

Patellofemoral instability

Anatomy & Pathophysiology

STATIC RESTRAINTS

- The medial patellofemoral ligament (MPFL) is a fan-shaped ligament extending from the medial femur to the proximal patella and serves as the primary static restraint to lateral patellar translation within the first 30° of knee flexion [16].
- The femoral origin of the MPFL is described as 9.5 mm distal and 9.5 mm anterior to the adductor tubercle [16].
- Radiographically, the femoral origin of the MPFL correlates with a point 1 mm anterior to a line extending along the posterior cortex, 2.5 mm distal to the posterior origin of the medial femoral condyle, and proximal to the posterior aspect of the Blumensaat line [16].
- At its patellar insertion, the MPFL merges with the attachment of the vastus medialis obliquus (VMO) and extends to the medial border of the patella and vastus intermedius tendon [16].
- The average width of the MPFL at its insertion is 30 mm, with 57% of fibers attaching to the patella and the remainder to the quadriceps tendon [16].
- The average ultimate strength of the MPFL has been measured at 178 N [16].
- Recent cadaver studies have identified additional fibers extending to the quadriceps tendon, leading to nomenclature such as the medial quadriceps tendon femoral ligament or medial patellofemoral complex [16].
- The distal soft-tissue restraints originate on the distal inferomedial patella and comprise the medial patellotibial ligament and medial patellomeniscal ligament (MPML) [16].
- The medial patellotibial ligament and medial patellomeniscal ligament restrict lateral patellar translation, tilt, and rotation at 90° knee flexion [16].
- In 22 cadaver knees, the MPFL and medial patellotibial ligament had comparable ultimate loads and stiffness, whereas the medial patellomeniscal ligament had lower failure loads and stiffness [19].
- Midsubstance failure was the most common type of failure reported in biomechanical testing of medial patellar stabilizers [19].

OSTEOCHONDRAL CONSTRAINTS

- At flexion angles greater than 30°, the osteochondral constraint of the trochlea provides primary stability to the patellofemoral joint [16].
- The mean depth of the trochlea in patients with normal anatomy is 4.0 mm, differing significantly by sex (3.4 mm in women and 4.2 mm in men) [16].
- The medial facet contributes to 37.4% of the width of the cartilage covering the trochlea, while the lateral facet contributes to 62.6% [16].
- Decreased trochlear depth reduces the effectiveness of the osteochondral restraint of the patella and contributes to patellar instability [16].
- Cadaver models simulating decreased trochlear depth showed increased lateral patellar tracking due to reduced trochlear constraint [16].
- Simulated trochlear dysplasia results in increased internal rotation, lateral tilt, and lateral translation, as well as increased contact pressures and decreased contact areas compared with controls [19].

DYNAMIC RESTRAINTS

- The vastus medialis obliquus (VMO) provides a dynamic restraint to lateral patellar translation [16].
- Increasing the force applied by the VMO decreases maximum lateral patellofemoral contact pressure and lateral patellar shift at multiple flexion angles [16].
- Administering a motor branch block to the VMO increases lateral patellar shift during knee extension [16].
- A significant delay in activation of the VMO with respect to the vastus lateralis is found in individuals who later experience patellofemoral pain [16].
- Measurements of lateral patellar translation and tilt correlate with a delay in the activation of the VMO in patients with pain [16].
- An increase in the activation ratio of the vastus lateralis to the vastus medialis is associated with increased lateral patellar tilt [16].
- Finite element analysis shows that patellofemoral cartilage stresses are sensitive to variations in vastus medialis forces [6].

ALIGNMENT AND KINEMATICS

- Abnormalities in lower extremity alignment influence the kinematics of the patellofemoral joint [16].
- Femoral anteversion and genu valgum measurements are greater in knees with patellar instability than in healthy control knees [16].
- Increased lateralization of the tibial tuberosity relative to the trochlear groove is a common type of lower extremity malalignment associated with patellar instability [16].
- Radiographic measurements of malalignment are significantly correlated with increased lateral shift and tilt of the patella in patients with patellar instability [16].
- Patella alta influences patellofemoral kinematics by increasing the extent of knee flexion before the patella can engage within the trochlear groove [16].

