Chapter 3

# Patellofemoral Instability: Diagnosis and Management

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Additional information is available at the end of the chapter

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## 1. Introduction

Patellofemoral articulation plays a major role in locomotion and other activities that involve knee flexion and extension. Problems of patellofemoral tracking are very common, ranging from mild lateral maltracking and tilt, to frank instability and dislocation of the patella. Patellofemoral instability can be defined as movement of the patella out of its normal position, and can be divided into dislocation and subluxation. Natural history of this condition is that of a relatively high recurrence. Even in the absence of recurrent instability, patients who sustain patella dislocation or subluxation may develop a number of significant problems, including persistent knee pain, functional limitations, decreased athletic performance, and arthritic degeneration of the patellofemoral articulation. Especially for the recurrent dislocator, surgical treatment plays an important role in management, since the natural history of this condition is that of relatively poor return to normal function.

Direction of patellofemoral instability is almost always lateral (rare cases of medial dislocation have been reported to occur secondary to iatrogenic causes). Overall incidence of this injury has been shown to be around 6 per 100,000, with the highest incidence occurring in the 2nd decade of life (around 30 per 100,000), and becoming significantly lower after 30 years of age (around 2 per 100,000).[1,2]Traditionally, this injury was thought to occur in sedentary, overweight, adolescent females, but most recent data has shown this stereotype to be inaccurate, with most injuries actually occurring in young athletic individuals, often males, during sports participation and other intense physical activity. [3]

Proper articulation and movement of the patella within the femoral trochlear groove requires complex interplay between a number of important static and dynamic soft-tissue stabilizers, the bony architecture of the patellofemoral joint, and the overall alignment of the lower extremity. Abnormalities in one or more of these factors can result in or predispose to clinically relevant patellofemoral instability, and are described below.

## 2. Anatomy of the patellofemoral joint and factors contributing to instability

### 2.1. Osseous anatomy of the patellofemoral articulation

Instability of the patellofemoral articulation can occur when the bony anatomy of the patella, the femoral trochlea, or both is abnormal, i.e. dysplastic. In order to understand how dysplasia contributes to instability, normal anatomy and biomechanics of this joint have to first be described.

The patella is the largest sesamoid bone in the body, i.e. it is a bone that is imbedded within a tendon – in this case the extensor mechanism of the knee. It has a multifaceted articular surface, with lateral and medial facets separated by a central ridge, and a much smaller odd facetlocated far medially. The articular cartilage of the patella is the thickest in the body, designed to withstand significant joint reactive forces that occur at the patellofemoral joint, which range from 0.5 to 9.7 x body weight with daily activities, and may approach values of 20 x body weight with certain sporting activities. [4]

The patella's most important function is as a fulcrum for the extensor mechanism. It increases the distance of the line of action of the extensor mechanism from the center of rotation of the knee, therebyincreasing the force that can be generated by contraction of the quadriceps. Total patellectomy has been shown to decrease the maximum force generated by the quadriceps by 50%. [5]

Anatomy of the femoral trochlea typically closely matches the articular shape of the patella, with a longer and higher lateral wall that serves as the most important bony restraint to lateral translation. In full extensionthe patella sits on the non-articular anterior surface of the distal femur, and typically enters the trochlea at 20-30 degrees of knee flexion, depending on the length of the patella tendon. The contact area increases and moves proximally with greater flexion; the lateral facet engages the trochlea first, while the medial facet engages it last.

Since the flexion angle at which the patella engages the trochlea depends on the length of the patella tendon, patella alta – the condition in which the length of the patella tendon is abnormally increased and the patella position is abnormally high - contributes to instability by increasing the range at which there is no bony contribution to stability. Patella alta has been shown to be associated with recurrent patellofemoral instability. [6,7]

Once the patella enters the trochlea, dysplasia of the patella, the trochlea, or both, can contribute to instability by decreasing the bony restraint and consequently the amount of energy required to dislocate. Patellofemoral dysplasia has been classified by Dejour et al. [8] (Figure 1) Dysplasia typically occurs on both sides of the joint, with congruous articulation between the two bones, although incongruous articulation can also occur, and leads to some of the worst instability.

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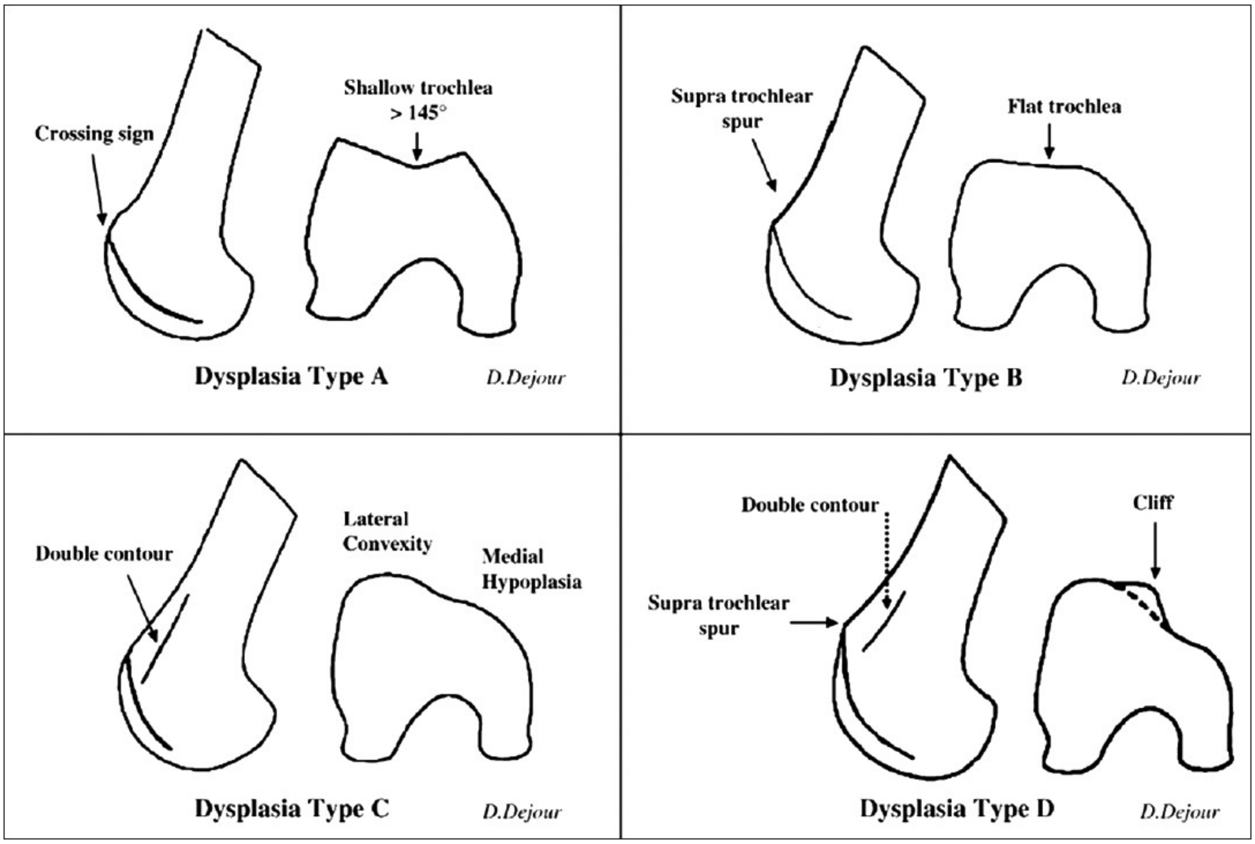


**Figure 1.** Dejour classification of trochlea dysplasia

### 2.2. Soft-tissue stabilizers

Soft-tissue structures important to the patellofemoral joint include the lateral retinaculum, the iliotibial band, and vastus lateralis muscle on the lateral side, and the medial retinaculum, medial patellofemoral ligament, and the vastus medialis oblique muscle on the medial side. Normally, these all work in concert to provide proper stability and tracking of the patellofemoral articulation. When medial stabilizers are weakened or disrupted, the typical lateral instability may occur. Tightness or excessive force by the lateral stabilizers typically does not cause actual instability, as long as the medial structures are normal, but may cause symptomatic abnormalities in patella tilt and tracking, as described below.

