Patellofemoral Instability

Brian J. White, M.D., and Orrin H. Sherman, M.D.

Abstract
This review describes the normal patellofemoral joint and detail the mechanism and anatomic elements that predispose patients to patellar instability. The treatment options for both acute and chronic injuries are described and the rationale behind their approach to this problem is explained. In general, most acute dislocations should be treated nonoperatively unless the instability is associated with an osteochondral injury. Chronic dislocators should be treated based on an understanding of the patient’s individual reason for recurrent instability. This is achieved with a thorough history, physical examination, and imaging studies. This information can help the clinician select the most appropriate proximal and or distal procedure.

The patellofemoral joint is the articulation between the patella and the trochlear groove of the femur. The patella is a sesamoid bone encased in the quadriceps mechanism; its presence increases the mechanical advantage of the quadriceps, protects the knee, and plays a role in overall cosmesis.1 The articulation and path of motion of the patella is complex, with the joint vulnerable to several levels, or types, of instability. Patellofemoral instability generally is defined as acute or chronic. Acute instability refers to a primary, traumatic episode in which the patella dislocates laterally, while chronic instability denotes recurrent dislocations. Medial dislocations are rare and are typically iatrogenic. Understanding this complex topic requires a sound knowledge of the anatomy and biomechanics of the patellofemoral joint, an ability to elicit a good history, and the skill to perform a thorough physical examination, as well as an understanding of the principles of both nonsurgical and surgical treatments.

Anatomy
At approximately 8 weeks gestation, the knee is in its adult form. The patella has developed and range of motion of the knee has begun.1 It is cartilaginous at birth and ossification occurs in early childhood from many centers. It is important to recognize that the shallow appearance of the femoral sulcus on radiographs is an illusion. The patella and condyles early in childhood are cartilaginous and not visible with plain radiography. Using ultrasound, Nietosvaara showed that the depth of the trochlea and the patellofemoral articulation were developed at birth, and the geometry of this joint resembled its adult form.2,3

The undersurface of the patella is covered in cartilage. The thickness of the cartilage is approximately 6 to 7 mm and is the thickest in the body. The patella has nine facets, but basically can be divided into larger medial and lateral facets that are separated by a median ridge. The lateral facet is longer and more sloped to match the lateral femoral condyle.1 The anterior surface of the distal femur forms the trochlear groove in which the patella articulates with increasing degrees of knee flexion. The lateral condyle forms the lateral wall of the patellofemoral articulation and is the most important restraint to lateral patellar translation once the patella is engaged. Patellofemoral engagement occurs at approximately 30° of knee flexion.4,5 The normal trochlear groove depth is 5.2 mm, with the lateral femoral condyle 3.4 mm higher than the medial femoral condyle.1

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The quadriceps muscle inserts into the patella. This sesamoid bone serves as a fulcrum for the quadriceps mechanism and increases the mechanical strength and efficiency of this muscle. The most important component of this muscle for patellofemoral tracking and stability is the vastus medialis obliquus (VMO). The orientation and direction of its fibers are approximately 50° to 60°. It is thought of as a medial dynamic stabilizer to lateral patellar displacement. Electro-myography (EMG) studies have shown that the VMO has its greatest activity from 0° to 30° of knee flexion, while the vastus lateralis is more active between 30° and 90°. Hence, terminal extension exercises are thought to target this muscle.

