Patellofemoral instability: an overview

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Abstract

Patellofemoral instability (PFI) occurs when patellar maltracking becomes symptomatic, ranging from a positive apprehension test to recurrent dislocation. It is a common condition in the knee, particularly in the adolescent population. There are a range of modalities helpful in investigating this group of patients. Emphasis must be placed on obtaining a good history and clinical examination, but appropriate imaging is essential. In reviewing this topic, many questions remain unanswered, in terms of the treatment options, but evidence is emerging and the trends for treating this complex group of patients are evolving. There has been a clear amalgamation of two schools of thought, with one school using a single universal method to treat all patients with PFI with a medial patellofemoral ligament (MPFL) reconstruction, and the other surgically correcting each identifiable risk factor, tailored to the individual patient. Over time, these two schools of thought have merged, and procedures such as trochleoplasty have been on the rise in combination with an MPFL reconstruction. The results of these procedures have been encouraging, although more robust long-term clinical data are still awaited.

Keywords anterior knee pain; Dejour classification; lateral release; MPFL; patellar tilt; patellofemoral instability; sulcus angle; tibial tubercle transfer; trochleoplasty

Introduction

Patellofemoral instability (PFI) is a common condition in the knee, particularly in the female adolescent population. Following a primary patellar dislocation, there is a recurrence dislocation rate of 17%. This increases to nearly 50% following a second patellar dislocation. Furthermore, untreated instability and recurrent dislocation can lead to progressively increasing articular cartilage damage and early osteoarthritis. Even without recurrent dislocation, 70% of patients complain of residual instability symptoms. PFI usually manifests as excessive lateral translation of the patella, whereas medial PFI is typically iatrogenic, secondary to an excessive lateral release.

The geometry of the patellofemoral joint (PFJ) is crucial for patellar stability. The trochlear groove needs to be deep enough and the lateral facet of the trochlea high enough to prevent excessive patellar translation in the coronal plane. The medial and lateral ligaments reinforce the bony architecture; the most important of which is the medial patellofemoral ligament (MPFL). Rabbit models have shown that a contained patella is important for trochlear development, much like a concentric reduced femoral head is required for normal acetabular development. Huri et al. further demonstrated this in rabbit models, with sectioned MPFLs developing a shallow trochlea.[1] Trochlear dysplasia can be related to either of the facets or to the groove itself. The hallmark feature is a shallow trochlea. This is quantified by an increased sulcus angle greater than 145°. There is a strong association between trochlear dysplasia and patellar instability.

Dejour classified trochleas in patients with PFI on true lateral knee radiographs in 30° of flexion. Type A correlates with minor dysplasia; B, C and D represent increasing severity of dysplasia (Table 1).

The MPFL is the primary soft tissue passive restraint in layer two of the medial side of the knee. The MPFL has been demonstrated to be the primary ligamentous restraint, accounting for up to 60% of the resistance force against lateral translation of the patella. The MPFL has been shown to be innervated, and it has been implied that it may have a proprioceptive role in addition to being a mechanical stabilizer of the PFJ. A correlative pathoanatomic study in the 1990s confirmed that the MPFL tears when the patella dislocates laterally. This forms the basis of consideration of MPFL repair or reconstruction to treat patellar instability.

The importance of understanding the MPFL anatomy is crucial to achieving a good surgical technique. If the reconstruction is performed non-anatomically, this can lead to non-physiological patellofemoral kinematics, which may lead to early failure of the procedure.

Most of the recent literature supports the MPFL origin as lying in a groove between the medial epicondyle and the adductor tubercle. In a recent systematic review by Aframian et al.[2] the MPFL was described as an hourglass structure, with a broad insertion and origin, as demonstrated in Figure 1.

Aetiology of patellar instability

The aetiology behind PFI is more often than not multifactorial. It can be structured into four categories. The first is generalized ligamentous laxity. This can be primary ligamentous laxity, assessed by the Beighton score, or associated with a collagenopathy. The second category is the bony anatomy, including patella alta or dysplasia of the trochlea. The third category relates to the soft tissues, including vastus medialis obliquus (VMO) atrophy, tight lateral structures (such as the capsule or iliotibial band) or incompetence of the MPFL. The final category concerns alignment, including femoral anteversion, external tibial torsion and genu valgum.

