

Review Article

Patellofemoral Joint Instability: A Review of Current Concepts

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Received 10 March 2016; Accepted 13 May 2016

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Abstract The patellofemoral joint remains the enigma of orthopedics and sports medicine. Patellar dislocation is a common problem in the younger and athletic population and it is more disabling than cruciate ligament injuries. The pathology is often multifactorial and complex with no one factor being the sole defining etiology. The current management of patella dislocation has been linked with poor patient satisfaction possibly due to a prolonged period of conservative treatment and the general tendency to delay surgical intervention. This review will address the main abnormal anatomical factors contributing to patellar instability, their clinical and radiological diagnoses, and the role of various surgical interventions, including the medial patellofemoral ligament reconstruction in stabilizing the patella.

Keywords patellofemoral joint instability; medial patellofemoral ligament reconstruction; trochlear dysplasia; tibial tuberosity transfer; trochleoplasty

1. Introduction

Patellofemoral joint instability (PFJI) covers a broad spectrum of abnormalities ranging from frank acute patellar dislocations to subtle maltracking. The incidence of acute lateral patella dislocations is 2–3% of all knee injuries [1]. Acute patellar dislocation could be the tip of the iceberg and the beginning of multiple subsequent recurrent patellar dislocations. It is evident that there is a 17–49% risk of redislocation following first-time acute patellar dislocation [2]. It is particularly higher in patients below 20 years of age [3]. The risk increases to 44–71% following a second-time dislocation [1] (Figure 1).

Acute dislocation has been associated with osteochondral lesions in 49% of PFJI patients, and with medial patellofemoral ligament (MPFL) disruption in over 90–100% of patients [4,5,6,7]. There is high patient dissatisfaction after conservative treatment, nearly two-thirds (58%) reporting limitations in strenuous activities even six months after treatment [8] and 55% of these patients fail to return to sporting activities. Chronic PFJI and recurrent dislocation may eventually lead to progressive cartilage damage and severe osteoarthritis (OA) if not treated adequately. The risk



Figure 1: Clinical photograph of a patient with recurrent patella instability.

of OA is 35% after conservative treatment [9]. Therefore, it is crucial to adopt a new strategy in dealing with this relatively common condition that mainly affects younger and athletic populations. Our understanding of PFJ biomechanics and pathogenesis has evolved over the last two decades, which would hopefully translate to better patient outcomes. This review article will address some of the challenges that are faced in quantifying PFJI and the surgical and nonsurgical options that are currently available to us.

2. Patellofemoral instability anatomy and abnormal anatomic factors

Stability of the patellofemoral joint is derived from a combination of local, distant, static, and dynamic factors. Locally, static stability is provided by bone/cartilage geometry and ligaments, while dynamic stability is primarily maintained by the extensor muscles including vastus medialis obliquus (VMO) [10, 11].

The most common distant static factors are femoral anteversion (normal 5–15 °C), knee rotation (normally 3 °C), and external tibial torsion (25–30 °C), whilst the main distant dynamic factors are the iliotibial band complex, hip abductors/external rotators, and foot malrotation, such as excessive subtalar joint pronation, which generates a dynamic valgus force vector that displaces the patella laterally [12, 13, 14, 15].

The bony structures of the patella and trochlea account for most of the patellofemoral joint stability in deeper knee flexion. The medial retinaculum consists of three distinct layers (L1: investing fascia; L2: MPFL and superficial MCL; and L3: deep MCL and joint capsule). The MPFL is regarded as the primary passive stabilizer of the patella in early knee flexion (20–30 °C) [16]. It guides the patella into the trochlear groove and provides anywhere between 50% and 80% of the stability required to prevent lateral patella displacement [10, 16, 17, 18] (Figure 2).

The MPFL has femoral and patella attachments. It is well accepted that the MPFL becomes conjoined with the deep portion of VMO before inserting into the upper two thirds of the medial patella. However, there has been a lot of controversy regarding the femoral attachment [19]. A previous anatomical study by Amis et al. in 2003 [20] concluded that the MPFL originated from the origin of the medial epicondyle of the femur. Desio et al. found that the femoral origin of the MPFL is 8.8 mm anterior to the line continuous with the posterior cortex of the femur and 2.6 mm proximal to a perpendicular line at the level of the proximal aspect of the Blumensaat line [16].

