronic, recurrent patellar instability. However, in our clinical experience (expanding over a period of 40 years), the nonoperative treatment of chronic patellar dislocations treated by an initial period of immobilization (using a cast or a brace) followed by rehabilitation has produced less satisfactory clinical outcomes; many of these patients have continued knee symptoms and recurrent patellar dislocations. There remains a paucity of scientific evidence on how to optimally manage patients with recurrent patellar dislocation (particularly, whether these patients should be given an initial trial of nonoperative treatment, how long the nonoperative treatment should be continued, and when surgical intervention should be recommended). This remains a subject of further clinical research. We believe many of the patients with chronic, symptomatic, recurrent patellar dislocations have predisposing anatomical risk factors (**Table 1**) and these patients invariably require operative treatment.

The natural history of acute patellar dislocation is that of a relatively high rate of recurrent instability, and long-term functional limitations and inability to return to baseline level of activity. Hence, surgery often plays an important role in the management of these patients. Prospective randomized trials comparing different surgical techniques are needed to determine which treatment options provide optimal clinical outcomes with restoration of knee function, low recurrence rate of patellar instability, and decreased risk of patellofemoral arthritis. The main goal of surgery is to restore the integrity of the MPFL and optimize the alignment of the lower extremity.

The MPFL acts as an important checkrein during the first 30 degrees of flexion (before the patella engages with the trochlea), thus allowing for a smooth knee motion. Rupture of the MPFL is often seen in patients with recurrent lateral patellar dislocation, leading to abnormal patellofemoral contact pressures, and resulting in pain, knee dysfunction, and early-onset arthritis. Hence, it is vital to undertake anatomic MPFL reconstruction to restore the kinetics and biomechanics of the patellofemoral joint.

Medial patellofemoral ligament reconstruction has become one of the most common and widely used surgical procedures to regain stability in patients with recurrent lateral dislocation of the patella. Recent studies have demonstrated low recurrence rates, improved patient-reported outcome measures, and a high rate of return to sports. No gold standard currently exists for MPFL reconstruction. Various surgical techniques of MPFL reconstruction have been reported employing different methods of graft fixation and tensioning. A detailed description of all available surgical techniques is beyond the scope of this chapter. Shah and associates [146] performed a systematic review to determine the rate of complications associated with MPFL reconstruction. In their study, a total of 164 complications occurred in 629 knees (26%). Therefore, efforts must be made to develop new operative techniques in order to minimize potentially devastating complications and optimize clinical outcomes.

Numerous graft sources, operative techniques, and fixation methods have been described with favorable clinical outcomes for reconstruction of the MPFL for patients with symptomatic patellofemoral instability. Several surgical techniques have been reported for fixation of the graft to the patella; these techniques include the use of suture anchors, interference screws, and transosseous tunnels. However, to date, no particular method has emerged as superior with regard to clinical outcome. Formation of a stress riser in the patella can result in a catastrophic complication after MPFL reconstruction. Large-diameter (4.5 mm), transverse, or long-oblique patellar bone tunnels have been associated with an increased risk of patellar fracture after MPFL reconstruction [147]. Schiphouwer et al. [159] reported a retrospective case series of 179 patients (192 knees) who underwent MPFL reconstruction, with or without additional bony realignment procedures. In their series, MPFL reconstruction was performed using two, transverse patellar bone tunnels. Seven patients (3.6%) sustained a patellar fracture without adequate trauma. This study highlights the associated, increased risk seen with the use of transverse patellar bone tunnel while performing MPFL reconstruction. Recently, Deasey et al. [161] have shown that the use of small-diameter (3.2-mm), oblique patellar bone tunnels was not associated with an increased risk of patellar fracture in comparison with the use of suture anchors for patellar fixation. Deasey et al. [161] concluded that the use of small (3.2-mm), short, oblique patellar tunnels can be a safe and reliable method of patellar graft fixation in MPFL reconstruction.

