12 Patellofemoral Joint Instability: Where Are We in 2018?

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12.1 Introduction

Acute patella dislocation makes up 2–3% of all acute knee injuries, with a higher incidence in younger and athletic patients [1–3]. Risk of re-dislocation following first-time injury is 17–49% [2], rising to 44–71% in patients younger than 20 years [1, 3].

The stability of the patellofemoral (PF) joint is derived from a combination of local, distant, static and dynamic factors. Locally, static stability is provided by bone/cartilage geometry and ligaments, whilst dynamic stability is primarily maintained by the extensor muscles including vastus medialis obliquus (VMO) [4, 5].

The principle distant static factors are femoral anteversion (normal 5–15°), knee rotation (normal 3°) and external tibial torsion (25–30°), 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 [6–9].

The bone geometry and cartilaginous 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: investing fascia, medial patellofemoral ligament (MPFL) and superficial medial collateral ligament (MCL) and deep MCL and joint capsule. The MPFL is regarded as the primary passive stabiliser of the patella in early knee flexion (20–30°) [10]. It guides the patella into the trochlear groove and provides anywhere between 50 and 80% of the stability required to prevent lateral patella displacement [4, 10–12].

The MPFL has femoral and patellar attachments. It is well accepted that the MPFL becomes

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conjoined with the deep portion of VMO before inserting into the upper two thirds of the medial patella (Fig. 12.1). However, there has been a lot of controversy regarding the femoral attachment site [13]. A previous anatomical study by Amis et al. in 2003 [14] 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 [10]. Schöttle [15], 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 MPFL reconstruction using Schöttle's point does not correlate with improved functional outcomes [16].

Recent cadaveric dissections performed by this chapter's first author [13, 17, 18] showed that the MPFL attaches to a broad area between the medial epicondyle and the adductor tubercle on the femur (Fig. 12.2). When the centre of the attachment was marked radiologically, it corresponded to a point just anterior to the confluence of Blumensaat's line and the curving line off the posterior femoral cortex and posterior to the straight extension line from the posterior cortex in a true lateral radiograph of the knee (Fig. 12.3). Hence, it could be called the confluence point. This radiographic point is more than 5 mm distal and posterior to Schöttle's point [17–21] (Fig. 12.4). Interestingly, this point corresponds to the instant centre of knee rotation. This distinction between Schöttle's point and the confluence point is of paramount importance; hence, cadaver studies have shown that a

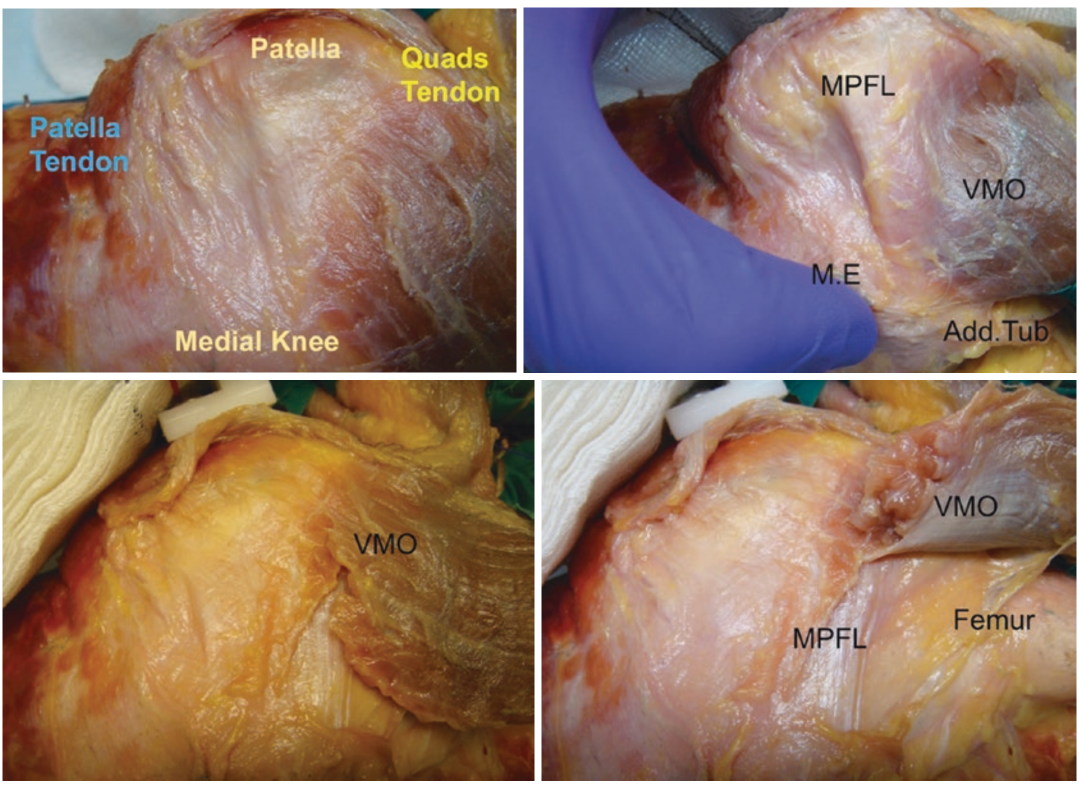

Fig. 12.1 Cadaveric dissections demonstrating that the MPFL attaches to a broad area between the medial epicondyle and the adductor tubercle

5 mm nonanatomic femoral attachment, either proximally or distally, causes a significant increase in medial contact pressures and medial patella tilt in flexion and extension, respectively [13]. The difference could be attributed to the quality of the cadavers and dissection techniques.