Schöttle [21], in his cadaver study, defined a radiographic point representing the MPFL femoral attachment. This was described on a lateral radiograph, with both posterior condyles projected in the same plane, as 1 mm anterior to the posterior cortex extension line, 2.5 mm distal to the posterior origin of the medial femoral condyle, and proximal to the level of the posterior point of the Blumensaat line. However, McCarthy et al. reported that Schöttle's point does not correlate with functional outcomes [22].

Our cadaveric dissections showed that the MPFL attaches to a broad area between the medial epicondyle and the adductor tubercle (Figure 3) posterior to the posterior cortex extension line, which corresponds to a point just anterior to the confluence of the posterior femoral cortex and Blumensaat's line in a true lateral radiograph of the knee. Hence, it could be called the confluence point [19, 23]. This point is posterior to the line extending from the posterior cortex of the femur (Figure 2)—more than 5 mm distal and posterior to Schöttle's point [23, 24, 25, 26, 27, 28] (Figure 4). Interestingly, this point corresponds to the instant center of knee rotation. This distinction between Schöttle's point and our confluence point is of paramount importance, hence cadaver studies have shown that a 5 mm



Figure 2: Axial T2-weighted MRI image demonstrating ruptured MPFL.

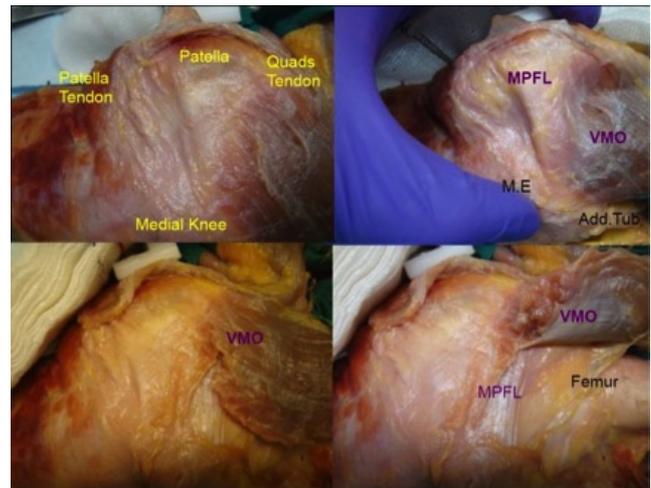


Figure 3: Cadaveric dissections demonstrating that the MPFL attaches to a broad area between the medial epicondyle and the adductor tubercle.

nonanatomic femoral attachment, either proximally or distally, causes a significant increase in medial contact pressures and medial patellar tilt in flexion and extension, respectively [27] (Figure 3). The difference may be related to the quality of the cadavers used and dissection technique.

The etiology of PFJI is multifactorial as it involves several abnormal anatomical factors such as generalized hypermobility (24%) [29], patella hypermobility (51%) [29], increased femoral anteversion (27%), core, and hip abductor weakness, abnormal knee rotation, trochlea

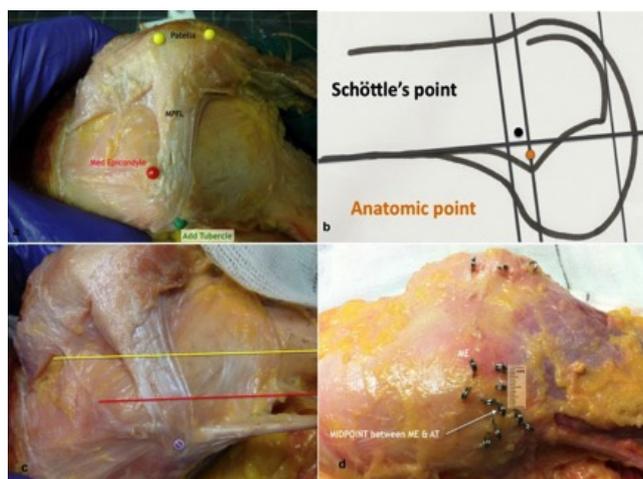


Figure 4: Cadaveric dissection demonstrating the confluence point more than 5 mm distal and posterior to Schöttle's point.

dysplasia (53–71%), abnormal Q angle, patella alta (60–66%) [30], muscle and soft tissue imbalance, external tibial torsion, and foot hyperpronation, which have been identified in patients with recurrent patella dislocation. In a recent magnetic resonance imaging (MRI) based study, 58.3% of patients had multiple anatomic factors associated with recurrent patella dislocation [30] (Figure 3).