In the 1990s, Dejour et al. first quantified four key risk factors for patellar instability: trochlear dysplasia, patella alta (with a Caton-Deshamps index greater than 1.2), a patellar tilt greater than 20° and a Tibial Tubercle-Trochlea Groove (TT-TG) distance greater than 20 mm. See Table 2.

More recently in 2014, Balcarek et al. devised the Patella Instability Severity Score (PISS)[3] (see Table 3). This group hoped it would help identify the subgroup of patients that would benefit from early surgical intervention following first-time lateral patellar dislocation. The anatomical risk factors were measured

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Dejour grading of trochlear dysplasia

A: Positive crossing sign (groove is flush with the facets) and a sulcus angle >145°
B: Crossing sign and supratrochlear spur ('bump')
C: Crossing sign and the double-contour sign (medial hypoplastic condyle)
D: All three signs

This has also been further simplified to low-grade dysplasia (Type A) and high-grade dysplasia (Types B, C & D).

Table 1

on MRI. An odds ratio for recurrent dislocation of 4.88 was calculated when the score was 4 or more.

In 2017 Jaquith and Parikh et al. devised their predictive tool for patients under the age of 18[4] (see Table 4). Their risk factors were then correlated to predict risk of recurrence, and hence to generate a treatment recommendation.

The four risk factors that had the highest odds ratios for predicting recurrent instability were trochlear dysplasia (OR 3.56), history of contralateral dislocation (OR 3.05), skeletal immaturity (OR 2.23) and a Caton-Deschamps index greater than 1.45 (OR 2.06). They published the model below in 2018, and this has therefore not yet had a chance to be externally validated.

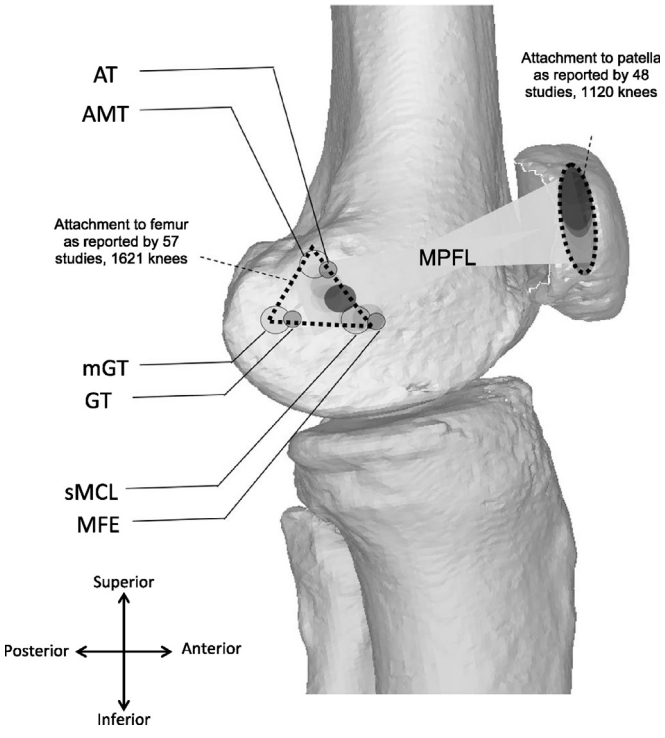

Figure 1 Diagram summarizing the MPFL attachments, based on systematic review. Darker shading represents study concordance. AT adductor tubercle, AMT adductor magnus tendon, GT gastrocnemius tubercle, mGT medial gastrocnemius tendon, sMCL superficial medial collateral ligament, MFE medial femoral epicondyle. Reproduced from reference.[2]