The aetiology of patellofemoral joint instability (PFJI) is complex and multifactorial. Several abnormal anatomical factors have been identified in patients with recurrent patella dislocation, including generalised hypermobility (24%) [22], patella hypermobility (51%) [22], increased femoral anteversion (27%), core and hip abductor weakness, abnormal knee rotation, trochlea dysplasia (53–71%), abnormal Q angle, patella alta (60–66%) [23], muscle and soft tissue imbalance, external tibial torsion and foot hyperpronation. In a recent magnetic resonance imaging (MRI)-based study, 58.3% of patients had multiple anatomical factors associated with recurrent patella dislocation [23].

The foundations for the management of PFJI have been laid out by the Lyonnaise school in their seminal paper, in which four principle factors were outlined, based on plain radiographs and slice imaging. These factors are patella height, patella tilt, trochlear groove-tibial tubercle distance (TT-TG) and trochlear morphology [5].

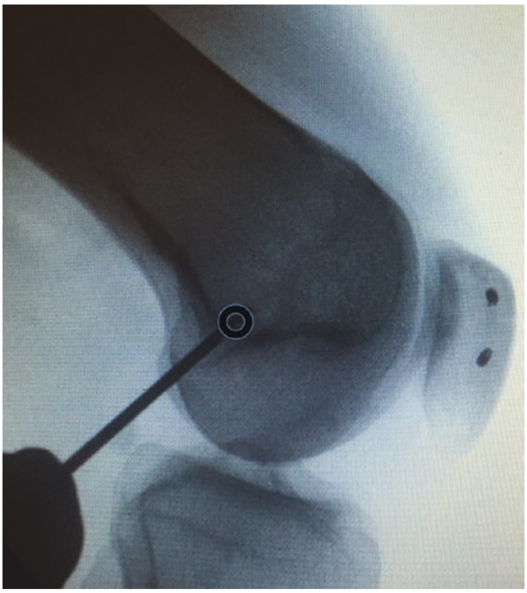

Fig. 12.2 True lateral intraoperative fluoroscopy image demonstrating the confluence point prior to drilling the femoral tunnel

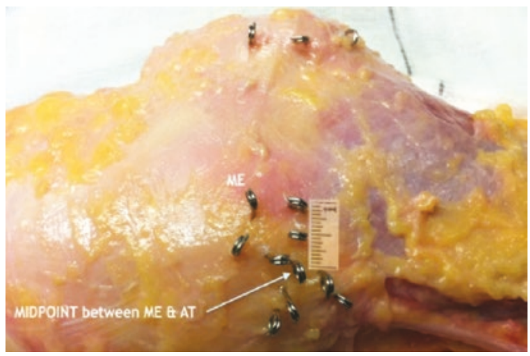

Fig. 12.3 Cadaveric dissection demonstrating pin marking details at various insertion points within 5 mm of each other to identify the optimum site for the femoral tunnel placement

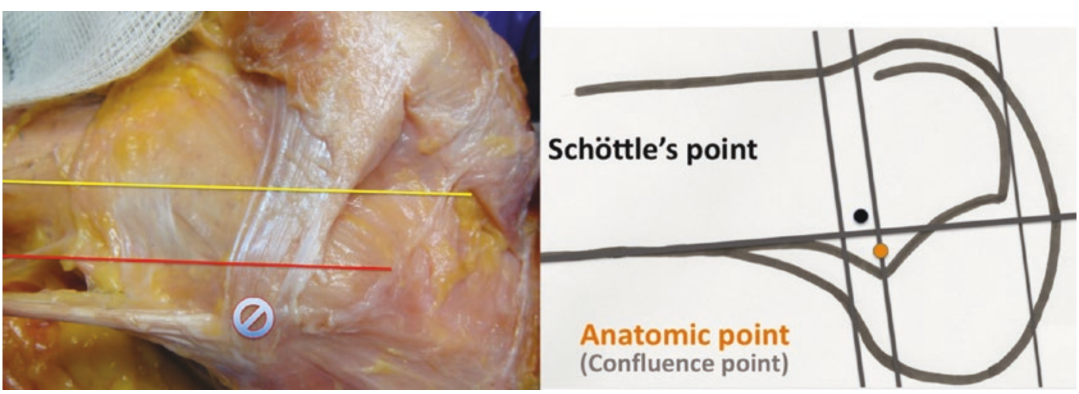

Fig. 12.4 Cadaveric dissection demonstrating the confluence point more than 5 mm distal and posterior to Schöttle's point

They divided PF disorders into three groups: objective patella instability, potential patella instability and painful patella syndrome. This study by Dejour et al. remains the largest follow-up in our literature on surgically treated patients with recurrent lateral patella dislocations.

In recent years there has been a renewed interest in PFJI, possibly related to the advances made in our understanding of various anatomic and dynamic factors that contribute to patella stability. The overall management of patella dislocation and instability has been linked with poor patient satisfaction, possibly due to a prolonged period of conservative treatment and the general tendency to delay surgical intervention [3].