3. Clinical and radiologic assessment of the patella

Detailed clinical history and general hypermobility assessment by using the Beighton scoring system should be carried out. It is crucial to exclude cruciate ligament instability before focusing on patellar examination, which should include the assessment of patellar alignment (Q angle), height (alta/baja), hypermobility, dislocation in extension (reverse J sign), quadriceps function, hamstring tightness, parapatellar tenderness, patellar apprehension, trochlea depth in full flexion, and PFJ crepitus.

The quadriceps angle (Q-angle), first described by Brattström [31], represents the angle between the vector of action of the quadriceps and patellar tendons. Traditionally, it is measured using the anterior superior iliac spine (ASIS), center of the patella and center of the tibial tuberosity as anatomical landmarks. With normal values estimated between 8°–17° in males and 12°–20° in females, an increased Q-angle is thought to be associated with an increased risk of anterior knee pain and patellar instability [32,33,34]. However, the Q-angle has been found to be neither valid nor reliable as it can be affected by the anatomical points used to record the measurement and whether it is measured with a manual or digital goniometer [35]. Further, the measurement will be influenced by whether the patient is standing or supine, the rotation of the limb in relation to

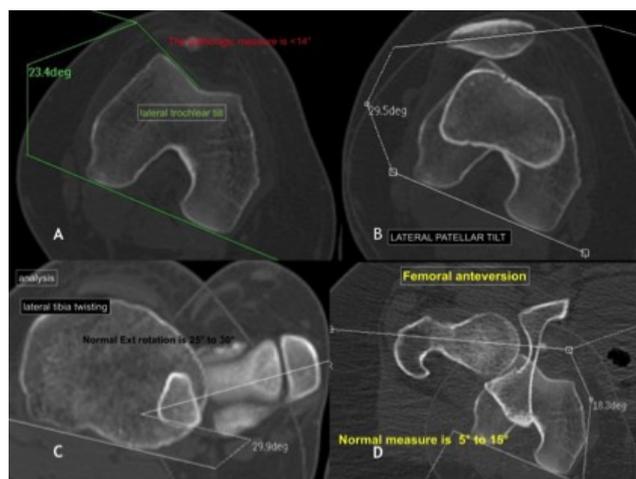


Figure 5: Rotational profile CT images to demonstrate the multiple anatomical factors involved in the pathoanatomy of patellofemoral instability.

the pelvis, the degree of flexion of the knee, and whether the quadriceps are relaxed or contracted [34,36,37]. Therefore, Q-angle is not a reliable indicator of patellar instability [38].

Patella height is best assessed using a true lateral radiograph with the knee flexed to 30° according to the method of Caton and Deschamps (i.e., the ratio between the distance from the lower edge of the patellar articular surface to the upper edge of the tibial plateau and the length of the patellar articular surface) [39,40]. A ratio of 1.2 or greater indicates patella alta, which predisposes the patient to patellar instability due to late engagement of the patella in the trochlea as the knee flexes.

We found that rotational profile computed tomography (CT) scans [13] (Figure 5) of the lower limbs in neutral rotation, as per Dejour's method [11], were very helpful in objectively assessing many anatomic factors that may contribute to the stability of the patella, such as femoral anteversion, knee rotation, external tibial torsion, tibial-tuberosity:trochlear groove (TT:TG) distance (Figure 6), patella index, patella tilt, trochlea tilt, and trochlea depth. The normal TT:TG distance is 2–9 mm, and it is generally accepted that a figure of >19 mm is pathological [41,42,43]. It is estimated that 42% of patients with PFJI have abnormal TT:TG distance [30]. Although TT:TG distance is regarded by many clinicians as one of the important measurements in assessing patellar instability and deciding about distal realignment procedures, our research has shown that it is not a decisive element in establishing therapeutic choices for instability [43,44].