- Radiographic measurements of patellar height are significantly greater in patients with patellar instability [16].
- Patella alta is associated with abnormal patellar tracking, demonstrated by greater lateral shift and tilt of the patella in subjects with an increased patellar height index [16].
- Patella alta can be associated with patellar instability because the patella may not articulate with the sulcus until higher degrees of knee flexion are reached, resulting in reduced contact and stability in knee extension and early flexion [13].
- The Q angle is the angle between the extended anatomic axis of the femur and the line between the center of the patella and the tibial tubercle [20].
- Limbs with larger Q angles have a greater tendency for lateral patellar subluxation [20].
- The vastus medialis obliquus acts to medialize the patella in terminal extension [20].
- The inferior articular surface of the patella first contacts the trochlea in approximately 20 degrees of knee flexion [20].
- The midportion of the patella articulates with the trochlea in approximately 60 degrees of flexion [20].
- The superior portion of the patella articulates with the trochlea at 90 degrees of flexion [20].
- In extreme flexion beyond 120 degrees, the patella articulates only medially and laterally with the femoral condyles, and the quadriceps tendon articulates with the trochlea [20].

PATHOPHYSIOLOGY OF INSTABILITY

- Multiple factors contribute to the stability of the patellofemoral joint, including static restraints, dynamic restraints, osteochondral constraints, and lower extremity alignment [1].
- The etiology of patellar instability is multifactorial [1].
- In 15–20% of cases, mostly in children, the first episode of patellar dislocation is followed by recurrent dislocation or subluxation after minimal stress [2].
- Recurrent dislocation is due in some measure to disruption or stretching of medially based ligamentous structures, such as the medial patellofemoral ligament [2].
- In a significant proportion of cases, there is no history of an acute strain, and the initial episode is thought to have occurred spontaneously [2].
- Predisposing factors for patellar dislocation include generalized ligamentous laxity, underdevelopment of the lateral femoral condyle, flattening of the intercondylar groove, maldevelopment of the patella, valgus deformity of the knee, external tibial torsion, and primary muscle defects [2].
- Repeated dislocation damages the contiguous articular surfaces of the patella and femoral condyle, which may result in further flattening of the condyle and facilitate further dislocations [2].
- Patellar dislocation is almost always towards the lateral side; medial dislocation is seen only in rare iatrogenic cases following overzealous lateral release or medial transposition of the patellar tendon [2].
- More than 90% of patellar instability events occur with lateral patellar translation [4].
- Common injuries occurring during a patellar instability event include torn medial patellofemoral ligament and/or medial retinaculum, avulsion fracture of the medial patella at the insertion of the MPFL,

osteochondral injuries resulting in intra-articular loose bodies, and bone bruising of the patella and lateral femoral condyle [4].

- Risk factors for patellar instability include valgus alignment, increased quadriceps angle, excessive femoral anteversion, excessive external tibial torsion, trochlear dysplasia, patella alta, previous patellar dislocation, skeletal immaturity, and disorders affecting ligamentous laxity such as Ehlers-Danlos or Down syndrome [4].
- Patellofemoral subluxation or dislocation can result from a direct blow forcing the patella out of place or from noncontact mechanisms [4].
- The patella is a sesamoid bone with an extraosseous blood supply consisting of an anastomotic ring that encircles the patella and receives blood from all the geniculates [9].
- The intraosseous blood supply of the patella is damaged during resurfacing, theoretically leaving only the superior lateral genicular artery after surgery [9].
- Experimental data suggest a 25% to 60% reduction in extension power following patellar resection [9].
- A substantial increase in tibiofemoral joint reaction forces may occur following patellectomy, which may explain the high incidence of arthrosis in the medial and lateral compartments [9].