Risk factors for patellofemoral instability

Hypermobility
Patella alta
Patellar tilt
Patellar morphology
Trochlear dysplasia
MPFL insufficiency
Increased TT-TG
VMO hypoplasia
Increased Q angle
- Genu valgum
- External tibial torsion
- Increased femoral anteversion
- Lateralized tibial tubercle
- Increased tightness of the lateral retinaculum

Table 2

Evaluation

Clinical assessment

A focused history of a patient's instability should be sought, including the age of first dislocation, the nature of the first dislocation (in terms of mechanism), and the frequency of subsequent dislocations. The functional impact upon the patient and the limitations and effects should also be determined. The gait may show an in-toeing pattern with a reduced foot progression angle suggestive of proximal femoral pathoanatomy. Tenderness over the medial retinaculum or over the medial epicondyle could represent an acute MPFL avulsion (Bassett's sign). An evaluation of hypermobility can be demonstrated with a Beighton score of 5 or more.

A number of specific tests to assess the pathoanatomy of the PFJ should be performed. These should include the patella tilt test, the Sage mobility test and Fairbanks apprehension test. Finally, an assessment of the rotational profile of the patient is also important.

Patella instability severity score[3]

Risk factor		Points
Age 16 or under	No	0
	Yes	1
Bilateral instability	No	0
	Yes	1
Trochlear dysplasia	None	0
	Mild	1
	Severe	2
Patella alta (Caton-Deschamps)	<1.2	0
	>1.2	1
TT-TG 16 mm or more	No	0
	Yes	1
Patellar tilt >20°	No	0
	Yes	1

Table 3

Jaquith and Parikh Prediction model[5]

Risk factors	Average predicted risk of recurrence	Recommendation
0	13.8%	Conservative
1	30.1%	Conservative
2	53.6%	Consider surgery
3	74.8%	Surgery
4	88.4%	Surgery

Table 4

Radiological assessment

Radiographs: plain radiographs remain the primary modality for investigating patients with patellar instability. Assessment of patellar height can broadly be divided into those that relate to the position of the patella to the femur (i.e. Blumensaat's line) and those that relate the patella to the tibia (i.e. the Blackburn-Peel index, the Insall-salvati ratio and the Caton-Deschamps index). The lateral 30° flexion knee radiograph also allows for an assessment of trochlear dysplasia. A positive crossing sign represents an abnormally elevated trochlear groove above the anterior wall of the femoral condyle. Other signs of trochlear dysplasia include trochlear depth less than 4 mm and an anterior trochlear bump greater than 3 mm.

The Merchant view, first described nearly 50 years ago, is taken with 40° of knee flexion with the beam from the top. It allows for calculation of the sulcus angle. The sulcus angle has been evaluated to be 138° ± 6°, and dysplasia is considered with angles greater than 145°. The congruence angle is measured by the angle formed between the sulcus bisecting line and the line formed between the apex of the sulcus to the deepest part of the patellar articular surface. A congruence angle greater than −6° is associated with lateral patellar instability.[6]

CT: the skyline view on CT allows assessment of lateral patellar tilt, subluxation and trochlea dysplasia. It also allows for the rotational profile of the patient to be assessed, including analysing the TT-TG distance. The TT-TG distance has been demonstrated as an important factor in patellofemoral instability. Dejour et al. reported that the TT-TG in their control group was 12.7 ± 3.4, but more than 20 mm in the pathological cases. Studies have demonstrated that measurements of the TT-TG on MRI and CT are similar, but one study did report discrepancies of 2 mm.[7] Furthermore, the TT-TG distance decreases by 1 mm for every 5° of knee flexion.[8]

In 2012, Seitlinger described the TT-PCL distance using MRI.[9] By keeping all reference points on the tibia, confounding variables such as knee flexion are eliminated. Rather than focusing on the path taken by the patella across the knee, this measurement focuses on pure lateralization of the tubercle. Thresholds have been determined (>20 mm), but in reality both TT-TG and TT-PCL provide useful information.