The lateral retinaculum tightness is commonly implicated in abnormal lateral tilt of the patella. However, it is not considered to be a major factor contributing to lateral instability of the patella. Lateral release alone in the setting of instability has been shown to result in 100% rate of recurrence [9], indicating the very limited, if any, contribution of the lateral retinaculum to development of lateral instability. Moreover, biomechanically the lateral retinaculum may even contribute up to 10% to medial stability [10], and addition of a lateral release to medial soft-tissue repairs has been shown to actually decrease the force required to dislocate the patella, compared to medial repair alone. [11]

Iliotibial band (ITB) is a continuation of tensor fascia lata, which originates on the anterior superior iliac spine, and inserts on the Gerdy's tubercle of the anterolateral proximal tibia. It exerts its effect on the patellofemoral joint via fibers attaching to the lateral retinaculum. Abnormal tightness of the ITB can result in lateral patellar maltracking with pain, and is a common finding in patellofemoral tracking abnormalities and patellofemoral pain syndrome (which is one of the most common causes of anterior knee pain). Non-operative treatment with stretching and therapeutic modalities can be quite successful in decreasing ITB tightness and alleviating symptoms.

The other dynamic stabilizer on the lateral side is the vastus lateralis muscle, which has a force vector 30-40 degrees lateral to anatomic femoral axis. Disruption of the attachment of the vastus lateralis to the patella from overly aggressive and excessively proximal lateral retinacular release can result in iatrogenic instability of the patella in the medial direction. [12]

The main dynamic stabilizer on the medial side, counteracting the pull of the vastus lateralis and the ITB, is the vastus medialis oblique (VMO) muscle, which has a 60 degree force vector to the anatomic femoral axis, and is most active at 0-30 degrees of knee flexion. In addition to its role as a dynamic stabilizer [13], the VMO also serves as a static stabilizer, and its sectioning has been shown to produce increased lateral translation of the patella. [14] After an injury to the quadriceps muscle group, the VMO is the typically the first to weaken and last to recover.

The most important of the static medial soft-tissue stabilizers is the medial patellofemoral ligament (MPFL), which provides 53-60% of the check-rein to lateral displacement of the patella at 0-30 degrees of knee flexion. [10, 15] Because of its importance for stability, MPFL's anatomy and function have been extensively studied. This ligament is located in the second layer of the medial knee - deep to the crural fascia, superficial to the knee joint capsule - in the same layer as the superficial medial collateral ligament (MCL). It is a very thin ligament, measuring 0.44mm in thickness, withan average length of 58mm, an hourglass shape, measuring approximately 13mm width at its midpoint, 17mm on the patella side, and 15mm on the femoral side. [16-18]MPFL attaches to the proximal half of the medial border of the patella and to the medial femoral condyle. Its femoral attachment is located anterior and distal to the adductor tubercle, and posterior and proximal to the medial femoral epicondyle and the origin of the MCL. [17,18]

Sectioning of the MPFL in cadaveric studies has been shown to increase lateral patella subluxation by 50% [19], and decrease the force required to translate the patella laterally by 10mm by 50%. [20] MPFL functions isometrically (meaning its length is unchanged) during early flexion, mostly between 0-30 degrees of flexion, where it is the most important static stabilizer; it becomes progressively lax after 70 degrees of flexion. Isometry of the MPFL has been found to be most sensitive to the femoral insertion. Therefore, it is crucial to locate the anatomic femoral insertion site of the MPFL during surgical repair or reconstruction of this ligament.

### 2.3. Lower extremity malalignment/Q-angle

In addition to abnormalities of bones and soft-tissues around the patellofemoral joint, instability of this joint can also result from abnormalities in the overall alignment of the lower

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extremity, especially those abnormalities that increase laterally-directed forces on the patella. Clinically, this can be measured by assessing the Q-angle.

The Q-angle is defined as the complement of the angle between the force vectors of the quadriceps and patella tendons. The Q-angle typically measures 12 degrees in males and 16 degrees in females, is highest in extension, and represents the laterally directed force acting on the patella. Malalignment that increases the Q-angle increases the laterally-directed forces and thus predisposes to patellofemoral instability. The Q-angle is increased by genu valgum, femoral anteversion, external tibial torsion, and pes planus.

To summarize contributions of various anatomic structures to patellofemoral stability, stability in extension and early flexion (up to 30 degrees) is primarily dependent on integrity and function of the medial soft-tissue stabilizers, both static (MPFL) and dynamic (VMO), while stability in greater degrees of flexion is dependent to a greater degree on bony architecture and congruity of the femoral trochlea and the patella. Factors contributing to instability include 1) inadequate bony restraints, such as patella alta and patellofemoral dysplasia; 2) inadequate medial soft-tissue restraints, such as VMO weakness or MPFL disruption/attenuation; and 3) excessive laterally-directed forces, typically resulting from lower extremity malalignment producing a high Q-angle. (Table 1)

| | |
|---|---|
| Inadequate Bony Restraints of the Patellofemoral Joint | Femoral trochlea dysplasia (excessively shallow)<br>Patella dysplasia<br>Combined patellofemoral dysplasia<br>Patella alta |
| Inadequate Medial Soft-tissue Restraints | MPFL tear or elongation<br>VMO disruption<br>VMO weakness |
| Lower extremity malalignment | Abnormally high Q-angle<br>Excessive femoral anteversion<br>Excessive external tibial torsion<br>Genu valgum<br>Proximal tibia vara<br>Pes planus |

**Table 1.** Factors Predisposing to Patellofemoral Instability

## 3. Clinical presentation of patellofemoral instability

The two most common types of clinical presentation of patella instability are 1) acute dislocation from an injury, and 2) recurrent instability (either dislocation or subluxation), typically occurring with minor or no injury, with a history of previous dislocation. Another common presenting complaint related to patellofemoral tracking is painful maltracking without sensation of instability, with or without history of previous dislocation.

### 3.1. Acute dislocation

Acute dislocation may occur from a direct or an indirect mechanism of injury. Indirect mechanism accounts for the majority of acute dislocations, and occurs most commonly with cutting, pivoting, and squatting movements with sports and other strenuous physical activities. Typically the foot is planted, the femur is rotated internally and/or the tibia is rotated externally, and there is a valgus force at the knee joint; in this position, sudden contraction of the quadriceps produces a strong laterally directed force vector, resulting in dislocation of the patella. Dislocation from a direct injury mechanism, which is much less common, occurs when the patella is struck with a laterally directed blow.

Most cases of acute patella dislocation reduce spontaneously as the knee is brought into extension, and therefore evaluation in the emergency room or doctor's office may not readily provide the diagnosis. Patient may report feeling or hearing a "pop" or a "snap" and seeing/feeling their kneecap "move out of place", followed by spontaneous reduction with a "clunk" as the knee is extended. On presentation typical complaints are those of pain, swelling, limited motion, and difficulty bearing weight. Occasionally the reduction is not spontaneous and requires reduction in the emergency room (by gently extending the knee and manipulating the patella back into the trochlear groove).

Physical examination after acute dislocation may be significantly limited by guarding due to pain and hemarthrosis (bleeding) in the knee. If this is the case, arthrocentesis should be considered, with aspiration of the hemarthrosis and injection of a short-acting local anesthetic. This allows for a more accurate examination of the knee, as well as quicker restoration of knee motion and strength.

Examination should focus on ruling out fractures, injuries to major ligamentous stabilizers of the knee joint, and finally assessing patellar stability. Combination of hemarthrosis and a sports-related mechanism of injury may initially suggest a diagnosis of ananterior cruciate ligament (ACL) tear, and careful examination of anterior, posterior, varus, valgus, and rotational stability of the knee should be performed.

Patients may exhibit medial knee tenderness and ecchymosis (bruising) at the femoral origin of the MPFL, near the medial epicondyle and adductor tubercle, and injury to the MCL (which also originates in this area) should be ruled out. There is often tenderness over the medial facet and lateral femoral condyle. Less commonly there is a palpable soft-tissue defect adjacent to the medial facet, especially if there is a complete tear at the VMO insertion. Range of motion of the knee is usually very limited due to pain and apprehension; crepitus during motion (in a knee without preexisting arthritis) is concerning for osteochondral fracture and presence of intraarticular fragments. Examination of patellar medial-lateral translation with the knee extended and at 30 degrees of flexion should be attempted, but may not be possible due to patient guarding. Apprehension with attempted lateral translation at 30 degrees of knee flexion is suggestive of patella instability and is known as the "patella apprehension" test.

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### 3.2. Recurrent instability

Patients with this problem sometimes report a clear history of recurrent dislocations or subluxations, but in other cases the presentation is more vague, and may include such complaints as sensation of the whole knee giving out, weakness of the knee, anterior and anterolateral pain, difficulty navigating stairs, and inability to participate in sports. A thorough history and careful physical examination are essential to arrive at the correct diagnosis. Important history points include previous injuries and dislocations, provoking activities and positions of the knee, family history of instability or laxity of other joints, and childhood problems of the lower extremity (including those of the hip and foot).