Clinical Presentation

HISTORY AND SYMPTOMS

- Patellofemoral disorders present as pain or instability [1].
- The clinician should differentiate between patellofemoral pain and instability based on the patient's history and physical examination [1].
- In 15–20% of cases, mostly in children, the first episode of dislocation is followed by recurrent dislocation or subluxation after minimal stress [2].
- The main complaint of recurrent patellar dislocation is that the knee suddenly gives way and the patient falls [2].
- The giving way may be accompanied by pain and sometimes the knee gets stuck in flexion [2].
- A clear description of symptoms helps distinguish patellar subluxation from knee buckling caused by pain or weakness [6].
- The mechanism of injury, chronicity, number of episodes, and type of episodes (dislocation versus subluxation) are important elements of the patient's history [6].
- With frank dislocation, the patella may spontaneously reduce or may require positioning with the leg in hip flexion and knee extension for reduction [4].

PHYSICAL EXAMINATION

- Girls are affected more commonly than boys and the condition is often bilateral [2].

- Although the patella always dislocates laterally, the patient may think it has displaced medially because the uncovered medial femoral condyle stands out prominently [2].
- If the knee is seen while the patella is dislocated, the diagnosis is obvious [2].
- There is usually tenderness on the medial side of the joint [2].
- Later, the joint becomes swollen, and aspiration may reveal a blood-stained effusion [2].
- Between attacks, clinical signs are sparse [2].
- The apprehension test is positive in patients with recurrent patellar dislocation [2].
- Point tenderness is maximal at the site of the retinacular or ligament tear along its course from the medial epicondyle to the medial patella [4].
- An effusion may be subtle or large [4].
- The apprehension test is typically positive in patellofemoral instability [4].
- General ligamentous laxity can be identified using criteria such as the Beighton hypermobility score [6].
- Assessment of alignment includes evaluating Q angle, genu valgus, and lateralization of the tibial tuberosity in a standing position [6].
- Excessive femoral anteversion can be detected in hip range of motion and is associated with squinting patellae when the patient stands in a neutral position [6].
- Patellar mobility is assessed using the glide test, with translation quantified based on patellar quadrants (25% of the width of the patella) [6].
- A positive apprehension test and J sign in the setting of increased lateral glide can represent a loss of patellar stability [6].
- A J-sign pattern with more than two quadrants of lateral translation has been correlated with patellar instability [6].
- Evaluation of axial and rotational alignment is performed during physical examination [4].
- The quadriceps angle is assessed during physical examination [4].
- A J-sign may be appreciated during physical examination [4].

IMAGING

- X-rays may reveal loose bodies in the knee from new or old osteochondral fractures [2].
- A lateral view with the knee in slight flexion may show a high-riding patella [2].
- Tangential views can be used to measure the sulcus angle and the congruence angle [2].
- MRI may show signs of previous patellofemoral soft-tissue disruption on the medial side of the knee or trochlear dysplasia [2].
- Plain radiographs may appear normal or may show an osteochondral loose body [4].
- Trochlear morphology and patellar height and tilt are evaluated on lateral and sunrise views [4].
- Ordering an MRI after a dislocation is advised if a tense knee effusion is present without radiographic signs of an osteochondral injury, as this effusion may signify a chondral loose body [4].

- Evaluation of tibial tubercle to trochlear groove (TTTG) distance is performed [4].
- Evaluation of skeletal maturity is performed if surgical intervention is planned [4].