The TT:TG distance was originally called tibial tuberosity:patella groove (TT:PG) distance by Goutallier in 1978 [45]. The TT:PG distance was measured in three groups. The first group ($n = 16$) was aged over 65 and had

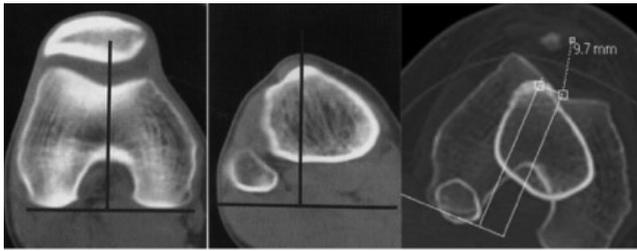


Figure 6: Axial CT images to demonstrate TT-TG distance.

normal knees, the second group ($n = 30$) was aged under 65, suffering from PFJ arthritis, and the third group ($n = 24$) was aged under 65, suffering from patellar dislocation. This was a descriptive paper on a heterogeneous population. Its methodology would have never passed the current stringent review process, thus the TT: TG distance should be treated with caution based on this consideration alone.

There are several potential problems with relying on TT: TG distance in isolation. There is a large variation in its normal value depending on the patient's size and height. In a small person, a 20 mm distance will have a greater impact on PFJ kinematics in comparison with a larger person, as the TT: TG distance is recorded as an absolute distance rather than relative to the patient's knee size. The same values cannot be applied to both CT and MRI scans as the osseous and cartilaginous geometry of the patellofemoral joint frequently differ [46]. In addition, there is poor inter-rater reliability; measurement errors of 3–5 mm have been reported due to difficulty in identifying the deepest point of the trochlea and the highest point of the tibial tuberosity, especially in dysplastic trochlea [43,44]. Finally, the measurement is very much dependent on knee flexion angle and the weight-bearing status of the patient. Therefore, TT: TG distance should be interpreted with caution during clinical evaluation of patella instability [47].

Trochlear dysplasia has been linked to PFJI and was classified by Dejour based on trochlea morphology: type A shallow trochlea, type B flat or convex, type C hypoplastic medial facet, and type D asymmetrical facets with vertical links [48]. It is typically measured on a true lateral radiograph, with the knee flexed to 30 °C, at the point where the trochlear groove crosses both condyles, and this “crossing sign” was observed in 96% of patients with recurrent instability and only 3% of controls [11]. Whilst dysplastic knees are correctly identified in the majority of knees, low inter-rater reliability has been reported in the correct identification of trochlear morphology according to Dejour's classifications [49].

Despite a thorough clinical examination, X-ray, MRI, and rotational profile CT, it is still difficult to quantify patellar malalignment and malrotation. It is, therefore, recommended to use more than one clinical test and radiologic

Table 1: The principles of surgical intervention based on the pathoanatomy of PFJI.

Pathoanatomy	Surgical options
Instability with malalignment	Tibial tuberosity medialization
Instability without malalignment	MPFL reconstruction
Instability with patella alta	Tibial tuberosity distalization
Trochlea dysplasia	Trochleoplasty
Rotational problems	Derotation osteotomy

measurement to identify the main pathology that is causing the patellar instability.

4. Evidence-based management

4.1. Nonoperative management

Functional rehabilitation is the mainstay of nonoperative management with particular focus on gait, core stability, and quadriceps strengthening [50]. A small number of older randomized trials comparing operative and nonoperative treatment of initial patellar dislocation found no benefit from immediate medial retinacular repair [51,52].

Currently, nonoperative treatment is indicated in acute first-time dislocators without associated osteochondral fracture or loose bodies. Despite the high rate of redislocation, the benefit of acute soft tissue repair or reconstruction is yet to be established. Recent level-one evidence studies, including six randomized controlled trials, showed that the rate of redislocation following surgical stabilization was significantly lower than nonoperative treatment [7,52,53,54,55,56,57]. However, it can be concluded from other level-one evidence studies that the outcome of nonsurgical treatment is less satisfactory, as 49% of the patients redislocated, nearly two thirds continued to have instability symptoms and anterior knee pain, with low patient satisfaction of 40%, and only 42% returned to preinjury level [1,2,3,8].

4.2. Surgical management

The principles of surgical management in patients with recurrent instability is to address the primary abnormal anatomical factor that contributes most to redislocation without creating a secondary pathoanatomy to compensate for it, as summarized in Table 1. Unfortunately, it is never as straightforward as the summary suggests. Often there are multiple abnormal anatomical factors that are interacting in the background. An event that leads to first-time dislocation disrupts knee homeostasis and causes it to decompensate. Homeostasis can be restored by simpler procedures such as MPFL reconstruction in more than 80% of the cases. However, in certain patients the patella is permanently dislocated or tracking in the lateral gutter, only relocating in full knee extension. This group of patients would require more than one procedure to achieve patellar stability.