The patellofemoral retinaculum and ligaments provide their greatest contribution to patellofemoral stability between full extension and 30° of knee flexion. It is at this point in the arc of motion that patellofemoral stability relies on soft tissue restraints. The anatomy of the medial aspect of the knee was originally described by Warren and Marshall. They described three distinct layers, the most important of which is the second. This layer contains the medial patellofemoral ligament (MPFL), which has been the subject of many recent studies and multiple reconstructive and repair techniques. The MPFL is believed to be the primary passive restraint to lateral patellofemoral translation. Cadaveric studies have demonstrated that the MPFL resists 50% to 60% of the force required to cause significant lateral translation of the patella, while the patellomeniscal and patellotibial ligaments provided significantly less restraint. This extrasynovial ligament is a distinct structure in the second layer and, as a result, can not be seen during knee arthroscopy. The MPFL is shaped like an hourglass with a mean width of approximately 13 mm. It originates from the adductor tubercle, medial epicondyle, and superficial MCL, and inserts on the upper two-thirds of the medial patellar border. The isometric point of this ligament is debated and will be addressed later. Also of note, is the fact that the deep fascia of the VMO attaches to the MPFL. This becomes significant with acute dislocations, as several investigators have argued that avulsion of this ligament can also result in detachment of the distal origin of the VMO, with displacement to a more superior and lateral position, ultimately changing its direction of pull.

**Biomechanics**

Stability and normal tracking of the patella with knee flexion requires a complex orchestration of static and dynamic components. From 0° to 30° of knee flexion, the primary restraint to lateral patellofemoral dislocation is the MPFL and other soft tissues. With greater knee flexion, the bony confines of the lateral femoral condyle and the trochlear groove capture the patella and provide stability. Normal tracking of the patella within the trochlear groove requires central tracking of the patella within the trochlear groove and without significant tilt. As the patella tracks with greater flexion, contact between the patella and the femur progresses from a distal to proximal direction. The forces through this joint can become significant and across the patellofemoral joint approach 2 to 5 times body weight with activities of daily living. Squatting in high flexion can produce joint reaction forces as high as 7 to 8 times body weight.

The quadriceps angle, or Q angle, also plays an important role in patellofemoral tracking and patellofemoral forces. It describes the direction of pull of the quadriceps mechanism relative to that of the patellar tendon. The clinical measurement of this angle is obtained by measuring the intersection of a line drawn from the anterior superior iliac spine (ASIS) to the patella with that of a second line drawn from the tibial tuberosity to the patella. For males the mean Q angle is approximately 10° and for females it is approximately 15°, plus or minus 5°. This difference in gender is the result of a wider pelvis in females and an associated increase in the extent of knee valgus alignment. As the Q angle increases, both the exerting lateral displacement force and patellar contact pressure increase. In addition, the tendency for lateral tilt also increases.

**Abnormal Patellofemoral Joint**

Many investigators have questioned whether a “normal” patellofemoral joint can dislocate. Most agree that there is an anatomic predisposition. Patients predisposed to patellofemoral instability may have an increased Q angle, dysplasia of the patella or trochlear groove, patella alta, or a dysplastic VMO.

Alterations in the Q angle can result from deviations in normal lower extremity skeletal anatomy. Thinking from proximal to distal, these include: increased femoral anteversion, genu valgum, tibia vara localized to the proximal tibia, external tibial torsion, and a varus subtalar joint. Normal anteversion of the femur is 11° ± 7°. With increasing femoral version, the femoral trochlea faces medially when the hip assumes a neutral position. This causes the patella to face inward, increasing the Q angle. The tibial tuberosity is the distal most insertion of the quadriceps mechanism. Genu valgum, tibia vara isolated to the proximal tibia (referred to as bayonet tibia), and external tibial torsion shift the tibial tubercle laterally. This acts to increase the Q angle at the knee. Miserable malalignment syndrome is a combination of malalignments of the leg and encompasses an internal rotation deformity of the femur with an inward facing patella, bayonetted tibia, external rotation of the tibia, and flat feet. Alterations distally can indirectly affect the position of the tubercle. This is exemplified by a varus subtalar joint. This alteration in the hindfoot causes the tibia to externally rotate, which then increases the Q angle.