Investigations

HISTORY AND PHYSICAL EXAMINATION

- The main objective of evaluating patellofemoral dysfunction is to identify contributing factors and differentiate between pain and instability [6].
- The mechanism of injury, chronicity, number of episodes, and type of episodes (dislocation versus subluxation) are important historical elements [6].
- Knowledge of earlier treatments and surgical procedures aids in determining treatment options [6].
- General ligamentous laxity is associated with an increased risk of patellar instability and can be identified using criteria such as the Beighton hypermobility score [6].
- Alignment assessment begins with the patient in a standing position to assess Q angle, genu valgus, and lateralization of the tibial tuberosity [6].
- Rotational malalignment due to excessive femoral anteversion can be detected in hip range of motion and is often associated with squinting patellae in a neutral standing position [6].
- Dynamic assessment includes evaluation of quadriceps strength, as patellofemoral cartilage stresses are sensitive to variations in vastus medialis forces [6].
- Deficits in hip strength, particularly in hip abduction and extension, have been identified in patients with patellofemoral pain compared with asymptomatic controls [6].
- The apprehension sign is elicited using a manually directed lateral force on the patella [6].
- Findings from the physical examination should be correlated with the patient's description of symptoms to determine whether the patellofemoral joint is functionally unstable [6].
- The main complaint in recurrent dislocation is that the knee suddenly gives way and the patient falls, which may be accompanied by pain and sometimes the knee getting stuck in flexion [2].
- Although the patella always dislocates laterally, patients may think it has displaced medially because the uncovered medial femoral condyle stands out prominently [2].
- There is usually tenderness on the medial side of the joint in cases of patellofemoral instability [2].
- Between attacks, clinical signs are sparse, but the apprehension test is positive [2].
- The patient should be carefully examined for features known to predispose to patellar instability [2].
- An effusion may be subtle or large in the setting of patellofemoral instability [4].
- Evaluation of axial and rotational alignment is performed during the physical examination [4].
- The quadriceps angle is assessed during the physical examination [4].
- A J-sign may be appreciated during the physical examination [4].

IMAGING

- MRI is helpful and may show signs of previous patellofemoral soft-tissue disruption on the medial side of the knee or trochlear dysplasia [2].
- Ordering an MRI after a dislocation is controversial but is advised if a tense knee effusion is present without radiographic signs of an osteochondral injury, as this effusion may signify a chondral loose body [4].
- Evaluation of tibial tubercle to trochlear groove (TTTG) distance is part of the imaging workup [4].
- Patella alta and patella baja are determined from various measurements made on lateral radiographs of the knee [13].

Treatment

NONSURGICAL

- Initial management of patellofemoral instability includes immobilization for comfort, rest, ice, compression, and elevation [4].
- Physical therapy is initiated to strengthen the injured extremity and address core and hip weakness [4].
- A patellar stabilizing brace can be used initially for activities of daily living and after the athlete is ready to return to play [4].
- Surgery may be indicated in patients with recurrent instability after unsuccessful nonsurgical treatment [1].

SURGICAL INDICATIONS

- Surgical indications for patellofemoral instability include osteochondral injury with loose body, recurrent instability, and failure of nonsurgical treatment with persistent pain or instability [4].
- Procedures that would compromise an open physis, such as tibial tubercle osteotomy or MPFL graft transphyseal tunnel, are contraindications in skeletally immature patients [4].

SOFT TISSUE PROCEDURES

- MPFL reconstruction is currently the most popular technique for stabilizing the unstable patella [26].
- Repair of the MPFL has traditionally been considered a good option after an acute first-time dislocation if the location of the tear can be identified, although recent research has cast doubt on this approach [26].
- Results of isolated MPFL repair for recurrent instability are inferior to those of MPFL reconstruction, with 8 of 29 knees (28%) having a later recurrence [26].
- MPFL reconstruction alone may not be enough to stabilize the patellofemoral joint in a patient with substantial malalignment [26].
- The tension of the MPFL reconstruction construct is set with the patella centered in the trochlea with the knee in 30° of flexion [4].