12.1.1 Clinical Examination

Detailed clinical history and general hypermobility assessment by using the Beighton scoring system should be carried out. Patella examination typically includes the assessment of patella alignment (Q angle), height (alta/baja), hypermobility, dislocation in extension (reverse J sign), quadriceps function, hamstring tightness, para-patella tenderness, patella apprehension, trochlea depth in full flexion and PF joint crepitus.

The quadriceps angle (Q angle), first described by Brattström [24], represents the angle between the vector of action of the quadriceps and patella tendons. Traditionally, it is measured using the anterior superior iliac spine (ASIS), centre of the patella and centre of the tibial tuberosity as anatomical landmarks. With normal values estimated between 8 and 17° in males and 12 and 20° in females, an increased Q angle is thought to be associated with an increased risk of anterior knee pain and patella instability [25–27]. 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 [28]. Further, the measurement will be influenced by whether the patient is standing or supine, the rotation of the limb in relation to the pelvis, the degree of flexion of the knee and whether the quadriceps are relaxed or contracted [27, 29, 30]. Cooney et al. highlighted that the Q angle does not necessarily correlate with radiographic measures of patellar alignment (e.g. TT-TG). Therefore, Q angle should not be relied upon in isolation to identify PFJI [31].

12.1.2 Radiologic Assessment

Patella height is best assessed using a true lateral radiograph with the knee flexed to 30° according to the method of Caton-Deschamps (i.e. the ratio between the distance from the lower edge of the patella articular surface to the upper edge of the tibial plateau and the length of the patella articular surface) [32, 33]. A ratio of 1.2 or greater indicates patella alta, which predisposes the patient to patella instability due to late engagement of the patella in the trochlea as the knee flexes.

Rotational profile computed tomography (CT) scans [7] (Fig. 12.5) of the lower limbs in neutral rotation, as per Dejour's method [5], is 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, 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 [34–36]. It is estimated that 42% of patients with PFJI have abnormal TT-TG [23]. Although TT-TG distance is regarded by many clinicians as one of the important measurements in assessing patella instability and deciding about distal realignment procedures, recent research has shown that it is not a decisive element in establishing therapeutic choices for instability [36, 37].

The TT-TG distance was originally called tibial tuberosity-patella groove (TT-PG) distance by Goutallier in 1978 [38]. The TT-PG distance was measured in three groups. The first group ($n = 16$) was aged over 65 years and had 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 patella dislocation. This was a descriptive paper on a

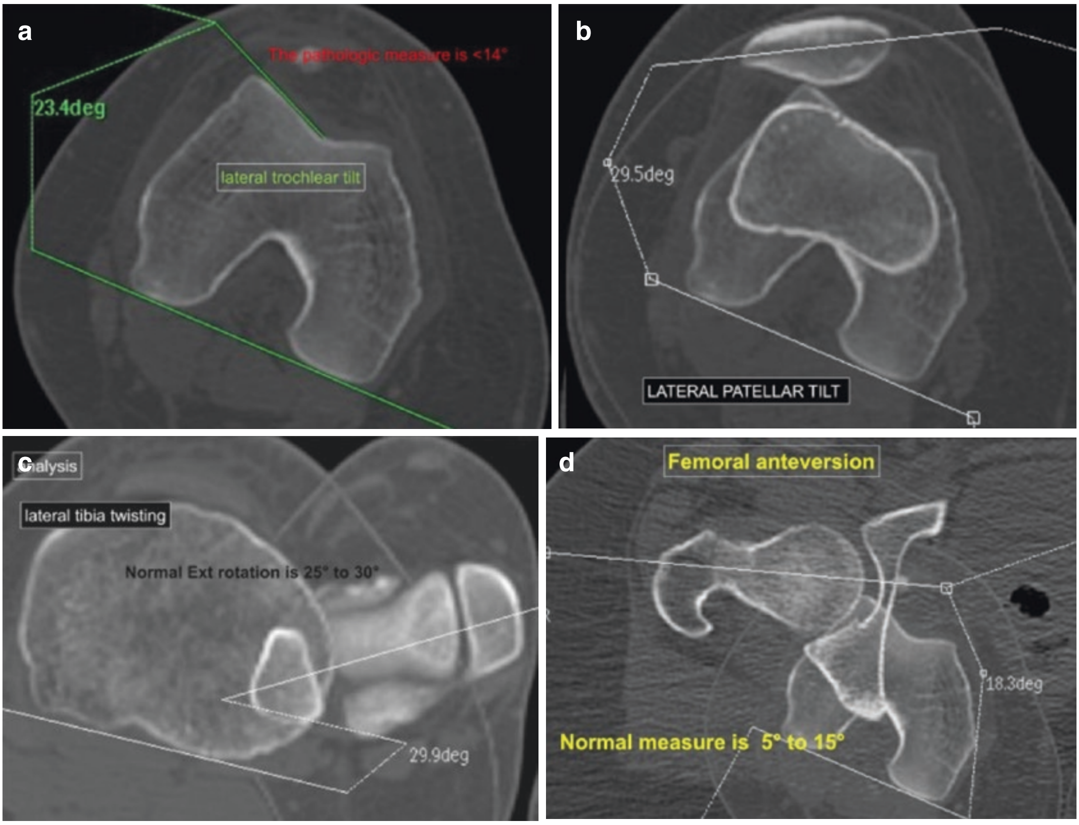

Fig. 12.5 Rotational profile CT images to demonstrate the multiple anatomical factors involved in destabilising the patella, including (**a**) lateral trochlear tilt, (**b**) lateral patellar tilt, (**c**) lateral tibia twisting and (**d**) femoral anteversion

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 patients' 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 [39]. In addition, there is poor inter-rater reliability; measurement errors of 3–5 mm have been reported due to the difficulty in identifying the deepest point of the trochlea and the highest point of the tibial tuberosity, especially in dysplastic trochlea [36, 37]. 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 [40].