As discussed previously, with knee flexion greater than 30°, the patella is captured within the trochlear groove. Consequently, a shallow trochlear groove, hypoplasia of...
the lateral femoral condyle, or hypoplasia of the patella can have profound effects on patellofemoral stability. In addition to the skeletal contributions, one must also consider the soft tissue around the knee. When patella alta is present, the patella becomes engaged with greater degrees of knee flexion. This results in a greater arc of flexion, where the patella is not captured and is at an increased risk for instability episodes. Simmons and Cameron achieved a 0% recurrence rate in patellofemoral instability when the tibial tubercle was transferred distally without medialization in patients with instability and significant patella alta. The idea that a dysplastic VMO contributes to instability is debated within the orthopaedic literature. In a cadaveric study, VMO weakness was simulated from 0° to 15° of flexion. This was found to increase lateral patellar translation. In contrast to this conclusion, Fithian and colleagues argue that no amount of muscle force imbalance will cause patellar dislocation unless a coexisting patholaxity of the medial ligamentous restraints is present.22

**Physical Examination**

The physical examination of the non-injured limb has standing, sitting, and supine components. While standing, the patient should be inspected for the overall alignment of the limb. As mentioned previously, alterations in the coronal plane can have profound effects on the quadriceps angle, and these often can be visualized with the patient standing; they include genu valgum, a bayonet tibia, squinting or inward facing patellae, and the miserable malalignment syndrome. With the patient sitting, the examiner should observe the patellar position. Normal patellas should be centered within the trochlear groove and face forward. When patellas assume a high and lateral position, they are described as “grasshopper eyes,” as they appear to look up and over the examiner’s shoulder. Next, the patient should extend the knee from a flexed position. The examiner, during this range of motion, should feel for crepitus, which may be a sign of cartilage injury or degeneration. Also, the patella should be observed for J-tracking. This type of tracking describes the abrupt lateral shift of the patella as it exits the trochlear groove with greater extension. It often is the result of an increased lateral force or an increased Q angle. Lastly, the tubercle sulcus angle can be measured with the knee flexed at 90°. A perpendicular line to the epicondylar axis is visualized and compared to a line paralleling the patellar tendon. These two lines should be parallel, and a difference of 10° or more is abnormal.

While the patient is supine, the quadriceps angle should be measured. This angle is formed by the intersection of a line from the ASIS to the patella and a line from the patella to the tibial tubercle. Factors that affect this measurement are the degree of knee flexion, isometric contraction of the quadriceps muscle, and the degree of rotation placed on the tibia. It is important to remember also that this is strictly a static measurement and has limitations in assessing a dynamic joint. The patella can also be tested for tilt and mobility. Assessing patellar tilt will allow checking for excessively tight lateral restraints. Normally, with the quadriceps relaxed and the knee extended, a posterior directed force on the medial patella will allow the lateral patella to reach a neutral or horizontal position in the sagittal plane. Inability to elevate the lateral portion of the patella to this plane signifies excessively tight lateral retinacular structures. To test patellar mobility the knee is flexed to 30°. Medially and laterally directed forces should displace the patella no more than half of its width. When assessing lateral translation, apprehension or the subjective discomfort from impending dislocation can also be assessed.

In the acutely injured knee, it is imperative to examine the contralateral limb as described above, due to the fact that this likely will not be possible in the injured extremity. Most acute patellar dislocations spontaneously reduce and the patient may not be able to tell you that the patella dislocated. Typically, patients exhibit tenderness over their medial facet and their adductor tubercle, which may be accompanied by significant medial ecchymosis. The degree of hemarthrosis present may be significant. One must check for crepitus within the joint, which may represent an osteochondral injury, as well as rents or detachment of the VMO should be looked for.