- The location of the graft attachment sites on the patella and femur should be checked to produce an isometric graft with the knee in 0° to 60° of flexion [4].
- The femoral attachment for MPFL reconstruction can be within 1 to 3 mm from the epiphyseal plate [4].
- In younger patients, the femoral attachment site is generally just distal to the physis, but in older adolescents, it can be at or proximal to the physis [4].
- Femoral drill tunnels should be aimed away from the physis, which may mean aiming distal and posterior if starting below the physis [4].
- The patella should have one to two quadrants of medial and lateral translation following repair, similar to the native patella, to avoid overconstraining [4].
- Flexion past 90° will be difficult after overtensioning of the repair or reconstruction [4].
- Excessive lateral release can result in iatrogenic medial instability or dislocation [4].
- Medial retinacular or MPFL repair is a surgical procedure option for patellofemoral instability [4].
- Medial plication of VMO fascia is a surgical procedure option for patellofemoral instability [4].
- Lateral release is a surgical procedure option for patellofemoral instability [4].

BONY PROCEDURES

- Tibial tubercle osteotomy is indicated in skeletally mature patients for increased TTTG distance [4].
- Tibial tubercle osteotomy should be avoided in skeletally immature patients to prevent angular deformity [4].
- Quadriceps/femoral nerve stimulation intraoperatively may be helpful to fine-tune the amount of medialization during tibial tubercle osteotomy [4].
- Rotational osteotomy of the femur and/or tibia is a surgical procedure option for patellofemoral instability [4].
- Guided growth with hemiepiphysiodesis is a surgical procedure option for patellofemoral instability [4].
- Removal or fixation of an osteochondral fragment is a surgical procedure option for patellofemoral instability [4].

OUTCOMES AND COMPLICATIONS

- Studies of MPFL reconstruction reported success rates of 80% to 96%, with few occurrences of recurrent instability [26].
- The largest study to date included 240 consecutive MPFL reconstructions at a single clinic, with the mean Kujala score improving from 62.5 to 80.4 at a minimum 1-year follow-up [26].
- A concomitant tibial tubercle osteotomy was performed in 23% of patients in the largest study of MPFL reconstructions [26].
- Some authors have reported better outcome scores when MPFL reconstruction is combined with tibial tubercle osteotomy in patients with a TTTG distance of 17 to 20 mm, patella alta, and preoperative J sign [26].

- The most common complications of MPFL reconstruction are recurrent instability, loss of motion, painful hardware, and patellar fracture [26].
- The largest study to date reported a 4.6% rate of recurrent dislocation after MPFL reconstruction [26].
- In the largest study to date, 14% of patients had a positive apprehension sign and 12% had a flexion deficit of 10° or more after MPFL reconstruction [26].
- A meta-analysis of 25 studies reporting on a total of 629 knees found that a complication occurred in 164 knees (26.1%) after MPFL reconstruction [26].
- The most common complications in the meta-analysis of 629 knees were recurrent apprehension (52/164 knees), loss of knee flexion (22), painful hardware (19), and patellar fracture (4) [26].
- Patellar fracture from violation of the anterior patellar cortex or large-diameter transverse patellar tunnels has led to the development of numerous alternative graft fixation techniques [26].
- Malpositioning of the femoral tunnel and securing of the graft with excessive tension are associated with medial patellofemoral articular overload, iatrogenic medial subluxation, and recurrent lateral instability [26].
- In a study of MPFL reconstructions, 10 of the 29 femoral tunnels were found to be malpositioned [26].
- Femoral tunnel malpositioning of greater than 10 mm was associated with postoperative complications but did not necessarily lead to an unsatisfactory outcome [26].
- Intraoperative fluoroscopy is useful for achieving optimal tunnel positioning in MPFL reconstruction [26].
- Confirmation of normal patellar translation and full knee range of motion is recommended before final graft fixation to prevent overtensioning of the graft [26].
- Complications of patellofemoral instability surgery include arthrofibrosis, recurrent dislocations, premature growth arrest, overcorrection of axial or rotational alignment, and iatrogenic medial dislocation [4].

REHABILITATION

- Immediate weight bearing locked in extension is allowed after patellofemoral instability surgery [4].
- Range of motion should be restricted to 0° to 90° for 4 to 6 weeks postoperatively [4].
- Early physical therapy is important for quadriceps activation and range of motion [4].
- Return to sports or activities may occur when strength and neuromuscular control has returned, generally around 6 months postoperatively [4].
- A patellar stabilizing brace may be used for return to play [4].