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 [41]. It is typically measured on a true lateral radiograph, with the knee flexed to 30°, at the point where the trochlear groove crosses both condyles, and this "crossing sign" was observed in 96% of patients with recurrent instability and in only 3% of controls [5]. Whilst dysplastic knees are correctly identified in the majority of the knees, low inter-rater reliability has been reported in the correct identification of trochlear morphology according to Dejour's classifications [42].

Despite a thorough clinical examination, radiographs, MRI and rotational profile CT, it is still difficult to quantify patella malalignment and malrotation. It is, therefore, recommended to use more than one clinical test and radiologic measurement to identify the main pathology that is causing the PFJI.

12.2 State-of-the-Art Treatment

12.2.1 Acute Patella Dislocation: Cast vs Early Immobilisation vs Surgery

Acute dislocation has been associated with osteochondral lesions in 49% of patients and with MPFL disruption in over 90–100% of patients [43–46]. There is high patient dissatisfaction after conservative treatment, with 58% reporting limitations in strenuous activities 6 months after treatment [47] and 55% of these patients failing to return to sporting activities. Chronic PFJI and recurrent dislocation may eventually lead to progressive cartilage damage if not treated adequately, and the risk of osteoarthritis (OA) has been found to be 35% after conservative treatment [48].

The best treatment of an isolated acute first patella dislocation is debatable. It is widely agreed that operative intervention is only recommended when there is evidence of a large osteochondral defects. In the past, isolated acute first patella dislocation was mainly treated conservatively, because older literature did not demonstrate any advantage of operative treatment in terms of re-dislocation rate [49–51].

Conservative treatment can take many forms, though most authors recommend an immobilising splint, cast or orthosis for 2–3 weeks, followed by physiotherapy focusing on building quadriceps. There is insufficient evidence to determine if weight-bearing restriction is necessary [51–54]. Most of the literature that is comparing operative with conservative treatment is unreliable due to variation in the reported surgical intervention. Long-term follow-up studies tend to include old-fashioned operative procedures that are no longer performed.

A recent systematic review and quantitative synthesis of literature found that re-dislocation rates were lower and short- to medium-term clinical outcomes were better after surgical treatment of primary acute patella dislocation, though no difference was seen in long-term follow-up [49]. A Cochrane review comparing surgical and non-surgical interventions reported that patients managed surgically had a significantly lower risk of recurrent dislocation following primary patella dislocation at 2–5 years follow-up. However, they concluded that adequately powered multicentre randomised controlled trials are needed [55].

Decision-making in management of acute patella dislocation, therefore, requires analysis of patient-specific instability predictors [56, 57]. Balcarek et al. suggested analysis of six parameters to determine the patellar instability severity score (PIS-score), which can identify patients who would benefit from operative management. The parameters are:

- Age
- Positive anamnesis of contralateral patella dislocation
- Patella tilt (<20°/>20°)
- Patella alta
- TT-TG distance
- Trochlea dysplasia

Patients with a PIS-score of 4 points or more have a higher risk of re-dislocation of the patella and, therefore, should receive operative treatment. As of yet, there are no long-term outcomes from the use of this classification, but individual analysis of patient factors in the decision-making process for operative or conservative treatment of dislocation and instability appears reasonable and is recommended by many experienced surgeons.

12.2.2 Is MPFL Reconstruction the Procedure of Choice?

A common current approach to patella stabilisation for recurrent lateral patella dislocation is MPFL reconstruction, for which many different techniques have been described [58].

The clinical challenge remains, however, in defining when isolated MPFL reconstruction (without a bony procedure) would provide consistent surgical success. To answer this question, studies are required to include evaluation and documentation of preoperative physical examination and imaging factors and relate these factors to measured surgical outcomes.

The vast majority of publications on "isolated MPFL reconstructions" define a relatively homogeneous population without excessive anatomic imaging factors that have resulted in successful surgical outcomes [59]. Current literature on MPFL reconstruction does not allow for strong evidence-based surgical decisions for those patients with anatomic instability factors above the previously established thresholds laid down by Dejour et al. [5], primarily due to the lack of reporting and/or inconsistent recording of pre- and postoperative anatomic variables.

Another barrier to clarity in the clinical approach to surgical management of lateral patella dislocation is the lack of specificity in the imaging measurements that are central to our current clinical algorithms. A recent systematic search with meta-analysis of MRI measurements revealed a wide range of imaging values within both controls and PFJI groups [60]. This showed that appropriate abnormality thresholds exist for anatomic patella instability MRI factors within groups of patients classified as having PFJI, indicating sensitivity. The wide range in the majority of measurements, especially in the control group, suggested poor specificity in most MRI measurements, indicating that these imaging measurements cannot be used in the absence of an appropriate history and physical examination to discriminate between patients with and without PFJI.