**Radiographic Evaluation**

The radiographic series for the examination of the patellofemoral joint includes an AP, lateral, and Merchant view. It is important to note that a significant amount of information can be gained from these studies, but they are limited in that they provide static images of a dynamic joint. Varus and valgus alignment can be assessed on the AP radiograph. The lateral view allows for assessment of patella alta or baja, based on the Insall-Salvati ratio. In addition, trochlear depth can also be assessed on this view. Dejour and associates based a three-part classification on the level of intersection of the floor of the trochlea with the medial and lateral femoral condyles. This classification can be useful for quantifying the degree of femoral hypoplasia. The Merchant view is an axial radiograph of the patellofemoral joint obtained with the knee in approximately 45° of flexion. It is helpful for assessing the sulcus angle, the congruence angle, reduction of the patellofemoral joint, and for the presence of osteochondral fragments. The sulcus angle is the angle formed between a line drawn from the center of the deepest portion of the trochlea to the medial femoral condyle and one to the lateral femoral condyle. This angle normally averages 138°. Increasing sulcus angles correlate with shallower or dysplastic trochlea. The congruence angle is formed from a bisector of the sulcus angle and a line drawn from the center of the trochlea to the lowest, central portion of the patella. By convention medial angles are negative and lateral angles are positive. Angles greater than +16° denote lateral subluxation of the patella.
ostechondral fragments is 5% to 30%, while the operative incidence approaches 30% to 70%, suggesting a significant portion of injuries are missed on plain radiographs.2,13,27-29

An MRI may be indicated in the acute setting if osteochondral injuries are suspected, as they are associated with a poor outcome if they are not addressed.27 The classic findings in acute patellofemoral dislocations on MRI include: focal impaction injuries of the lateral femoral condyle, osteochondral injuries to the medial facet, and medial retinacular injuries.30 The classic “kissing lesion” bone bruises on the lateral femoral condyle and the medial patella result from the lateral dislocation of the patella and its relocation.31 MRI also may demonstrate inflammation around the VMO and may show MPFL tears or avulsions. The majority of MPFL injuries are tears or avulsions at or near its origin on the femur.32

Kinematic MRI may be useful in the chronic setting. It provides the most physiologic means of evaluating the patellofemoral joint, as dynamic images are obtained that allow for the interpretation of muscular contributions. On these images, the patella should remain centered in the trochlear groove through its full range of motion.31

CT scans are useful in the chronic setting for assessing the bony anatomy and architecture of the patellofemoral joint at different angles of flexion. The protocol includes mid-axial images obtained from 0° to 60° of flexion in 10° increments. It is useful in better assessing the sulcus angle, congruence angle, trochlear depth, and the ATT-TG distance. The ATT-TG distance is a measure from the center of the trochlea to the tibial tubercle and is obtained from superimposing the two appropriate axial CT images. It is very helpful in quantifying the amount of lateralization of the tibial tubercle. Normal measures are 2 to 9 mm and borderline is 10 to 19 mm; greater than 20 mm is felt to be highly abnormal.14,31 Patients with distances greater than 20 mm are believed to be good candidates for distal procedures designed to medialize the tibial tubercle.14

Acute Injuries

The mechanism of acute patellofemoral dislocations may be either direct or indirect. Direct injuries result from a lateral blow to the patella, which forces it laterally. More commonly, dislocations occur from an indirect mechanism. This involves a planted foot with a valgus force applied and either internal rotation of the femur or external rotation of the tibia. The direction of dislocation is typically lateral.31 The most common patient is an adolescent female. A recent study found the incidence to be 31:100,000 for the second decade, 11:100,000 for the third decade, and 2:100,000 for the fourth and fifth decades combined.31

Occasionally, a patient may present with the patella dislocated. If this occurs, simple extension of the knee will reduce the patella. Frequently, patellar dislocations spontaneously reduce, and often patients are unable to describe their patella as having dislocated. It is not uncommon for these injuries to be mistaken for ACL injuries.33 Signs consistent with patellofemoral dislocation on physical examination are a hemarthrosis, tenderness over the medial facet of the patella and the adductor tubercle, ecchymosis medially, and a positive apprehension sign. The degree of hemarthrosis may help quantify the amount of energy required to dislocate the patella. More dysplastic patellofemoral joints require less injury to dislocate and may be associated with a smaller hemarthrosis (Fig. 1).14,35 Also, as less energy is required to dislocate a dysplastic patellofemoral joint, they are associated with less significant osteochondral injuries (Fig. 1).36