Physical examination must include evaluation of lower extremity alignment, including measurement of the Q-angle, as well as a comparison to the contralateral knee. The Q-angle is typically measured in a supine position, and is formed by the intersection of a line drawn from the ASIS (anterior superior iliac spine) to the patella and from the patella to the tibial tubercle.

Examination of patients with patella instability should also assess genu varum (“bowlegs”) or genu valgum (“knock-knees”), external tibial torsion, femoral anteversion (best assessed by abnormally increased femoral internal rotation with the patient prone), pes planus (“flat feet”), and generalized ligamentous laxity. Strength of the quadriceps, hip flexors, abductors, and rotators must be assessed, as weakness in these muscle groups can contribute to patellofemoral maltracking and instability.

The patellaitself can be evaluated for resting position, tilt, passive translation, apprehension, and dynamic tracking. In extension and 30 degrees of knee flexion the patella position should be central within the trochlear groove, and while it may rest laterally tilted, the examiner should be able to “lift it off” the lateral trochlea and bring it to at least a horizontal position. Inability to do this suggests excessive tightness of the lateral retinaculum. With the knee in flexion, the normal position of the patella should be pointing directly forward; a “grosshopp-per eyes” appearance may be noted in patients with recurrent instability or lateral maltracking, with both patellae pointing superiorly and laterally.

Passive lateral translation of the patella is measured with the knee flexed to 30 degrees and the quadriceps muscles relaxed, and must be compared to the contralateral side. Passive lateral translation should be no more than one half the patellar width, without sensation of apprehension or pain. Pain and/or crepitus with patellar compression into the groove (“patella grind”) may indicate arthritis or osteochondral injury. Finally, patellofemoral tracking during active knee range of motion should be central. Abnormal tracking is classically manifested by a positive “J-sign”, which is a sudden lateral movement of the patella as it exists the femoral trochlea during terminal extension.

## 4. Radiographic imaging of patellofemoral instability

Radiographic imaging is essential for proper evaluation of a patient suspected of having patellofemoral instability. The imaging modalities most commonly used for this condition include plain radiographs, magnetic resonance imaging (MRI), and ultrasound (US). The computed tomography (CT) scan is used less commonly. Initial evaluation should always begin with plain radiographs, while more advanced imaging is ordered as necessary, based on clinical examination and plain radiographic findings.

The plain radiographic evaluation should include a minimum of three views – anterior-posterior (AP), lateral, and axial, or "sunrise", views. The AP view allows assessment of coronal plan malalignment, such as genu varum or valgum, as well as presence of any tibiofemoral arthritis. The lateral view is used to assess patella alta or baja.Several signs of trochlear dysplasia can also be appreciated on the lateral view, including the crossing sign, supratrochlear spur, and the double contour. [8](Figure 2)

**Figure 2.** "Crossing sign" on a preoperative lateral radiograph in a 35 year old female with recurrent instability, significant malalignment and trochlea dysplasia. This sign represents abnormally elevated floor of the trochlear groove rising above the top of the wall of one of the femoral condyles (arrow).

The two most commonly used techniques for axial, or "sunrise", radiographs of the knee, are Merchant's and Laurin views. These views, especially in comparison to the contralateral knee (ideally on the same cassette) are invaluable in detecting such abnormalities as lateral patellar tilt, patellar subluxation, dysplasia, patellofemoral arthritis, vertical fractures of the patella

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(including avulsion fractures), and osteochondral fragments. A number of angles and indices measured on the axial views have been described to objectively characterize patellofemoral dysplasia, subluxation and tilt. The sulcus angle (normally 138 +/- 6 degrees) for example, as measured on the Merchant view, identifies trochlear dysplasia when it is greater than145 degrees, and has been noted to beabnormal in significant number of patients with patella instability. [21](Figure 3)

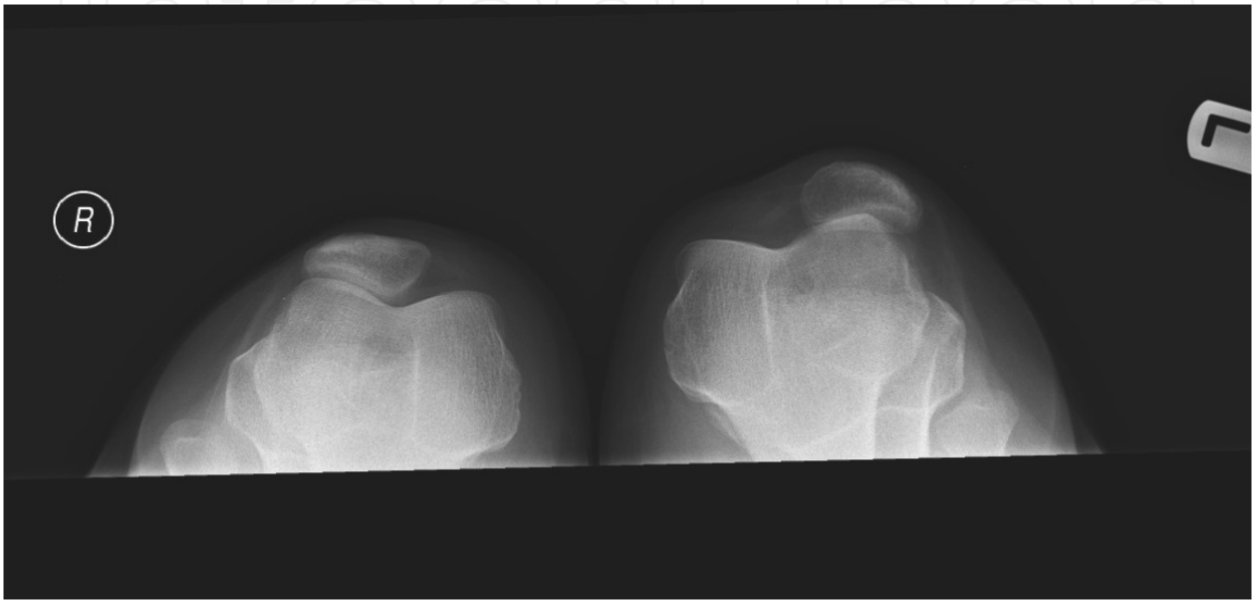

**Figure 3.** Example of a shallow trochlea, with a sulcus angle measuring 148 degrees, and lateral patella subluxation, in the same patient from Figure 2, on a preoperative Merchant's view

The more advanced imaging modalities used in evaluation of patellofemoral instability include ultrasound, CT, and MRI. Ultrasound was recently shown in one study to have a 90% accuracy and predictive value in identifying the location and severity of injury to the MPFL. [22]MRI also has high sensitivity and accuracy in detecting MPFL injuries [23], and additionally is very useful for indentifying articular cartilage damage and osteochondral fragments, over 40% of which may be missed on plain radiographs. [24,25]A relatively high number of associated injuries have been found on MR imaging of knees after patella dislocation, including as many as 21% with meniscal tears, 19% with MCL injury, 7% with patella fractures, 13% with loose bodies, and 49% with osteochondral injury. [25] Finally, in cases where the history, physical examination and plain radiographs are inconclusive, MRI can help arrive at the diagnosis of a recent acute patella dislocation by demonstrating a classic bone bruising pattern on the medial patella facet and the lateral femoral condyle.(Figure 4)

The most common location of MPFL injury from a patella dislocation has been debated. What is known for certain is that this ligament can tear anywhere along its course, including femoral avulsions, patella avulsions, and midsubstance ruptures. Moreover, a not insignificant number of patients may have combined injuries, and some studies suggest that these may be more common in children compared to adults. [25, 26]

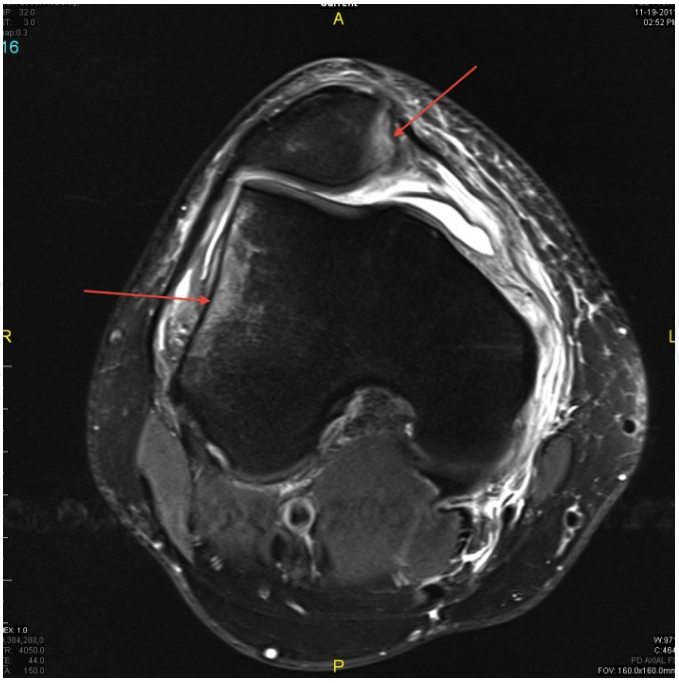

**Figure 4.** Classic bone bruise pattern of the lateral femoral condyle and medial patella facet after an acute first-time patella dislocation; other than a partial tear of the MPFL no other abnormalities were noted in this 45 year old male.