The clinical challenge that remains is detailing the anatomic thresholds for surgical correction of anatomic patella instability factors such as patella height, trochlear dysplasia and increased quadriceps vector (e.g. increased TT-TG) and determining which surgical procedure is most appropriate for correction of such factors. The question remains as to whether it is necessary to correct all identified factors.

The following guidelines are offered:

An ideal candidate for an isolated MPFL reconstruction, without bony procedures, should have a history consistent with recurrent dislocation and a physical examination demonstrating excessive lateral patella translation, with minimal or absent pain between episodes of instability and a normal or low-grade dysplastic trochlea (e.g. type A Dejour classification). There should be no radiological evidence of lateral PF load, tubercle sulcus angle between 0° and 5° valgus, and no excessive patella height (reasonable overlap of patella and trochlea surfaces on sagittal MRI measured by patella-trochlea index [61]). The Caton-Deschamps index up to 1.4 can be acceptable, except where there is a very short trochlea or significant knee hyperextension.

Where lateral retinacular tightness is present on clinical examination with TT-TG less than 20 mm, lateral retinacular lengthening, with or without partial lateral facetectomy, could be recommended in order to unload the lateral patellofemoral joint. However, where there is no retinacular tightness and TT-TG is more than 20 mm, medial tibial tubercle osteotomy is preferred.

Ultimately, surgical decisions involve a blend of imaging and physical examination features, combined with patient expectation and surgeon's experience and judgement.

12.2.3 Which Bony Procedure?

A large percentage of patients who suffer from PFJI can benefit from soft tissue procedures. However, in some patients this is not enough. Bony procedures are critical tools to address the underlying pathology and to ensure a successful outcome. It is clear that, in correctly selected patients and after careful technical considerations, soft tissue procedures can have high success rates, and this is evident by the variation in outcomes reported in the literature. After technical failures, one of the most important reasons for failure is often because a bony procedure was indicated, and an isolated soft tissue reconstruction was not the correct operation. So when and which bony procedure should we perform?

Failure to consider trochlea dysplasia and TT-TG is the common reasons for poor outcomes in soft tissue stabilisation procedures [62]. Dejour taught that it is vital to consider the major risk factors in patella instability carefully to plan the correct procedures [5].

The key bony procedures for patella instability are:

- Trochleoplasty
- Tibial tuberosity osteotomy
- Femoral osteotomy (derotation or angular)

Selecting the correct procedure or combination of procedures is the key to successfully treating these interesting and challenging patients [63].

Trochleoplasty surgery, either with a thick or thin flap technique, is a very powerful procedure to help treat patella instability in patients with significant trochlea dysplasia. Typically, this procedure is indicated in patients who have Dejour type B, C or D dysplasia. Usually, these patients present in their teens with atraumatic recurrent instability, significant apprehension on examination, easily dislocatable patella and a strongly positive J sign. They usually have mild patella alta. In Dejour type D, patients can be chronically dislocated or have significant patella tilt should also be considered for trochleoplasty surgery [64, 65]. The published outcomes of trochleoplasty in this patient group are promising. Good results have been reported with both the thick flap and thin flap techniques [66–68]. Dejour has reported good results with trochleoplasty in the revision setting [69].

Tibial tuberosity osteotomy (TTO) has developed a bad reputation over the years [70]. This is at least in part due to the indications it has been used for. The outcome of TTO that is performed for treating PFJ pain has been disappointing. However, the results of correcting instability are good, but often this is associated with increased pain and early onset osteoarthritis.

The TTO is usually reserved for patients with significant patella alta (Fig. 12.6) (Catton-Decamps index >1.3). It has been observed that is it rare to find a significantly increased TT-TG in the absence of trochlea dysplasia. Therefore, typically many clinicians use this procedure to distalise the patella only. The excellent work of Fulkerson and others have shown that the antero-medialisation osteotomy can yield good