Patellar tilt can be measured with the extended knee, assessing the angle tangentially subtended by the posterior femoral condylar axis and the patellar medio−lateral axis. An excessive patellar tilt can be defined on CT with a tilt angle of greater than 20°.

MRI is often the investigation of choice after X-ray for PFI, and because patella alta, TT-TG, patellar tilt and now TT-PCL can all be measured as accurately on MRI, CT has been largely superseded.

MRI: MRI can be helpful in looking for associated injuries, including articular cartilage, for assessing the MPFL integrity and potential loose bodies. The consensus from The International Patellofemoral Study Group is that the majority of respondents would obtain an MRI for first-time patellar dislocations, looking for large osteochondral fragments or loose bodies, which could be associated with the patellar dislocation.[10] MRI has been shown to be a reliable test at detecting MPFL injuries, with a sensitivity and specificity of 85 and 80% respectively, compared to the gold standard of open exploration. In addition, the MRI based patella-trochlear index is now a well-recognised method of assessing patellar height on MRI.

Ultrasound: data is emerging that high frequency ultrasound and MRI have comparable sensitivities and specificities for the evaluation of MPFL lesions following acute lateral patellar dislocations. However, the ability to assess associated chondral injuries via ultrasound is limited, and ultrasounds remains user-dependent.

Treatment

The aims of treatment are to prevent further episodes of dislocation, to improve the patient's confidence on their knee (to eliminate apprehension) and restore (or at least improve) functional activity levels, to treat as best as possible any associated concomitant damage in the joint (such as articular cartilage damage) and to reduce the potential likelihood of future patellofemoral arthritis. This is best achieved by ensuring patellar containment with normal tracking throughout the range of motion of the knee.

Non-operative

Lifestyle changes may be advised to specifically avoid activities that confer increased risk of instability. Most modern rehabilitation regimes encourage early active range of moment, to prevent arthrofibrosis and wasting of the quadriceps. Meta-analysis of immobilization post lateral patellar dislocation conclude that the evidence base is insufficient to justify the use of immobilization. Physiotherapy regimes include stretching and strengthening exercises, with short arc quadriceps extension, gluteal strengthening and closed chain VMO exercises. Taping and bracing with a patella cut-out have been shown to improve proprioception and stability.

Operative

The surgical technique employed depends on the underlying pathology, and must be tailored to the individual patient. Parikh et al. elegantly summarized the evolution of surgical management in patellar instability, noting there were two schools of thought.[5] Evolving from France, one philosophy was to surgically correct all major risk factors that were customized to that individual patient. The other philosophy was to have a single universal method to treat this group of patients: namely to reconstruct the MPFL, intentionally ignoring some of the other

risk factors. MPFL reconstruction should not, however, be considered as the remedy for all PFI problems. Over time, these two schools of thought have merged, and MPFL reconstruction can be combined along with correction of other additional risk factors.

Isolated lateral release: a lateral release refers to a procedure that incises the lateral stabilizing structures of the patella, in particular the lateral retinaculum, to reduce the lateral force vector of the patella. The intended benefits are reduction in pain and improved stability. Isolated lateral release procedures are now rarely performed, and this is in keeping with current consensus.[10] There are significant complications associated with this procedure, most notably the risk of causing iatrogenic medial patellar instability due to excessive release and, infrequently, there is a risk of potentially defunctioning the lateral quadriceps. The current evidence suggests that the role of lateral release is primarily in congenital conditions and in the treatment of lateral patellar compression syndrome; but even this is perhaps in combination with a tibial tubercle osteotomy.

A lateral lengthening procedure was first described by Biedert et al., who discussed a Z-plasty of the lateral retinaculum. Performing a lengthening instead of a release reduces the risk of many of the complications associated with a release. Most surgeons still, however, concur that an isolated lateral lengthening procedure remains in the realms of treating lateral patellar compression syndrome.

MPFL repair: historically, repair of the MPFL has shown poor results and hence there was an evolution to techniques focussing on reconstruction. A recent paper by Dragoo et al. concludes that both MPFL repair and MPFL reconstruction may lead to clinically acceptable results at 2 years.[11]

However, most of the literature demonstrate relatively high failure rates for repair, and some series reveal a re-dislocation rate as high as 28%.