Russ and colleagues [154] have shown that the use of transpatellar bone tunnels with interference screw fixation offers a biomechanically stronger fixation as compared to the use of suture anchors. Despite being biomechanically weaker, Russ et al. [154] did find that suture anchor fixation nevertheless allows for a reconstruction that withstands greater mechanical loads before failure than the native MPFL. The use of suture anchors also minimizes the risk of violating the articular surface when reaming the tunnels and decreases the risk of patellar fracture. Song and colleagues [150] prospectively evaluated the clinical and radiographic outcomes following anatomic MPFL reconstruction using patellar suture anchor fixation for patients with recurrent patellar instability. Twenty patients (20 knees) were enrolled in this study. The median age of the patients was 21 years, and the median follow-up was 34.5 months (range, 24 to 50 months). Reconstruction was performed using a hamstring autograft fixed with two suture anchors at native patellar site of the MPFL. The preoperative Kujala scores were 52.6 ± 12.4 and the postoperative Kujala scores were 90.9 ± 4.5 ($p < 0.001$). The preoperative Lysholm scores were 49.2 ± 10.7 and the postoperative Lysholm scores were 90.9 ± 5.2 ($p < 0.001$). The Tegner score increased from 3.0 (range 1 to 4) preoperatively to 5.0 (range 4 to 7) postoperatively ($p < 0.001$). No patient experienced a patellar fracture or recurrent dislocation in their series. This study shows that anatomic MPFL reconstruction using two suture anchors is a reliable treatment option for management of patients with recurrent patellofemoral instability.

We have previously reported our surgical technique of MPFL reconstruction that uses two suture anchors along the patella for graft fixation to provide a biomechanically favorable construct [130]. In our clinical experience, anatomic MPFL reconstruction (utilizing the autogenous gracilis tendon and patella footprint technique) has produced satisfactory clinical and functional outcomes in majority of the patients. We emphasize that MPFL reconstruction requires precise graft placement at the anatomic origin and insertion points of the MPFL. Anatomic graft placement, appropriate graft length and tension are critical to prevent over-constraint of the patellofemoral joint while undertaking reconstruction of the MPFL. By utilizing two suture anchors in the patella, the MPFL footprint was secured in a single-bundle setting to restore the native MPFL anatomy and patellar stability [130]. Furthermore, we ensure a secure fixation by submerging the tail of the gracilis graft with the interference screw at the femoral footprint. We believe our Patellar Footprint Surgical Technique provides an easy to replicate anatomical MPFL reconstruction utilizing an autogenous gracilis tendon graft that is secured to the medial border of the patella using two suture anchors [130]. **Table 2** highlights the pearls and pitfalls of the Patella Footprint Technique of MPFL reconstruction. The advantages and disadvantages of our described surgical technique are outlined in **Table 3**. Future studies are warranted comparing the outcomes between different fixation options, as well as exploring the long-term clinical and functional outcomes.

Reconstruction of the MPFL is typically indicated for patients with recurrent patellofemoral instability, with or without trochlear dysplasia, who have a normal TT-TG distance and a normal patellar height. The procedure may be performed with concomitant procedures, such as distalization of the tibial tuberosity in a patient with patella alta, or trochleoplasty in a patient with high-grade trochlear dysplasia.

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Distal patellofemoral realignment procedure (such as the anteromedial tibial tuberosity transfer) is indicated for patients with recurrent instability, who have an increased TT-TG distance, abnormally high Q-angle, patella alta, lateral and/or distal patellar chondrosis, and absence of trochlear chondrosis. The degree of anteriorization, distalization, and/or medialization of the tibial tuberosity depends on the presence of associated arthrosis of the lateral patellar facet and/or the presence of patella alta. It is worth noting that the distal realignment procedure is contraindicated in patients who have a normal TT-TG distance or in those patients who have associated proximal and/or medial patellar chondrosis.

Groove-deepening trochleoplasty is a complex and technically challenging surgical procedure. This procedure is indicated for patients with Dejour type-B and type-D trochlear dysplasia, whereas a lateral elevation or proximal recession trochleoplasty is indicated for patients with Dejour type-C dysplasia.