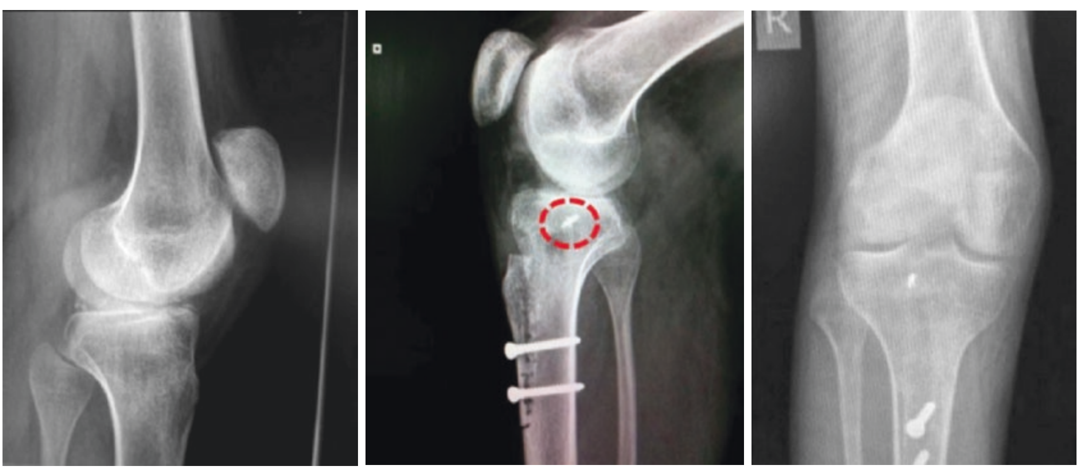

Fig. 12.6 Tibial tubercle distalisation for patella alta

results in the cases of increased TT-TG and trochlea dysplasia [71, 72]. This is an alternate option to trochleoplasty in mild/moderate trochlea dysplasia. Medialisation should be performed with care to avoid over medialisation as this can create a number of chronic problems.

Occasionally, a femoral osteotomy is required to address the patella instability. A derotational osteotomy is indicated in rare cases with significantly increased femur anteversion. It is important to assess the rotational profile of patients to ensure that this is not overlooked. An angular distal femoral osteotomy is occasionally indicated in patients who develop patella instability as a result of excessive valgus alignment.

12.2.4 Failed MPFL? What to Do Next?

There is no doubt that MPFL reconstruction for the treatment of objective patellofemoral dislocation has gained popularity in the last two decades. This rise in surgical intervention has brought about various complications. Recently, several surgical techniques have been described with various methods of fixation, knee flexion angle at the time of fixation, the choice of the graft and the tension which should be applied [73–80].

In the current literature, several studies have shown how the MPFL reconstruction provides significant improvement in patient-reported outcome measures and a high percentage of return to previous activity level [81–84]. However, despite its popularity, MPFL reconstruction is not free of complications. Indeed, in a systematic review of the literature, Shah et al. [85] found an overall complication rate of 26.1%, with almost one third (32%) of patients reporting recurrent instability. Meanwhile, the results published by Parikh et al. [86] reported complications in 16.2% of patients, with approximately half (47%) of them due to technical errors.

Almost all the complications could be categorised into two groups: complications that are due to an incorrect indication by failing to recognise the other risk factors that could have contributed to the dislocation and complications due to technical errors.

The first prerequisite to avoid complications and failure of an MPFL reconstruction is to properly select the patient. When evaluating a patient with patellofemoral complaints, it is mandatory to recognise that patellofemoral instability can present in a spectrum of manifestations. Therefore, it is important to differentiate between patients who have a documented true dislocation associated with haemarthrosis and those who report instability and "giving way" during low-energy activities which could be due to quadriceps inhibition following prolonged knee pain.

Anterior knee pain and excessive lateral patella tilt or lateral patella subluxation on imaging without a history and a physical examination for objective patella instability should never be treated with MPFL reconstruction.

On the other hand, the failure to take into account the major risk factors for patella instability [5] represents a common cause of failure of a MPFL reconstruction. Along with the clinical assessment, a complete imaging study is essential. One of the most relevant and major factors to consider is high-grade trochlear dysplasia, type C and D according to Dejour's classification [87], which can be responsible for an excessive laterally directed force on the patella [88] and overloading of the MPFL graft and fatigue rupture [64, 89, 90]. Therefore, high-grade trochlea dysplasia should be treated by trochleoplasty in order to avoid residual patellofemoral instability after isolated MPFL reconstruction [91, 92].

The patella height determines at which point the patella engages in the trochlea [93]. In patella alta, the engagement between patella and trochlea occurs at a higher degree of flexion and consequently with a lower contact area. For example, the contact area at 40° of knee flexion in patients with patella alta is comparable with the magnitude of contact area at 20° of knee flexion in patients with normal patella height. Hence, patients with patella alta have a mean of 19% less contact area than the control subjects over the range of 0–60° of flexion. Moreover, in patients with patella alta, the lateral patella tilt showed values of 39% higher than patients with normal patella height, and a 20% more lateral patella displacement has been reported [94].

Plain lateral radiographs are essential for the measurement of patella height by using different methods [33, 95, 96]. Recently, a new MRI index was introduced to assess the functional engagement between patella and trochlea in the sagittal plane [61, 97]. The sagittal patellofemoral engagement index, measured as the ratio between the articular cartilage of the patella and the trochlear cartilage length taken on two different MRI slices, may help to identify the cases where inadequate engagement is recorded despite the absence of patella alta, so that the need for tibial tuberosity osteotomy may be reassessed [97]. Therefore, the presence of patella alta with an insufficient functional sagittal patellofemoral engagement represents an indication to a distalisation of the tibial tuberosity in order to obtain a normal index.

The excessive TT-TG distance represents the third factor of patella instability and is a direct measure of the valgus alignment of the extensor mechanism and consequent valgus-displacing vector acting on the patella [98]. In particular, an excessive lateralized position of the tibial tuberosity reduces patella stability and increases patellofemoral joint contact pressure and lateral patella tracking. As a consequence of this, in the knees with overly lateralized position of the tibial tuberosity, the clinical maltracking may stretch the MPFL and allows lateral patella motion when the quadriceps are contracted, leading to failure of the graft and recurrent instability [99]. Different studies reported worse clinical and functional outcomes of isolated MPFL associated with high values of TT-TG distance [64, 92]. From a biomechanical point of view, a tibial tuberosity medialisation significantly reduces the lateral patella translation and the lateral patellofemoral joint contact pressure without increasing medial joint pressure. Therefore, when the TT-TG distance is increased over 20 mm, a tibial tuberosity medialisation osteotomy is performed in order to obtain a postoperative value between 10 and 15 mm [100]. Careful preoperative planning and an intraoperative confirmation of patella tracking are crucial to avoid complications resulting from overmedialisation.