MPFL reconstruction: MPFL reconstruction was first described by Gomes et al. in 1992. The ultimate goal is to reconstitute a structure that acts as a restraint to prevent the patella from subluxing or dislocating out of the trochlea. The grafts used can be autografts, allografts or synthetic composites. Numerous techniques are described, but the principle is that the graft is attached to the anatomic origin and insertion on the patella and femur via anchors or bony tunnels. MPFL reconstruction can be performed in conjunction with an arthroscopy of the knee, to assess the chondral surfaces, and also be combined with other deformity correction procedures, as discussed below.

Mountney et al. performed a cadaveric study and demonstrated that whilst the MPFL native ligament had a mean tensile strength of 208 N, other techniques including sutures alone (37 N), bone anchors plus sutures (142 N), blind tunnel tendon graft (126 N) were inferior. They demonstrated that the through tunnel tendon graft was not significantly weaker than the native MPFL at 195N.[12]

The literature surrounding MPFL reconstruction demonstrates generally good results. Drez et al. wrote their case series of 19 patients using hamstrings or fascia lata, with a 93% improvement with good or excellent results on the Fulkerson's Functional Knee Score, with mean follow-up of 31.5 months.[13] Nomura et al. published their long-term follow-up of a case series of 24 knees with a mean follow-up of 11.9 years, and showed that 88% had good to excellent outcomes.[14] Liu et al. published their data in 2018, with a minimum 2-year follow-up of 121 isolated MPFL reconstructions in patients with a mean of 4.4 dislocations prior to the surgery. 92% of their patient cohort had Dejour B, C or D trochlear dysplasia.[15] They concluded that for patients without significant patella alta or elevated TT-TG distances, isolated MPFL reconstruction alone using hamstring allo- or autograft provides a safe and effective treatment for PFI.

The success of the MPFL reconstruction rests on three important technical factors:

1. graft positioning
2. graft tensioning
3. graft length.

Graft positioning in MPFL reconstruction – Bollier et al. reported a series of five patients with mal-positioned femoral tunnels leading to early failure. A femoral attachment that is too anterior or too proximal can cause a medial tilt or subluxation.[16] They discuss the ideal point as located at or very close to Schottle's point. In 2007, Schottle's cadaveric study described a reproducible anatomic and radiographic point, 1 mm anterior to the posterior cortex extension line, 2.5 mm distal to the posterior original of the medial femoral condyle and proximal to the level of the posterior point of Blumensaat's line on a lateral radiograph. This point demonstrates the mean femoral MPFL centre.[17]

Zeigler et al. demonstrated that fluoroscopic images taken just 5° out of the true lateral plane can result in a tunnel malposition of up to 9.2 mm, emphasizing that if fluoroscopy is to be used, a true lateral radiograph is important.

Multiple studies demonstrate that mal-positioning of the femoral tunnel changes the isometric properties and increases failure rates. Furthermore, the importance of correct femoral tunnel positioning and graft tensioning appears more important than the type of graft, with respect to restoring normal PFJ kinematics and articular cartilage contact stresses.

The patellar insertion point for the MPFL reconstruction is an equally debated topic. Barnet et al. describe this point on a true lateral radiograph as being 7.4 ± 3.5 mm anterior to the posterior patellar cortical line, and 5.4 ± 2.6 mm distal to the perpendicular line intersecting the proximal patellar articular margin. It is generally accepted that the insertion point of the native MPFL is in the proximal third of the patella, and reconstruction techniques should avoid anchor or tunnel placement below the equator of the patella.

The literature supports a trend of surgeons moving towards anchor fixation, to avoid complications associated with patellar tunnels and patella fractures.