The accepted indications for surgery in the acute setting are osteochondral fragments, persistent patellar subluxation and detachment of the VMO and medial retinaculum from the medial aspect of the patella. The surgery may be directed toward the above problem, and does not necessarily include realignment surgery.14 If the above are not present, the knee may be immobilized in extension for 3 to 6 weeks, followed by physical therapy aimed at regaining motion, proprioception, and increasing VMO strength. Garth and coworkers have advocated a more aggressive rehabilitation protocol that utilizes a patellofemoral brace with a lateral pad and strap, which obviates the need for immobilization.37 Caution should be used with this protocol as kinematic MRI studies have shown that patellofemoral braces provide subjective improvement in symptoms, but do not correct patellar tilt, nor do they centralize the patellar tracking.38 As such, immobilization may be required for the injured medial structures to heal after the acute dislocation. Recurrent instability occurs in 15% to 50% of patients treated nonoperatively.27,35,37,39,40

Given the high rate of recurrence, many investigators recommend early surgery to decrease the incidence of future instability.12,13,41,42 Sallay and colleagues make a compelling argument for early operative intervention. They contend that as a result of acute injury, the MPFL and VMO are avulsed
and rest in a more superior and lateral position. If they heal or scar down in this position, their force vector and degree of medial restraint will be altered.  

Early surgical options include repair of the MPFL with or without augmentation. Direct repair of the MPFL has been described with suture anchor techniques. A medial transverse incision in line with the MPFL is utilized for exposure and the ligament is repaired with suture anchors. Studies have demonstrated that patients treated with acute repair or repair with augmentation develop recurrent instability in 0% to 10% of cases. However, a significant portion of these patients report continued postoperative pain.

Should patients with acute dislocations be treated with early surgery to reduce the incidence of recurrent instability? Upon first inspection of the literature, it appears that early repair reduces the incidence of recurrence. However, a significant number of patients complain of pain. Most literature addressing early surgical repair is limited, as it is retrospective in nature, involves a small group of patients, and has limited follow-up. Studies investigating nonoperative treatment are more often prospective in nature and have longer follow-up. An additional limitation to research is the wide spectrum of patellofemoral instability predisposition and the difficulty in truly establishing similar cohorts. To date, there exists only one study in which patients were prospectively randomized to nonoperative versus operative treatment for acute instability. Nikku and associates’ data, at 2 and 5 years across several studies, showed no difference in recurrent instability with either treatment arm. Their recommendation was that patients be treated initially with nonoperative management. Additionally, the investigators noted that between their 2 and 5 year studies, an additional one-third of their patients had a subsequent instability episode. This highlights the need for long-term follow-up of this problem to determine the true usefulness of a procedure in reducing recurrent instability. In general, most investigators now favor nonoperative treatment for acute first-time patellofemoral dislocations.

Chronic Instability

Recurrent instability often necessitates surgical intervention. There are many types of surgery described. It is important to elucidate the patient’s reason for repeated instability episodes. Physical examination can demonstrate deviations from normal anatomy that predispose the patient to instability. These again include an increased Q angle (increased femoral anteversion, genu valgum, tibia vara isolated to the proximal tibia, or external tibial torsion). MPFL insufficiency, patella alta, or patellofemoral dysplasia. CT scanning also may be very helpful in delineating the etiology of recurrent dislocations. Surgical treatment ought to be aimed at addressing the predisposition. In general, the surgeries may be subdivided into proximal and distal procedures.

Examples of proximal procedures include the Madigan quadricepsplasty, arthroscopic medial imbrication, and MPFL reconstruction. The ideal candidates for a proximal procedure have a normal Q angle, no significant arthrosis of the medial facet, insufficiency of the medial structures (namely the MPFL), and initial instability resulting from a traumatic event.