It is crucial to keep in mind that trochleoplasty could reduce the TT-TG distance, acting as a proximal realignment [68] and that with a 10 mm distalisation 4 mm of medialisation is automatically achieved [87, 101].

The presence of an isolated patella tilt is not an indication for surgical treatment. However, the presence of a lateral patella tilt of more than 20° in patients with an objective patella instability associated with a negative medial patella tilt test could represent an indication to perform a lateral release.

Among the technical mistakes in MPFL reconstruction, the most recurrent and critical error is an incorrect femoral fixation point (Fig. 12.7), which is of crucial importance as it is

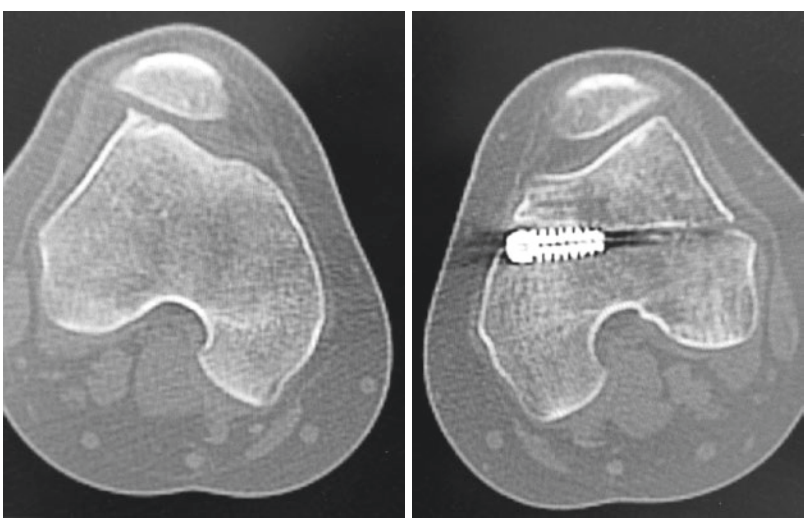

Fig. 12.7 Axial CT scan showing malpositioned femoral tunnel after MPFL reconstruction in the left knee

responsible for length change and graft tension during knee motion [18, 102]. In order to identify the anatomical femoral insertion of the MPFL, it is important to use intraoperative fluoroscopy. In this regard, it is imperative to obtain a true lateral radiographic image to identify the confluence point of the posterior cortex extension and the Blumensaat line [15, 103].

An excessively proximal or anterior femoral insertion is responsible for increased flexion tightness [104] which could lead to medial patellofemoral articular overload with pain and loss of flexion. This could even cause iatrogenic medial subluxation and subsequent recurrent lateral patella dislocation due to stretching of the graft [105]. Conversely, with an overly distal posterior tunnel placement, the graft may be loose in flexion and too tight in extension, causing pain with leg straightening, an extensor lag or stretching of the graft, with recurrent patella instability [104, 106].

Moreover, knee flexion angle during graft fixation is also crucial. If the graft is fixed in a misplaced tunnel whilst the knee is in extension, this leads to tightness and pain in flexion. If misplaced in flexion, the graft is loose and recurrent patella instability occurs in extension [91, 105].

Overtensioning the graft during fixation is another common technical error, which could lead to failure of MPFL reconstruction. Particularly, if the graft is too tight in flexion, it may increase medial patella facet pressure [107], causing pain, crepitus and loss of flexion, whilst the most frequent clinical presentation in cases of excessive tightness in extension is an extensor lag, with pain to fully straighten the leg [108]. Fithian and Gupta [109] described a medial gutter debridement in the case of medial knee pain after MPFL reconstruction. Meanwhile, Thaunat and Erasmus [108] described a gradual step-by-step percutaneous release of the graft. Both reported good resolution of pain and recovery of range of motion without instability.

Multiple studies have shown that the optimum tension for the MPFL graft is 2 newtons (204 g) at 30–60° knee flexion angle [18, 105, 108, 110]. In order to avoid excessive tension on the graft, intraoperatively the reconstructed MPFL should translate two to three patella quadrants and have a hard stop, without excessive constraint on the patella [85]. A comparison with the contralateral side can be helpful in determining appropriate graft tension [111].