Complications

GENERAL AND INSTABILITY-SPECIFIC

- The complications of patellofemoral instability surgery often can be avoided by using appropriate surgical techniques [1].

- Complications following surgery for patellofemoral instability include recurrent instability, stiffness, patellar fracture, patellofemoral arthrosis, and persistent pain [28].
- A 2013 study reported a 16.2% complication rate for MPFL reconstruction in patients younger than 21 years [28].
- Forty-seven percent of complications in MPFL reconstruction patients younger than 21 years were secondary to technical factors and considered preventable [28].
- Female sex and bilateral MPFL reconstruction were risk factors associated with postoperative complications in MPFL reconstruction [28].
- Subjective outcomes and recurrence rates were worse in patients with trochlear dysplasia or an increased TT-TG distance in which isolated MPFL reconstruction was performed [28].
- Recurrence rates can be higher in MPFL repair (26.9%) or medial retinacular repair/plication (16.5%) compared with MPFL reconstruction (6.6%) [28].

PATELLOFEMORAL ARTHROPLASTY COMPLICATIONS

- Patellofemoral complications include patellofemoral instability, patellar fracture, patellar component failure, patellar component loosening, patellar clunk syndrome, and extensor mechanism rupture [10].
- First-generation patellofemoral arthroplasty designs failed because of narrow trochlear grooves and high constraint, which often produced maltracking, patellar catching, or persistent anterior knee pain [7].
- The most common reason for failure of second-generation patellofemoral arthroplasty implants is progression of tibiofemoral arthritis [7].
- Patellofemoral instability after arthroplasty can be caused by extensor mechanism imbalance in which the lateral retinaculum is too tight or the medial soft tissues are too loose [10].
- Medial retinacular laxity may occur with postoperative rupture of the medial capsular repair, which can be caused by a closure that is too tight or by a traumatic event in the early postoperative period [10].
- Suboptimally positioned patellar, femoral, or tibial components may lead to patellofemoral instability [10].
- Excessive lateral patellar facet resection is possible because of the normal asymmetry of the medial and lateral patellar facets [10].
- Lateral placement of the patellar component on the cut surface of the patella fails to reproduce the normal median eminence of the patella and can lead to lateral subluxation of the patella in extension [10].
- Suboptimal position of the tibial component in an internally rotated position increases the Q angle by moving the tibial tubercle laterally, leading to lateral subluxation [10].
- Internal rotation and medial translation of the femoral component move the trochlea more medial relative to the extensor mechanism, leading to lateral subluxation [10].
- Patellar fracture after TKA is uncommon, occurring in less than 1% of patients [10].
- Patellar fracture has been correlated with excessive patellar resection, vascular compromise secondary to lateral release, patellar maltracking secondary to component malposition, excessive joint line elevation, knee flexion of more than 115 degrees, trauma, thermal necrosis from PMMA polymerization, and revision TKA [10].

- In a series of 1146 TKAs, a statistically significant association was found between lateral release and patellar fracture [10].
- Patellar thickness and sacrifice of the superior lateral geniculate artery were not associated with patellar fracture [10].
- Nonunion and hardware failure are frequent after internal fixation of patellar fractures after TKA [10].
- Periprosthetic patellar fractures associated with an intact extensor mechanism and stable implant (type I) should be treated nonoperatively with a knee immobilizer or cylinder cast for 6 weeks [10].
- Displaced periprosthetic patellar fractures with extensor mechanism discontinuity (type II) should be treated operatively [10].
- Loose patellar components (type III) should be excised and not replaced because this may impair fracture healing [10].
- Stable patellar components that impair fracture fixation also should be removed [10].
- Proximal or distal pole periprosthetic patellar fractures should be treated with partial patellectomy and suture repair [10].
- Patelctomy and extensor mechanism repair are indicated when extreme comminution or poor bone stock preclude stable bony fixation [10].

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