Proximal quadricepsplasty involves a release of tight lateral structures and advancement of the VMO insertion distally and laterally on the patellar surface. This medial imbrication procedure re-tensions the medial soft tissue restraints and restores a medially-directed force to the patella. Many surgeons still utilize this simple procedure, believing that the MPFL scars down and can be re-tensioned with distalization and medialization along with the VMO. Some, however, argue that it is a nonanatomic procedure and is limited in its utilization. In addition, if Sallay’s contention is accurate, that the MPFL and VMO heal in a more superior and lateral position following patellofemoral dislocation, then the re-tensioned pull is not truly medializing.

Arthroscopic medial reefing is a slight deviation from the quadricepsplasty procedure as re-tensioning of the medial structures remains the same goal. However, it is performed with an all-inside arthroscopic technique. These studies are limited and some believe that this procedure is best indicated for the patient with symptomatic subluxation rather than those with frank dislocations.

MPFL reconstruction has gained recent attention as an evolving technique that has the potential to restore anatomically the primary medial restraint to lateral instability. Many proponents feel that this is the essential lesion in patellofemoral instability. Nomura has devised a three-part classification for the chronically injured MPFL. Type I is a loose femoral attachment (9/49), type II is an elongated scar posteriorly (29/49), and type III is complete absence of the ligament (11/49).

Multiple techniques have been described for MPFL reconstruction with slight variations, but the key steps in each technique are the same. The first is the determination of the isometric point for the femoral attachment of the graft. This is the key step, as poorly positioned grafts can lead to pain, problems with knee range of motion, and degenerative changes to articular cartilage. Through their work on cadaveric knees, Smirk and Morris determined the most isometric points on the femur to be 1 cm distal to the adductor tubercle and 5 mm posterior to it. Points slightly distal or slightly posterior to this point were also found to be acceptable. Fixation techniques at both the femur and the patella vary considerably, though the goal is the same: secure fixation of the graft to the appropriate location on both the femur and the patella. One technique describes fixing the graft, either hamstring allograft or autograft, to the femur with a tenodesis screw. This is followed by drilling a transverse hole across the patella at or slightly above
failure. The final step involves suturing the VMO to the patella. The graft is tensioned at 30° and provisionally fixed. The knee is taken through a range of motion and patellar glide is assessed. If appropriate, the graft is fixed in position by screws. Weightbearing is limited postoperatively, given the reported complication of fracture. The decision between TTM and AMZ procedures should be based on the presence or absence of patellar chondrosis. Chondrosis of the medial facet of the patella is a contraindication to medialization procedures of the tibial tubercle.

A recent cadaveric study by Ramappa and colleagues was designed to evaluate patellofemoral contact pressures and contact areas following TTM and AMZ procedures. The group measured contact areas and pressures using a Tekscan instrument in normal and increased Q angle states, and then quantified the change seen with both simulated TTM and AMZ procedures. The Tekscan instrument allowed for dynamic patellofemoral contact measures throughout the flexion cycle. Both procedures corrected the elevated patellofemoral contact pressures and maltracking seen in the increased Q angle state. There was a trend in lower contact pressures with the AMZ group.

**Conclusion**

Treating patients with both acute and chronic instability requires a thorough understanding of the anatomy and biomechanics of this joint. Based on the literature, initial acute patellofemoral dislocations should be treated with immobilization and rehabilitation, as a majority of patients...
will do well without surgery. MRI should be utilized to assess for osteochondral lesions, as they are associated with a poor prognosis if they are not addressed. In the chronic setting, it is imperative to understand each patient’s reason for repeated instability. This can be determined through a detailed history, focused physical examination and radiographic studies included CT scanning. Once determined, proximal procedures and distal procedures, or either alone, can be tailored to the individual patient and be utilized to correct patellofemoral biomechanics. Given the wide spectrum of patient predisposition to instability, literature with small cohorts and retrospective designs should be regarded with caution. Long-term follow-up should be sought, before new therapies are accepted.

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