CT imaging during work-up of patellofemoral instability is most useful for assessing bony anatomy(dysplasia and incongruence) and malalignment. CT imaging is probably most useful in assessing the tibial tubercle to trochlear groove distance (TT-TG distance), which measures the lateral offset of the tibial tubercle from the deepest point of the trochlear groove, and is considered to be the true measure of the Q-angle. The normal TT-TG distance is a range of 7-17mm (average 13mm), whereas values of greater than 20mm have been found to be predictive of patellofemoral instability [27], and should prompt consideration of a distal (tibial tubercle) realignment procedure when surgical treatment is contemplated (discussed below).

In summary, radiographic imaging of patellofemoral instability should always begin with a series of plain radiographs, including an AP, lateral, and sunrise views. Acute dislocations should receive additional imaging with a MRI, to assess injury to the MPFL, and evaluate for intraarticular fragments and other associated injuries. An ultrasound can also be used to evaluate the MPFL, but is less helpful in assessing articular cartilage injuries. Finally, a CT scan is most commonly used for pre-operative assessment of trochlear dysplasia, tibial tubercle offset, and localization of bony fragments.

## 5. Non-operative treatment of patellofemoral instability

While it is reasonable to attempt non-operative treatment for most first-time acute patella dislocations, it is important to remember that “non-operative treatment” does not mean “no

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treatment". Initial management should be aimed at controlling pain and swelling, and protecting the knee from further injury.

There is no consensus on the type and duration of immobilization after an acute episode of patellar dislocation. Treatment protocols reported in the literature range from immediate range of motion and weightbearing to brace or cast immobilization in full extension for 6 weeks. Studies have shown that more rigid methods of knee immobilization (i.e. with a cast), result in lower risk of recurrent dislocations, but higher risk of knee stiffness. [28]

The authors' treatment protocol for acute first-time dislocation includes immobilization with a knee brace locked in extension for a minimum of 2 weeks, with weight-bearing allowed in the brace. Younger patients (who tend to be at a higher risk of recurrent dislocation) may be immobilized for a longer period of time, up to 4 weeks for documented complete tears of the MPFL.

Once the acute inflammation has subsided, physical therapy is helpful to reduce swelling, improve range of motion and muscle strength, stabilize patellofemoral tracking, regain proprioception of the knee, and normalize the gait pattern. Physical therapists often prefer to do patella taping during rehabilitation, as it has been shown in some studies to increase quadriceps muscle torque, control patellar motion, and activate VMO earlier than VL during stairs ascent/descent. [29,30] With regard to strengthening exercises, studies have shown that closed-chain exercises may be more efficacious in strengthening the vastus medialis,compared to open-chain exercises.[31,32]

Pre-requisites for allowing return to sportsinclude complete resolution of pain and swelling, no sensation of instability, full range of motion of the knee, and return of at least 80% of quadriceps muscle strength. This may be expected by approximately 3 months from initial injury. A patellar-stabilizing low-profile brace may be worn for athletic activities, although no studies have demonstrated efficacy of bracing in preventing recurrence of instability. [33]

## 6. Natural history of patellofemoral instability

Studies looking at the natural history of a first-time patella dislocation suggest an overall rate of recurrence of 15-44%, while persistence of instability after one episode of recurrence can be as high as 65%. [28,34,35]There is 7 times higher odds of recurrent instability in patients with a previous history of dislocation, compared to first-time dislocators, with the risk being higher for both knees. [2] The initial injury from a first time dislocation compromises the integrity of the MPFL. A torn or stretched out MPFL decreases the energy required to dislocate the patella laterally, and may predispose to recurrent instability even with less strenuous activities. Recurrent dislocations may produce further injury to the articular cartilage, ligaments and retinaculum, with irreversible articular cartilage damage being especially of concern, particularly in the young patients.(Figure 5)

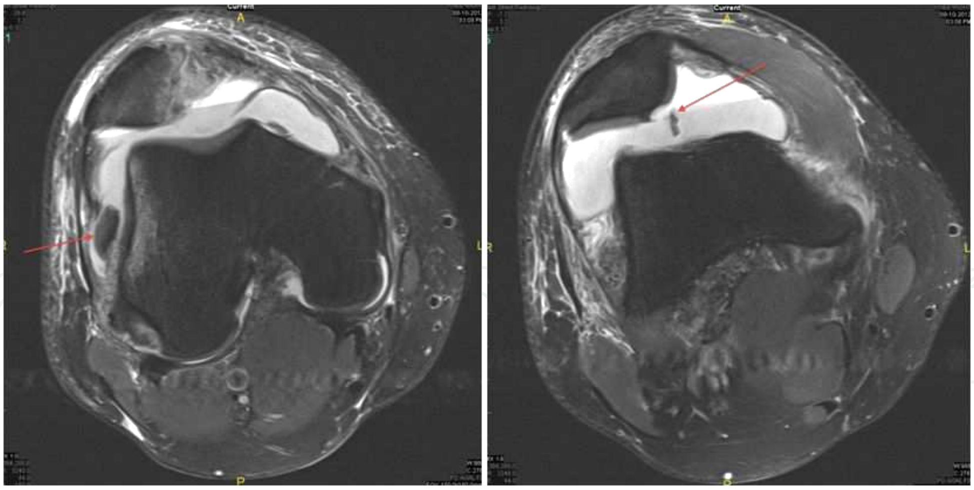

**Figure 5.** Axial MRI images of the same patient in Figure 4 after a 2nd dislocation, this time producing multiple osteochondral fragments with significant injury to both the patella and femoral articular surfaces

Even in the absence of recurrent instability, the natural history of a first-time patella dislocation may include other problems, such as persistent pain, mechanical symptoms, and knee-related dysfunction with inability to return to pre-injury functional status. Unsatisfactory results of non-surgically treated patella dislocators were as high at 63% and 75% in some studies. [28,35] Over half the patients with a first-time patella dislocation reported, at 6 months after the injury, being significantly limited in their ability to engage in strenuous physical activity, and unable to return to sports. [1]

Despite the relatively unsatisfactory outcomes of non-operative treatment for patellofemoral instability, the natural history of a first-time dislocation has not been significantly improved by an acute medial repair. A number of prospective trials (level 1 and 2) comparing medial repair versus non-operative treatment for first time dislocation showed no difference in recurrent instability or functional outcome scores. [36-40] Therefore, non-operative treatment is typically recommended after the initial episode of instability, with indications for acute surgery including presence of osteochondral fragments or persistent static patella subluxation. [24]

## 7. Surgical treatment of patellofemoral instability

The surgical procedures for patella instability can be divided into the general categories of proximal and distal realignment. (Table 2) Proximal realignment most commonly is done to the soft-tissue stabilizers, and includes procedures such as VMO advancement, medial retinaculum and MPFL imbrication, MPFL repair, and MPFL reconstruction. Distal realignment is typically done by changing the position of the tibial tubercle via one of several osteotomies (Elmslie-Trillat, Fulkerson AMZ, and Hughston). Patellofemoral instability which results from severe dysplasia of the femoral trochlea can also be treated with reshaping of the trochlea (trochleaplasty). The surgical procedures and their outcomes are discussed below.

| | Proximal Realignment | Distal Realignment |
|---|---|---|
| **Soft-tissue procedures** | Medial retinaculum and MPFL imbrication<br>MPFL repair<br>MPFL reconstruction<br>VMO advancement | Procedures mostly of historic significance<br>–Rough-Goldthwait (lateral slip of patella tendon transferred medially)<br>–Galleazzi (semitendinosis tendon transferred to the patella) |
| **Bony procedures** | Femoral trochleaplasty | Tibial tubercle osteotomy/transfer<br>–Hughston (for patella alta)<br>–Elmslie-Trillat (for instability)<br>–Fulkerson/AMZ (for instability and arthritis) |

**Table 2.** Surgical Options for Treatment of Patellofemoral Instability

### 7.1. Lateral retinacular release

As previously mentioned, lateral retinacular is the one procedure that has definitively been shown to be ineffective as a stand-alone surgical option for treatment of patella instability. [33] Studies have demonstrated a very high instability recurrence rate (up to 100% in one study) and poor results in terms of patient satisfaction when lateral release was used as the main surgical treatment for patella instability. [9,41,42] Even as an add-on procedure to medial repair or reconstruction, the utility of the lateral release has been questioned [11], and therefore this procedure should be reserved for patients with significant static lateral tilt of the patella, lateral patellofemoral compression and pain. Lateral retinacular release can be performed with an arthroscopic or an open approach, and involves dividing the lateral retinacular layer from the level of the patella tendon up to the insertion of the vastus lateralis. Care must be taken to protect the lateral geniculate artery while performing the proximal portion of the release.