6. Conclusions

- Recurrent patellofemoral instability is a common cause of knee pain and functional disability in adolescent and young adult patients, resulting in loss of time from work and/or sports.

- There are numerous factors that contribute to recurrent patellofemoral instability; these factors include tear of the MPFL, weakening or hypoplasia of the VMO, trochlear dysplasia, increased TT-TG distance (>20 mm), valgus malalignment, increased Q-angle, malrotation secondary to internal femoral or external tibial torsion, patella alta, and generalized ligamentous laxity.

- A detailed history and a thorough physical examination are crucial to clinch an early, accurate diagnosis.

- Imaging studies play an important role to confirm the clinical diagnosis and also help to identify concomitant intra-articular pathologies. CT scans are useful for assessment of the trochlear morphology, TT-TG distance, patellar tilt, as well as femoral and tibial torsions. MRI scans are used to identify the soft tissue injury (especially, injury to the medial patellar retinaculum, MPFL and VMO). It also helps to detect the osteochondral fractures, loose bodies and bone bruises involving the medial patellar facet and lateral femoral condyle in acute cases.

- In general, nonoperative management of chronic patellar instability with immobilization followed by rehabilitation has produced unsatisfactory clinical results.

- A diligent attempt should be made to identify the underlying pathologic abnormality in each case and the surgical treatment should be customized to correct the offending anatomic and radiographic abnormality.

- An individualized case-by-case approach is recommended based on the underlying anatomical risk factors and radiographic abnormality.

- Careful preoperative patient selection is crucial to ensure optimal clinical outcome.

- Patients should be counseled preoperatively regarding expectations and outcomes of treatment.

- Most of the current surgical treatment options for chronic patellofemoral instability are based on Level-IV evidence. Multicenter, prospective randomized controlled studies are necessary to determine the optimal surgical treatment for patients with chronic, recurrent patellar instability.

- Isolated lateral release of the patella has not proven to be of long-term benefit for the treatment of patellofemoral instability. It may be performed (when indicated) as an adjunct procedure to MPFL reconstruction or to distal realignment of the extensor mechanism.

- Patients with recurrent instability, with or without trochlear dysplasia, who have a normal TT-TG distance and a normal patellar height, are candidates for surgical reconstruction of the MPFL, using either autograft or allograft (based on patient and/or surgeon preference).

- MPFL reconstruction requires precise graft placement at the anatomic origin and insertion points of the MPFL. Anatomic graft placement, appropriate graft length and tension are critical to prevent over-constraint of the patellofemoral joint while undertaking reconstruction of the MPFL.

- Distal patellofemoral realignment procedure (such as the anteromedial tibial tuberosity transfer) is indicated for patients with recurrent instability, who have an increased TT-TG distance, patella alta, lateral and/or distal patellar chondrosis, and absence of trochlear chondrosis. The degree of anteriorization, distalization, and/or medialization of the tibial tuberosity depends on the presence of associated arthrosis of the lateral patellar facet and/or the presence of patella alta.

- The distal realignment procedure is contraindicated in patients who have a normal TT-TG distance or in those with associated proximal and/or medial patellar chondrosis.

- Groove-deepening trochleoplasty is indicated for patients with Dejour type-B and type-D trochlear dysplasia, whereas a lateral elevation or proximal recession trochleoplasty is indicated for patients with Dejour type-C dysplasia.

- Associated injury to meniscus, cruciate ligament or collateral ligament should be recognized and appropriately treated.

- Pain, recurrent instability and patellofemoral arthrosis are likely complications of any surgical procedure that is performed for patients with patellofemoral instability.

Conflict of interest

AJS has received research support from ISO-biologics, is a paid consultant for Mitek, is a board or committee member of the American Academy of Orthopedic Surgery and the New Jersey Orthopedic Society, and has stock or stock options in Biomet, CONMED Linvatec, Johnson & Johnson, Pfizer, Smith & Nephew, and Stryker. The remaining authors declare no conflict of interest.

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