Graft tensioning in MPFL reconstruction – there is debate about how the MPFL should be tensioned. LeGrand et al. described that the graft should be tensioned at 60° knee flexion to prevent over tensioning.[18] This was expanded to the use of 2N of force in 30° to 60° flexion in a cadaveric lab study.[19] Over-constraint of the PFJ due to an over-tensioned graft can lead to increased medial facet contact pressures in the PFJ, predisposing to pain, early failure, medial patellar tilt and osteoarthritis. Another group performed a cadaveric study assessing strain within the native and reconstructed MPFL, and concluded that

tensioning of the MPFL at 45° is preferable to tensioning at 20°, as the strain across the reconstruction then more closely resembles the native MPFL strain state.[20]

Graft length – in a recent anatomic study, Burrrus et al. demonstrated that the graft length in full extension becomes increasing altered if the graft is secured in extension.[21] Hence, their group recommend graft fixation in lower degrees of knee flexion.

Complications of MPFL reconstructions – fracture of the patella is a well-known complication following MPFL reconstruction, particularly with the use of a drill hole technique in the patella. Parikh et al. describes a 3% risk of patellar fractures in their series of 179 knees.[22] The same group a few years prior described a classification system for these fractures. Type 1 is transverse through one of the drill holes, and should be treated with a tension band wire. Type 2 is a superior pole avulsion, and should be treated analogous to a quadriceps avulsion. Type 3 is medial rim fracture, and this is treated with internal fixation.

Other complications include arthrofibrosis, re-dislocation and donor site complications from the harvesting of autografts.

Single or double-bundle techniques – in a recent cadaveric study, Wang et al. found that both single and double-bundle MPFL reconstruction can restore patellar stability. However, the force required to shift the patella 10 mm laterally in the double-bundle technique is higher, thus implying that the double-bundle has a greater propensity to resist patellar dislocations.

Tibial tubercle transfer: tibial tubercle transfers may be required when treating patients with PFI. They should be considered especially when the TT-TG distance is greater than 20 mm (although this cut-off value has been debated) or when patella alta exists.

The types of tubercle transfers could broadly be graded into vector directions. A distalization is employed to correct patella alta. A medialization is employed to treat an increased TT-TG distance. Both can be performed accurately, as preoperative calculations can determine transfer distances. There have been no studies directly comparing the different tibial tubercle transfers amongst a homogenous group of patients. Specific indications for tubercle transfer in the literature are quoted as a TT-TG greater than 20 mm or a Caton-Deshamps index greater than 1.4. It should be noted that in general, tibial tubercle transfers are contraindicated when the physis is still open.

The literature describes good results with combined tibial tubercle transfers with MPFL reconstruction. A randomized control trial by Damasena et al. in 2017 looked at the 5-year follow-up of two groups of patients: a lateral release with a tubercle transfer compared to a MPFL reconstruction with a lateral release and tubercle transfer. The 5-year study confirmed improved alignment parameters (congruence and patellar tilt angle) and improved patient satisfaction in the reconstruction group. However, there was insufficient evidence to conclude superiority of one group over the other in terms of re-dislocations.

Elmslie-Trillat procedure – the Elmslie-Trillat procedure was described in 1964 by Trillat, Dejour and Couette, whereby the tibial tubercle is transferred in a purely medial vector. Barber et al. published their series of 35 knees with a mean follow-up of 8 years, and concluded that the Elmslie-Trillat procedure was successful at eliminating recurrent patellar instability in 91.4% of patients. Modifications of the Elmslie-Trillat have been described, such as making a curvilinear horizontal cut and raising a thick osseous fragment, with suggestions that this might give a higher union rate. The long-term outcomes of the Elmslie-Trillat procedure have been shown it to be a good treatment for eliminating recurrent patellar instability. However, the evidence suggests that there is an increased incidence of arthritic changes of the PFJ following this procedure, thought to be due to increased contact pressures in the PFJ secondary to tightness in the transposed tendon. Nakagawa et al. published their series of 31 knees that underwent an Elmslie-Trillat procedure, and 42% of these knees had definite osteoarthritic radiographic changes at mean follow-up of 161 months. However, studies have been unable to prove a causal effect of the procedure, i.e. address the confounding factor of patellar instability with associated injuries leading to the degenerative changes. Care should be taken to avoid over-medialization, as even 10 mm over-medialization leads to an increase of 27% in contact pressures on the medial facet.