### 7.2. MPFL repair

Most proximal soft-tissue realignment procedures focus on restoring the integrity of the MPFL, as injury to this ligament is considered the "essential lesion" of patella instability. With its important to patellofemoral stability well demonstrated in multiple biomechanical studies, some argue that full dislocation is impossible without significant MPFL injury. [43] Clinical reports support this notion, showing a ruptured MPFL in as many as 90% of acute dislocations [44], and either rupture or attenuated MPFL in almost 100% of cases of recurrent instability. [45] After an acute injury the MPFL either fails to heal or heals in a non-anatomic position, losing its isometry and ability to work properly as a medial stabilizer. Restoration of MPFL integrity, including its anatomic insertion sites, has been shown to restore patellofemoral tracking to normal [15,19,46], and is an important component of any surgical plan for patella stabilization. Options for restoring MPFL integrity include imbrication/tightening of the elongated ligament, repair of the ligament, or reconstruction of the ligament.

Ideal situation for an MPFL repair is an acute injury with avulsion from the patella or femoral insertion site, in a patient without significant predisposing factors such as dysplasia or malalignment. Femoral avulsions may be especially important injuries to consider for acute repair study, since at least one study demonstrated much higher rate of recurrent instability in first-time dislocators with MPFL avulsion from the femur. [47] MFPL avulsions from the insertion sites can be repaired through bone tunnels or with suture anchors, and mid-substance ruptures can be repaired with a strong non-absorbable braided suture. The repair is typically performed open, but arthroscopic techniques for repairing avulsion from the patella have also been described. [48,49]

Imbrication of the medial stabilizing structures is sometimes used for cases of mild recurrent instability (subluxation, rather than frank dislocation), and an intact but elongated MPFL. It is a "non-anatomic" procedure, which cannot address problems at the insertion sites of the ligament. With inability to precisely quantify how much of the ligament and retinaculum should be imbricated, this procedure may either fail to restore appropriate tension to the MPFL and result in recurrent instability, or over-tension the medial stabilizers and result in excessive compressive forces of the medial side of the patellofemoral joint. [50] Medial imbrication can be done arthroscopically or open,[51-53]and is similar in its technique and goals to capsular plication in the shoulder.

Outcomes ofmedial repair and imbrication procedures have shown promise in some studies[49,51,54-59], including one prospective study that demonstrated a higher rate of return to pre-injury activity level after arthroscopic repair, when compared to non-operative treatment. [40] However, randomized controlled trials have not shown any significant benefit of surgical repaircompared to non-operative treatment for first-time dislocators, with similar rates of recurrent instability and similar functional outcomes scores. [36-39]

A 2007 systematic review of 70 level I-IV trials evaluating medial repair and non-operative treatment for first-time patella dislocators concluded that initial management of these injuries should be non-operative except in select cases, including: 1) presence of intraarticular osteochondral fragments (Figure 6); 2) what the authors describe as "significant disruption of medial patellar stabilizers"; 3) lateral subluxation of the patella on the injured side, when compared to otherwise normal contralateral alignment (Figure 7); 4) persistent symptoms despite non-operative treatment; and 5) recurrent instability event.[24] With regard to recurrent instability, MPFL repair has been shown to have a relatively high rate of failure (26-46%) [60,61], and is not recommended as a stand-alone procedure.

### 7.3. MPFL reconstruction

Given the relative failure of medial repair to decrease the risk of recurrent instability and improve functional outcomes, much attention over the past two decades has been directed to MPFL reconstruction. Historically, non-anatomic procedures (such as Roux-Goldthwait and Galleazzi transfers),were used to re-create the medial stabilizers, but in the long-term these procedures has shown relative high rates of recurrent instability (22%), osteoarthritis (78%), and patient dissatisfaction (54%). [62] Unlike these and other medial soft-tissue stabilization procedures, the recently popularized techniques of MPFL reconstruction have shown excellent outcomes in terms of recurrent instability and function, [63] as well as relatively low risk of development and progression of arthritis. [64]

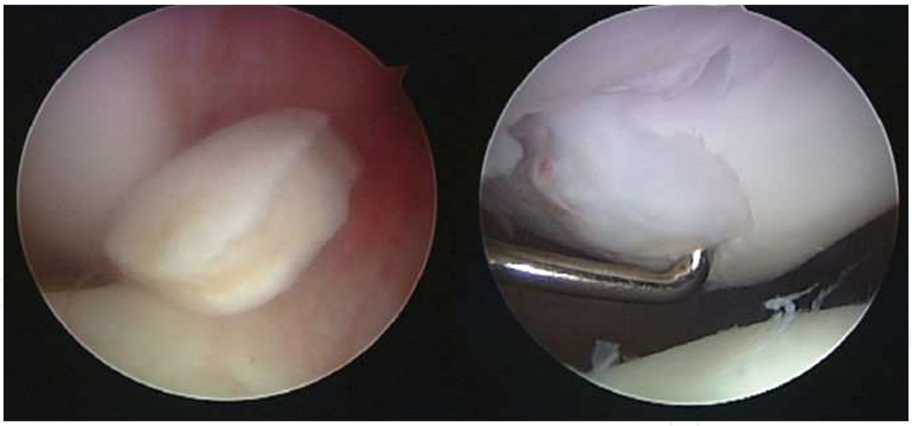

**Figure 6.** Arthroscopic picture of a large osteochondral fragment after a previous patella dislocation, and a donor site on the medial patellar facet from which it likely originated (overgrown with fibrocartilage)

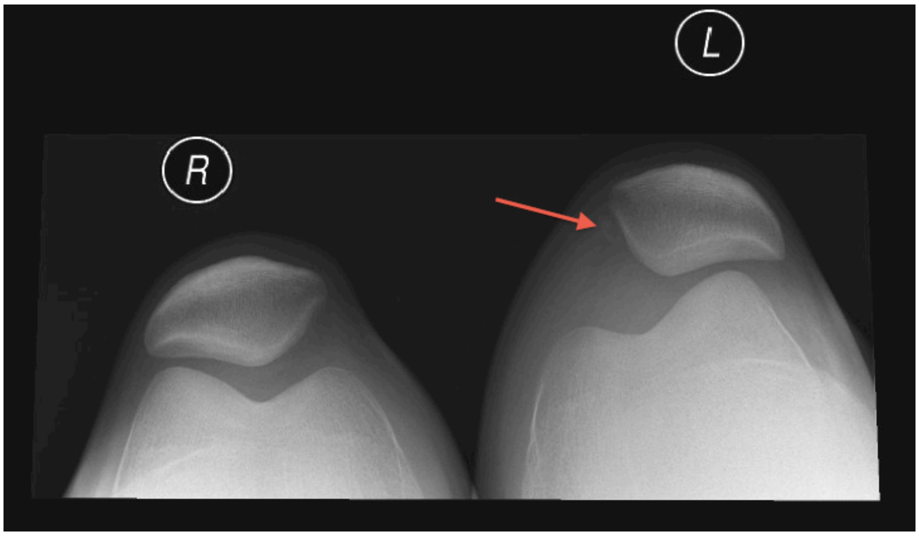


**Figure 7.** Axial radiograph showing static subluxation of the left patella in a 16 year old boy after an acute first-time dislocation. Note the small bony fleck adjacent to the medial patella facet, representing patellar avulsion of the MPFL.