A variety of surgical techniques have been described to reconstruct the MPFL. We prefer to use gracilis tendon autograft and fix it with a screw in the femur and either two suture anchors in small patellae, usually female patients, or a bony tunnel in the anterior patella in larger patellae, normally male patients. There is still a paucity of studies presenting long-term data. In a recent meta-analysis, a total of 1,065 MPFL reconstructions were identified in 31 studies, and it was found that autograft reconstructions were associated with greater postoperative improvements in Kujala scores when compared to allograft, and that double-limbed reconstructions were associated with both improved postoperative Kujala scores and lower failure rate [58]. Overall, in the absence of significant malalignment, MPFL reconstructions appear to provide long-term functional improvement with improved Kujala scores, low rate of redislocation, and decreases in apprehension and patellofemoral pain [59,60,61,62,63,64]. However, the current literature on MPFL outcomes has substantial methodological limitations with small sample sizes and limited follow-ups [65]. Standardizing the surgical technique on an adequate sample size with long-term follow-up will be necessary for future outcomes studies.

The presence of trochlear dysplasia can be addressed with a trochlear groove deepening trochleoplasty procedure, as described by Dejour (Lyon's procedure) [66], or its variants which led to good clinical outcomes in the literature [41,67,68,69,70,71,72]. Long-term studies on the effectiveness of trochleoplasty are scarce. In their series, Utting et al. [73] reported on 54 consecutive patients (59 knees) with PFJI secondary to trochlear dysplasia, who were treated by a trochleoplasty by a single surgeon. Overall, 92.6% of their patients were satisfied with the outcome of their procedure. Rouanet et al. [72] reported on their series of 34 patients with average 15 years (12–19) follow-up who underwent deepening trochleoplasties using multiple outcome scores. They reported restoration of patellofemoral stability even in patients with severe dysplasia. However, it did not prevent patellofemoral osteoarthritis.

Distal realignment procedures include tibial tuberosity transfer, typically with distalization and/or medialization, to address patella alta and malalignment [74,75] (Figure 7). In a cadaveric study, we found that in knees with preoperative TT:TG distances of up to 15 mm, patellofemoral kinematics and contact mechanics can be restored with MPFL reconstruction [76]. However, for knees with preoperative TT:TG distances greater than 15 mm, more aggressive surgery such as tibial tuberosity transfer may be indicated [76]. This, however, is difficult to translate to patients with PFJI as they normally have more than one anatomic abnormality unlike the cadavers studied, and their knees are subjected to various dynamic weight bearing forces that are difficult to reproduce in laboratory investigations.



Figure 7: Intraoperative photographs and plain X-rays demonstrating tibial tubercle transfer procedure.

Contraindications of tibial tuberosity transfer include medial and/or proximal patellofemoral chondrosis that would be subjected to increased loading with a transfer of the tuberosity [77]. In a recent systematic review of outcomes and complications looking at MPFL reconstruction with concomitant tibial tuberosity transfer in five studies with 92 knees and a mean follow-up of 38 months (range 23–53), this combined procedure was found to be effective in the setting of malalignment [77].

5. Conclusions

PFJI is relatively common. It can be caused by a range of factors including generalized hypermobility, patella hypermobility, increased femoral anteversion, core and hip abductor weakness, abnormal knee rotation, trochlea dysplasia, abnormal Q angle, patella alta, muscle and soft tissue imbalance, external tibial torsion and foot hyperpronation. Due to the multifactorial nature of PFJI, common clinical and radiological outcomes, such as the Q angle and TT:TG distance, cannot be relied upon in isolation. It is, therefore, vital to conduct a thorough clinical and radiological investigation to determine the main cause of instability, prior to treatment. Relatively simple surgical procedures, such as medial patellofemoral ligament reconstruction, can restore PFJ stability in a high proportion of unstable knees, especially in those with lower TT:TG distances. A deepening trochleoplasty is rarely indicated in isolation. Tibial tuberosity transfer can be used to address more significant instability, often in combination with MPFL reconstruction. A greater number of long-term investigations are needed to achieve a better understanding of patient outcomes following these procedures.

Conflict of interest The authors declare that they have no conflict of interest.

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