Complications of tubercle osteotomies – fractures of the proximal tibia have been noted with tubercle transfers, and patients are often protected by employing a non-weight-bearing regime post-operatively. Stiffness and non-union of the osteotomy are also significant risks. Specifically with tubercle osteotomies, nearly three quarters of patients may require metalwork removal.

Trochleoplasty: a trochleoplasty can be defined as a procedure that alters the morphology of the femoral trochlea, and the aim of trochleoplasty is to create a centralized groove for containment of the patella. Some experts consider trochleoplasty to be a salvage procedure, given the technical complexity of the procedure. However, many surgeons now believe this procedure has a crucial role in treating patients with high-grade dysplastic trochleas with significant PFI.

One significant advantage of the trochleoplasty procedure is that the trochlear groove centre can be re-created more laterally, thus allowing high TT-TG offsets to be reduced without the need for a concomitant tibial tubercle osteotomy.

Trochleoplasty was first described by Albee in 1915, with bone graft wedges to elevate the lateral trochlear facet. Surgical restoration of the intercondylar groove was then described by Masse in 1978, who described removal of subchondral bone to recreate a central groove. The modified modern day trochleoplasty was popularized by Dejour over a decade later, with an osteotomy of the osteochondral flaps creating a sulcus deepening 'V' groove.

Despite controversial clinical outcomes and technical challenges associated with trochleoplasty, 80% of participants from the patellofemoral study group consensus agreed that there is a role for trochleoplasty, especially in the context of trochlear dysplasia.[10] Furthermore, the group felt this procedure should be referred to high-volume centres due to the technical challenges and associated potential complication profile.

In a very recent systematic review, Balcarek et al. concluded that both MPFL reconstruction and trochleoplasty with extensor mechanism balancing provided significant improvements in patient-reported outcomes. They noted that trochleoplasty with

extensor mechanism balancing had a lower recurrence of instability compared to isolated MPFL reconstruction. On the other hand, however, there is still evidence emerging that for patients with significant trochlear dysplasia but without a significantly elevated TT-TG distance or patella alta, isolated MPFL reconstruction provides a safe and effective treatment for patellofemoral instability. Contraindications include an open physis, similar to tubercle transfers.

Different trochleoplasties lend themselves to different groups of patients, i.e. a sulcus deepening trochleoplasty would be appropriate for Type B and Type D. Dejour et al. acknowledge that the lateral facet elevating trochleoplasty would be appropriate for Type C dysplasia. Dejour's group also acknowledge that they almost always carry out an MPFL reconstruction together with deformity correction of the trochlea.

The literature also supports isolated trochleoplasties, with good clinical outcomes. Camathias et al. discuss their series of 50 isolated trochleoplasties in patients without rotational or axial malalignment with a minimum 2-year follow-up. They conclude that their group of patients had good clinical outcomes. This group also argue that while the MPFL acts as a static checkrein during the first 20° of flexion, a normal trochlea offers stability throughout the full range of motion.

Schottle and Bereiter reported their experience of the Bereiter 'U' trochleoplasty in 2005, with a 3-year mean follow-up. They experienced no re-dislocations, and an 84% subjective improvement. Other studies looking at the Bereiter trochleoplasty demonstrate good outcomes. Nelitz et al. describe 26 knees that had combined Bereiter trochleoplasties with MPFL reconstruction. At mean follow-up of 2.5 years there were no recurrent dislocations, with significant improvement of knee function and patient satisfaction. In 2017, a longer-term follow-up series by Metcalf et al. of 214 consecutive trochleoplasties concluded that trochleoplasty was an effective treatment for PFI, with good medium-term results.[23] They, however, noted an 8.3% re-dislocation rate, with a 14% re-operation rate. Sixteen out of the 27 re-operations were to carry out an MPFL reconstruction (nine) or tibial tubercle transfer (seven). There was an 88% satisfaction rate with the operation, and 90% of patients felt their symptoms had improved.