The first report of anatomic MPFL reconstruction was described by Ellera Gomes in 1992 [65], and since then many variations on the procedure have been described. Variations in surgical techniques include different choices of surgical approach, graft material, and fixation method. Furthermore, there are options of associated procedures to be performed along with the MFPL reconstruction, such as the lateral retinacular release, VMO advancement, and tibial tubercle transfer. To the authors' knowledge, there have not been any comparative studies showing advantage of one technique or approach over the other.

The typical grafts used for MPFL reconstruction (most commonly the semitendinosus tendon) have biomechanical properties significantly superior to those of the native MPFL, with higher strength, stiffness, and load to failure. [17,66] The advantage of these superior biomechanical characteristics is the ability of the graft to withstand greater loads in cases of dysplasia and malalignment. Conversely, overtightening or malpositioning the graft can lead to maltracking and excessive medial compressive forces.

Multiple studies of MPFL reconstruction for acute and recurrent patella instability have shown excellent results, with low rates of recurrent instability, low complications rates, and good improvement in subjectively and objectively reported outcomes. [63,65,67-73] However, no consensus has been achieved with regard to the surgical approach, choice of graft, graft positioning, and fixation methods. [63,72] With this in mind, several important points of the surgical technique of MPFL reconstruction, with the relevant pearls and pitfalls, deserve mention.

### 7.4. MPFL reconstruction: Technical pearls and technical errors

A single or a double incision technique may be used, and the goal of both approaches should be to comfortably and safely access the femoral and patella insertion sites of the MPFL; visualization of the mid-substance of the ligament is less important. However, the layer where MPFL normally runs (2nd layer of the medial knee – same layer that contacts the superficial MCL and VMO aponeurosis) must be identified, so that the graft can be properly placed into this layer, and remain extraarticular.

Next, patella and femoral insertion sites of the MPFL are located and prepared for graft implantation. While patellar insertion site of the MPFL can be approximated to the proximal half of the medial facet, the femoral attachment site needs to be located more precisely, as isometry and function of this ligament are especially sensitive to its femoral insertion. Locating the femoral insertion site may be difficult with direct visualization, especially through a small incision, and intraoperative radiographic imaging (fluoroscopy) is typically used to localize this site via previously described landmarks. [74] Once both patella and femoral sites are indentified and prepared, the graft is secured to one of the sites (surgeon's choice), brought through the 2nd layer of the knee to the other site, tensioned, and secured. Multiple techniques for graft fixation on both the patella and femoral sides exist, including suture anchors, bone tunnels, interference screws, knotless anchors, and suspensory buttons. While no single technique has been shown to be superior to others in clinical studies, suture anchor fixation of the graft to the surface of the bone has been shown to be weaker than fixation of the graft within a tunnel. [43]

Technical errors of MPFL reconstruction typically result from improper graft position and/or graft tension. Recurrent instability can occur when the tension on the reconstructed ligament is inadequate. In biomechanical studies properly tensioned grafts have been shown to restore stability and normal tracking of the patellofemoral articulation without excessive contact pressures, while overtensioned grafts restricted motion and resulted in increased medial patellofemoral pressures. [75] Malpositioning the graft and making it too short may as much as double the graft tension in flexion [76], which is likely to lead to eventual development of patellofemoral arthrosis.

The authors' preferred technique for MPFL reconstruction is with a double-incision approach, using a semitendinosis autograft or allograft (based on patient preference). The medial facet

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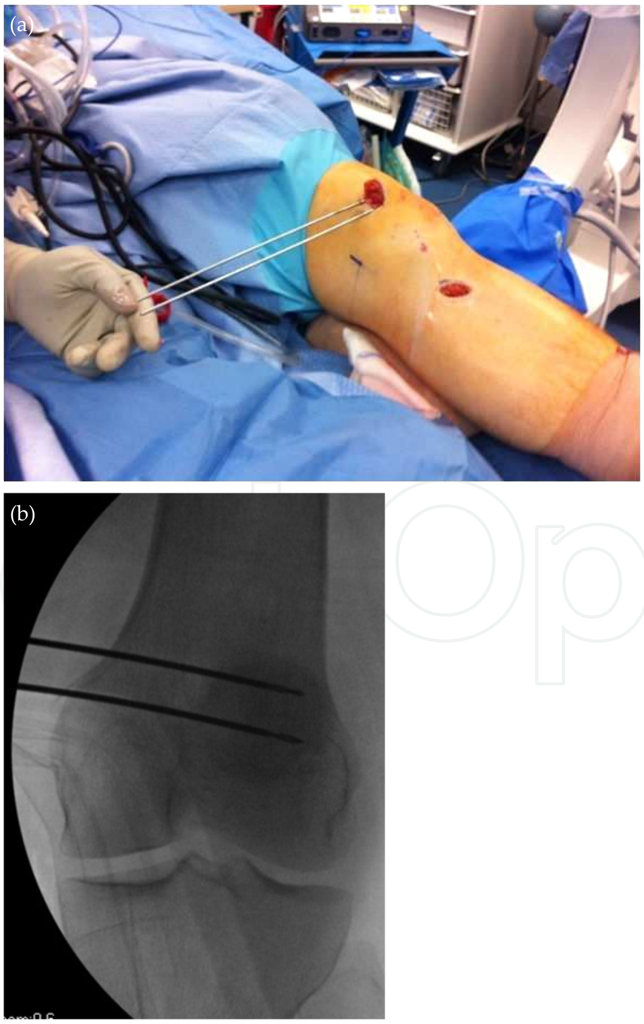
of the patella is exposed first and burred down to bleeding bone, to encourage healing. Two tunnels are created in the medial facet by reaming over guidewires (Figure 8A), the position of which can be checked with fluoroscopy (Figure 8B). The graft is loaded onto an adjustable suspensory fixation device and its free ends aresecured into the patellar tunnels with interference screws. (Figure 8C) The femoral insertion site is identified with fluoroscopy using a radiographic template (Figure 8D) and a guidewire is drilled into this area, exiting on the lateral side of the knee. Once this guidewire is in place, a suture is passed from the patellar insertion to the femoral guidewire, and the knee is then taken through the range of motion to assess isometry of the suture at the early angles of flexion, which predicts the isometry of the reconstructed ligament. A femoral tunnel is then reamed to but not through the lateral cortex (Figure 8E). The graft is now brought through the appropriate layer to the entrance of the femoral tunnel (Figure 8F); the button of the suspensory deviceis passed through the tunnel and flipped on the lateral femoral cortex, and the graft is then drawn into the tunnel (Figure 8G and 8H). The graft tension is then adjusted, and once appropriate tension is obtained, interference screw is used to back-up graft fixation at the medial aperture of the femoral tunnel. Additional procedures are performed as necessary.




(c)
(d)
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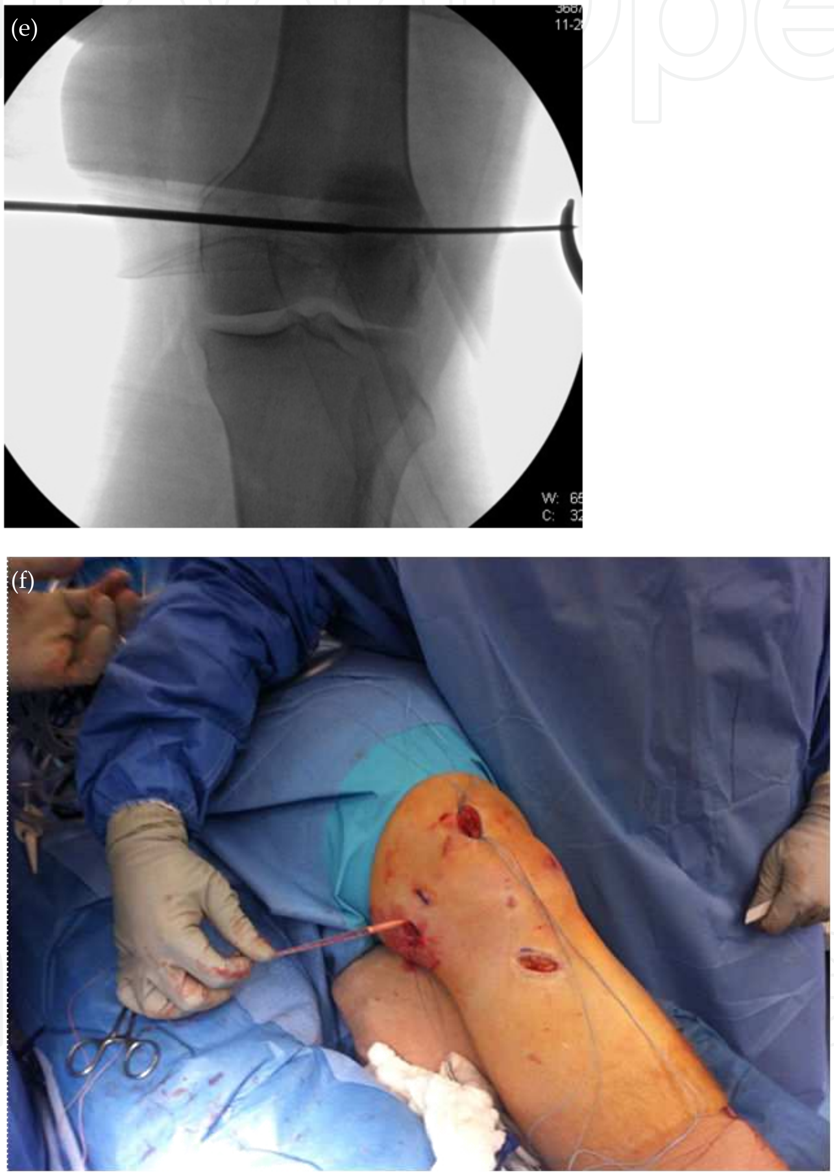