Another major complication that leads to MPFL failure, generally due to technical error, is patella fracture. In literature, patella fractures after MPFL reconstruction have been categorised into three groups [112]:

- Type I fractures are transverse fractures generally associated with the patella tunnel or drill hole. These tunnels can act as stress risers and reduce the strength of the bone. Particularly, violation of the anterior patella cortex during tunnel creation represents the main cause of this complication, and, therefore, preservation of the anterior cortex of the patella is mandatory to avoid this complication. This kind of fracture is generally treated surgically using a tension-band wiring technique.
- Type II fractures are sleeve avulsion fractures or superior pole fractures, [110] generally encountered when proximal realignment, lateral release or excessive dissection at the superior aspect of the patella are performed. One of the suggested causes of this kind of fracture is vascular damage of the proximal part of the patella. Therefore, it is critical to perform an accurate dissection to preserve one or more of the genicular arteries during combined procedures on the medial and lateral sides of the patella. The treatment is similar to that of quadriceps tendon tears, consisting of suturing the quadriceps tendon to the superior pole of the patella through longitudinal drill holes.
- Type III fractures are medial rim avulsion fractures through the osseous bridge between the tunnels in the patella and are generally associated with recurrent lateral patella dislocation after patella stabilisation procedures [109, 113]. These fractures are generally treated with open reduction and internal fixation of the fragments with the use of screws or anchors.

Generally, in order to reduce the risk of a fracture after an MPFL reconstruction, it is better to avoid transverse patella tunnels, reduce tunnel diameter, maintain an adequate bone bridge, avoid devascularisation of the superior pole of the patella and perform an anatomic tunnel placement in the femur and the patella.

12.2.5 Patella Instability: Management Summary

12.2.5.1 Nonoperative Management

Functional rehabilitation is the mainstay of nonoperative management with particular focus on gait, core stability and quadriceps strengthening [55]. A small number of older randomised trials comparing operative and nonoperative treatment of initial patella dislocation found no benefit from immediate medial retinacular repair [51, 114].

Currently, nonoperative treatment is indicated in acute first-time dislocators without associated osteochondral fracture or loose bodies. Despite the high rate of re-dislocation, the benefit of acute soft tissue repair or reconstruction is yet to be established. Recent level one evidence studies, including six randomised controlled trials, showed that the rate of re-dislocation following surgical stabilisation was significantly lower than nonoperative treatment [46, 51–53, 115, 116]. However, it can be concluded from other level one evidence studies that the outcome of non-surgical treatment is less satisfactory, as 49% of the patients re-dislocated, nearly two thirds continued to have instability symptoms and anterior knee pain, with low patient satisfaction of 40%, and only 42% returned to pre-injury level [1–3, 47].

12.2.5.2 Operative Management

The principles of surgical management in patients with recurrent instability are to address the primary abnormal anatomical factor that contributes most to re-dislocation without creating a secondary pathoanatomy to compensate for it, as summarised in Table 12.1. Unfortunately, it is never as straightforward as the summary suggests.

Table 12.1 The principles of "a la carte" surgical intervention based on the most contributing factor in PFJI

Pathoanatomy	Surgical options
Instability with malalignment	Tibial tuberosity medialisation
Instability without malalignment	MPFL reconstruction
Instability with patella alta	Tibial tuberosity distalisation
Trochlea dysplasia	Trochleoplasty
Rotational problems	Derotation osteotomy
Combined pathology	Multiple simultaneous surgical interventions

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 or tibial tuberosity distalisation in severe patella alta. 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 patella stability.

A variety of surgical techniques have been described to reconstruct the MPFL. Considering that the native MPFL resistance is around 208 N, the graft choice should reflect the required ultimate load to failure. It appears that the gracilis tendon has stiffness closer to that of the native MPFL compared to the semitendinosus tendon. One of the preferred ways is to fix the gracilis tendon autograft with a screw in the femur and either two suture anchors medially in a small patella, usually female patients, or a bony tunnel in the anterior patella in larger patients, normally male. There is still a paucity of studies presenting long-term data. In a recent meta-analysis, a total of 1065 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 [117]. Overall, in the absence of significant malalignment, MPFL reconstructions appear to provide long-term functional improvement with improved Kujala scores, low rate of re-dislocation and decreases in apprehension and patellofemoral pain [76, 84, 118]. However, the current literature on MPFL outcomes has substantial methodological limitations with small sample sizes and limited follow-ups [119]. Standardising 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) [120], or its variants which led to good clinical outcomes in the literature [34, 121–125]. Long-term studies on the effectiveness of trochleoplasty are scarce. In their series, Utting et al. [126] 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. [125] reported on their series of 34 patients, with an average of 15 years of follow-up who underwent deepening trochleoplasties using multiple outcome scores. They reported the 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 distalisation and/or medialisation, to address patella alta and malalignment [84, 127] (Fig. 12.6). In a cadaveric study, it was found that in the knees with preoperative TT-TG distances of up to 15 mm, patellofemoral kinematics and contact mechanics can be restored with MPFL reconstruction [99]. However, for the knees with preoperative TT-TG distances greater than 15 mm, more aggressive surgery such as tibial tuberosity transfer may be indicated [99]. 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.

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 [128]. In a recent systematic review 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), showed that the combined procedures are effective in the setting of malalignment [128].

12.3 Future Treatment Options

In the future, the graft choice may move towards synthetic or biologically engineered grafts to reduce the donor site morbidity and reduce operating time. In addition, in vivo intra-articular contact pressure and patella tracking measurement during bony or soft tissue realignment may be one of the ways to avoid the current problems with alignment accuracy and tunnel misplacement. Using an intraoperative graft tensioner, instead of eyeballing and manual dexterity, may overcome the problems with misjudging the graft tension.

12.4 Take-Home Message

Patellofemoral joint instability is relatively common. It can be caused by a range of factors including generalised 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 [129].

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