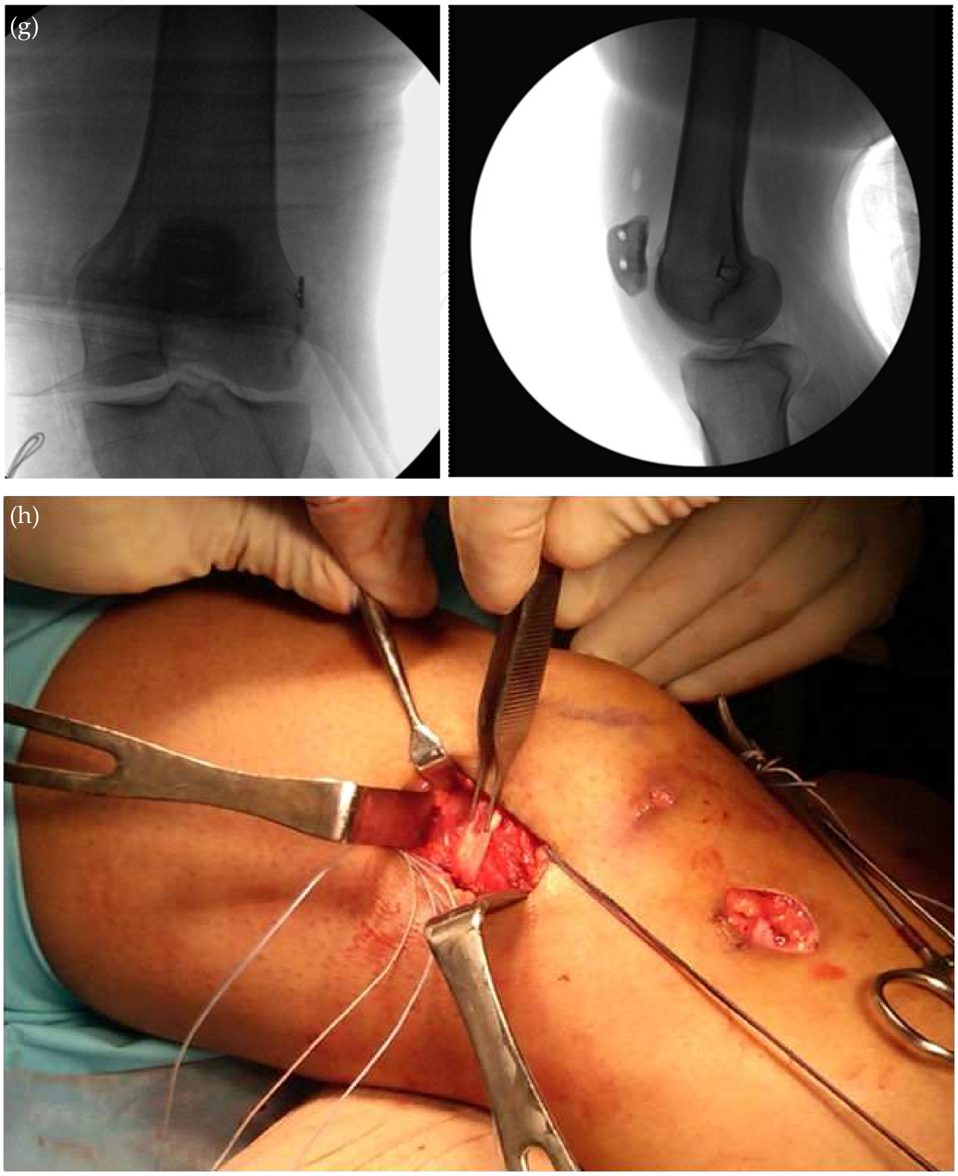


**Figure 8.** MPFL reconstruction with a double incision technique, using semitendinosus autograft, interference screws/knotless anchors on the patella side, and interference screw + cortical suspensory button-loop device on the femoral side. a) guidewires drilled into the medial facet of the patella; note the incision for semitendinosus harvest; b) position of the guidewires confirmed radiographically; c) semitendinosus graft secured to the patella; d) intraoperative lateral image showing a radiographic template overlying the distal femur, allowing placement of the guidewire in the appropriate position for a femoral tunnel; e) femoral tunnel is reamed under fluoroscopic visualization; f) graft is passed to the femoral tunnel; g) intraoperative radiographs (AP and lateral) of the final reconstruction, demonstrating patella tunnels and the suspensory button-loop fixation device on the lateral femoral cortex; h) intraoperative photograph of the final reconstruction (different case – single incision technique, with gracilis autograft)

### 7.5. Distal realignment – Tibial tubercle osteotomies

A number of osteotomies and transfers of the tibial tubercle have been described, aiming to realign, offload or do both to the patellofemoral joint. These can address such problems as patella alta and excessively high Q-angle.

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Hughston osteotomy transfers the tibial tubercle distally and medially. It improves the TT-TG distance and also inferiorizes the position of the patella, and is a useful surgical procedure for severe patella alta. However, there is a risk with this procedure of globally increased patello-femoral contact pressure.

In the absence of patella alta, the two osteotomies most commonly for patellofemoral instability are the Elmslie-Trillat osteotomy, otherwise known as Tibial Tubercle Medialization (TTM), and the Fulkerson osteotomy, otherwise known as tibial tubercle anteromedialization (AMZ). Elmslie Trillat is a single-plane osteotomy that translates the tibia tubercle straight medially, and has demonstrated relatively low rates of recurrent instability, good functional outcomes and return to activities, although patient satisfaction decreases over time. [77-79] The AMZ is an oblique-plane osteotomy, translating the tubercle anteriorly and medially, (Figure 9) allowing both improvement of the TT-TG distance and offloading of the lateral and distal patella facet and the lateral femoral trochlea, and is commonly used both for patellofemoral instability and lateral patellofemoral arthrosis. It does, however, increase the load on the medial trochlea and patella, and is contraindicated when there is preexisting arthritis in these areas. A number of studies evaluating outcomes of the AMZ have shown 74-95% good or excellent results, with better outcomes in males, patients with intact patellar cartilage, and in cases when osteotomy was done for instability (and not for painful maltracking/arthritis). [80-82]

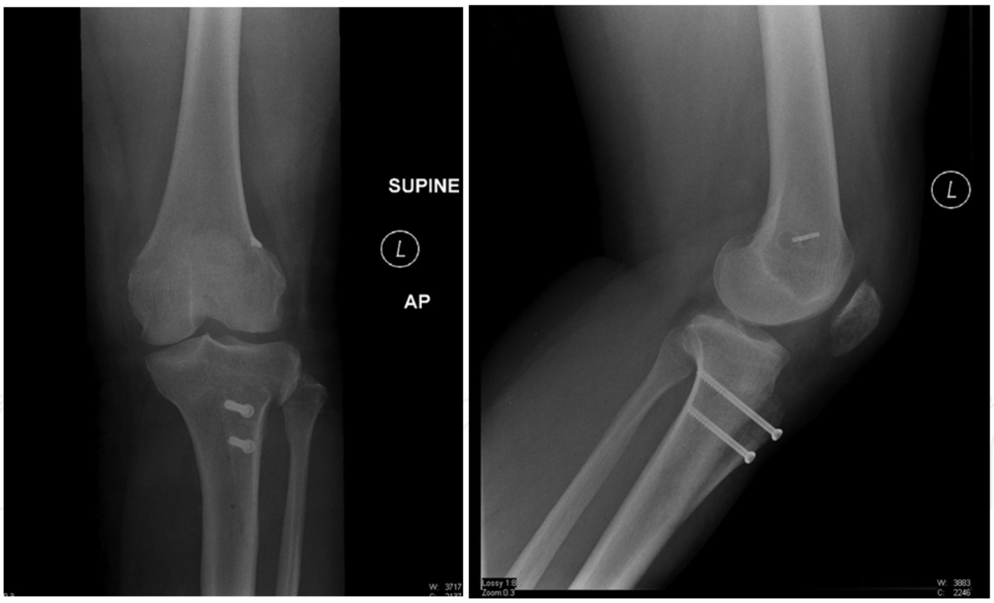


**Figure 9.** Postoperative radiographs after AMZ procedure (combined with MPFL reconstruction), in the same patient as in Figures 2 and 3 (AP and Lateral views).

### 7.6. Proximal Bony Realignment - Trochleaplasty

Femoral trochleaplasty is a relatively new procedure which seeks to address severe femoral trochlea dysplasia, such as with “dome-shaped” trochlea. The surgical technique involves removing a sulcus of cancellous bone from under the trochlear groove, and then impacting the cortical shell into this space. The procedure has been shown to improve stability of the patellofemoral joint, but does not prevent development of subsequent patellofemoral arthritis. [83]

### 7.7. Algorithm for Selecting Appropriate Treatment for a Patient with Patellofemoral Instability (Table 3)

Initial management of a first-time dislocator should include immobilization of the knee in extension and appropriate imaging, including plain radiographs (bilateral patellofemoral views for comparison) and an MRI. Patients without osteochondral injury, static subluxation, or predisposing factors can typically be treated nonoperatively, with a period of immobilization (2-4 weeks), followed by therapy to restore motion, strength, stability and proprioception. Consideration may be given to acute MPFL repair in cases of severe injury to the ligament, especially avulsions from bone. The authors prefer to perform such a repair with two suture anchors.

Patients with significant osteochondral injury typically require arthroscopic or open procedure to remove or repair the fragment, and consideration should be given to addressing the MPFL injury at the same time, with repair or reconstruction. Patients with significant predisposing factors such as dysplasia or malalignment are at particularly high risk for recurrent dislocation with non-operative treatment, and should be considered for MFPL reconstruction, even after a first-time dislocation. The goal of this seemingly aggressive approach is to prevent recurrent instability that may result in additional osteochondral injury, and thus predispose to patellofemoral arthrosis.

Recurrent dislocators who wish to remain active and athletic, as well as patients who experience instability with daily activities, typically require MPFL reconstruction, although arthroscopic or open plication of the MPFL and medial retinaculum can be done for patients with mild instability (subluxation, rather than dislocation) and no significant dysplasia or malalignment. In patients with recurrent instability and lower extremity malalignment consideration should be given to tibial tubercle transfer. Selection of appropriate osteotomy is as follows: Hughston osteotomy (distal and medial) for patella alta, Elmslie-Trillat (medial) for recurrent instability with increased TT-TG distance but normal patellar height, and Fulkerson/AMZ (anterior and medial) for recurrent instability and lateral patellofemoral arthrosis or compression. Patients with severe trochlear dysplasia, such as a “dome-shaped trochlea” should be considered for trochleaplasty.

## 8. Post-operative rehabilitation after patellofemoral stabilization

Immediate postoperative care is focused on multimodal pain management program, swelling control, and protecting the repair, reconstruction or osteotomy.Physical therapy protocols vary depending on the degree of preoperative instability, the type of surgery performed (bony versus soft-tissue, repair versus reconstruction, etc.), and patient-specific factors.

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| Presenting event | Associated factors | Recommended treatment |
|---|---|---|
| First-time dislocation | No dysplasia<br>No malalignment<br>No intraarticular fragments<br>No static subluxation of the patella | Non-operative (initial immobilization, followed by rehabilitation therapy) |
| First-time dislocation | Intraaticular fragments | Arthroscopy or open procedure for fragment removal or repair |
| First-time dislocation | MPFL avulsion from bone (femur or patella) AND static subluxation of the patella (compared to contralateral side) | Acute MFPL repair (with suture anchors) |
| First-time dislocation | Patellofemoral dysplasia and/or malalignment | MFPL reconstruction +/- tibial tubercle osteotomy (TTO) |
| Recurrent dislocation | No significant dysplasia or malalignment | MPFL reconstruction |
| Recurrent dislocation | Significant malalignment (high Q-angle, TT-TG distance > 20mm) | MPFL reconstruction with TTO |
| Recurrent dislocation | Severe trochlear dysplasia | MPFL reconstruction with trochleaplasty |
| Recurrent subluxation | No dysplasia or malalignment, intact MPFL | Consider arthroscopic or open imbrication of the MFPL and medial retinaculum |

**Table 3.** Algorithm for selecting appropriate treatment for a patient with patella instability

For soft-tissue procedures, the knee is initially immobilized in extension, and weight-bearing with the brace locked in extension is typically allowed. The brace is continued for 6-8 weeks or until quadriceps control is regained. Typically, after MPFL reconstruction, especially with secure graft fixation in bone tunnels, limited passive range of motion of the knee can be initiated immediately after surgery. In cases of MPFL avulsion repairs with suture anchors the authors prefer to immobilize the knee for 3-4 weeks prior to initiating any range of motion, to allow some healing of the repair.

The majority of bony procedures performed for patellofemoral instability are tibial tubercle osteotomies, and the goal of early rehabilitation after this type of surgery is to prevent excessive traction on the patella tendon. Therefore, an extension brace is worn, weight-bearing is typically protected for 4-6 weeks, while passive range of motion may be allowed to a limited degree, as long as fixation of the osteotomy is secure. Active knee extension is typically restricted for at least 6 weeks, or until the osteotomy is healed.

The postoperative physical therapy protocol after patellofemoral stabilization is typically divided into 3 phases. (Table 4) Phase I (0-6 weeks) focuses on controlling the inflammatory process, protecting the bony or soft tissue fixation, and regaining quadriceps and VMO control, typically with isometric strengthening. Phase II (6-12 weeks) involves exercises to regain full range of motion, patella mobilization and continued VMO strengthening to stabilize patellar tracking, and return to a normal gait pattern. Phase III (after 12 weeks) progresses with strengthening and endurance exercises to regain full quadriceps strength and proprioception. Return to sporting activity is allowed only when the patient has no pain, no sensation of instability, regains full range of motion, andhas normal or near normal quadriceps strength. For tibial tubercle transfers healing of the osteotomy on radiographs should be confirmed prior to allowing sports participation. Return to full athletic activity typically takes 4-6 months after surgery.

| | |
|---|---|
| Phase I (0-6 weeks) | Decrease inflammation<br>Protect surgical fixation<br>Regain quadriceps/VMO control (isometric strengthening) |
| Phase II (6-12 weeks) | Regain full range of motion<br>Mobilize the patella<br>Continue quadriceps/VMO strengthening<br>Normalize gait |
| Phase III (>12 weeks) | Achieve full strength<br>Build up endurance<br>Regain proprioception |
| Phase IV - Return to sports | No pain<br>No sensation of instability<br>Full range of motion<br>Normal or near normal quadriceps strength<br>Radiographic healing of osteotomy (if done) |

**Table 4.** Postoperative Rehabilitation Protocol After Patellofemoral Stabilization Surgery

## 9. Conclusion

Patellofemoral instability typically affects the young and athletic patient population. Initial trial of non-operative treatment is warranted for patients after a first-time dislocation, and without intraarticular osteochondral fragments, severe injury to the medial stabilizers, significant malalignment or patellofemoral dysplasia. When surgical treatment is contemplated, the focus should be on restoring integrity of the MFPL and optimizing the alignment of the lower extremity and specifically of the patellofemoral articulation. MPFL reconstruction has produced the best results in patients with mild or no dysplasia and malalignment, while tibial tubercle osteotomies are indicated in patients with abnormally high Q-angle and increased TT-TG distance.

The natural history of acute patellofemoral instability is that of a relatively high rate of recurrence as well as long-term functional limitations and inability to return to baseline level of activity, and thus surgery often plays a role in management of these patients. Prospective randomized trials comparing different surgical techniques are needed to determine which treatment options provide optimal restoration of function, minimize recurrence, and decrease the risk of arthritic degeneration.

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