Apart from the open surgical methods of Dejour and Bereiter, an arthroscopic sulcus deepening trochleoplasty has also been described.

A meta-analysis from 2018 comparing the complication rates after the Bereiter and Dejour trochleoplasties concluded that trochleoplasty leads to outcomes that are within the range of other patellar stabilizing procedures, including MPFL reconstruction and tibial tuberosity osteotomies. They also showed similar results for end points such as re-dislocation, stiffness, and further surgery.

Complications – trochleoplasty is a technically demanding procedure, and as such, it is expected to have a steep learning curve. Complications include PFJ incongruence, arthrofibrosis, and chondral lesions. Recurrence of instability is thought to be rare, however. In 2017, a systematic review compared trochleoplasty to MPFL reconstruction.[24] This systematic review looked at 15 studies and confirmed a re-operation rate of 25% following trochleoplasty surgery, including arthrolysis and removal of metalwork.

Femoral de-rotational osteotomy: increased femoral anteversion is a recognized risk factor for patellar instability. A recent cadaveric study in 2017 confirmed that 20° of internal femoral torsion is a significant risk factor when the MPFL is intact, but only half the degrees, that is 10°, of femoral torsion is required to create significant patellar instability when the MPFL is defunctioned.[25]

Nelitz et al. described their series of 12 patients with combined femoral derotation osteotomy plus MPFL reconstruction, with a mean follow-up of 16 months, and showed there were improvements in the knee scores and no re-dislocations. However, it should be noted that their follow-up was less than 2 years, with a small patient cohort. The same group also wrote up their 2-year results of combined trochleoplasty with MPFL reconstructions, as discussed above.

Tibial de-rotational osteotomy: Drexler et al. reported their results from combined tibial derotational osteotomy and tibial tubercle transfer in 15 knees in patients with external tibial torsion >45°, with a mean follow-up of 84 months, and showed satisfactory outcomes, but with significant complications in 13% of patients.[26]

Fouilleron's group from Lille in France have described one of the largest series of proximal tibial derotation osteotomies, with 94% of the patients achieving satisfactory outcomes. Notably, only five of the cases had preoperative instability and none of this subgroup had a recurrence of their instability.

Treatment of other clinical subtypes of PFI

Acute first-time dislocation

Historically, most first-time dislocations have tended to be treated non-operatively unless associated with large fixable osteochondral fragments or loose bodies. Randomized controlled trials have been available in the literature from over a decade ago confirming no advantage in treating first-time patellar dislocations operatively. These early trials compared non-operative treatment to MPFL repair and/or lateral release, and there was no comparator group to modern MPFL reconstruction.

A more recent trial comparing initial acute surgical stabilization *versus* no surgery demonstrated improved outcomes and reduced redislocation rates in the surgical group, but the authors concluded that this did still not support treating all acute first-time dislocations with surgery. It should be emphasized that the surgery in this study was purely soft tissue.[27]

Liu et al. published expert consensus from the international patellofemoral study group in 2017, using a three-step modified Delphi technique of reporting.[10] The group concluded that non-operative management is the current standard of care for first-time dislocations in the absence of osteochondral fragments or loose bodies requiring excision. There was a 100% concordance with this algorithm. On the other hand, a systematic review by Nwachukwu et al. in 2016 concluded that surgical treatment of first-time patellar dislocations in children and adolescents was associated with a lower risk of recurrent dislocation and higher health-related quality of life and sporting function.[28] The group pooled 11 studies with 470 conservatively managed and 157 surgically operated knees, and found that there were 31% and 22% rates of recurrent dislocation, respectively.

Several other meta-analyses, also published in 2016, report significant reductions of patellar re-dislocations and improved functional scores with surgical treatment following first-time patellar dislocation. Saccomanno et al.'s meta-analysis of nine studies accepts the limitations of heterogeneity in surgical techniques, but does conclude that surgery reduces redislocation rates and provides better results on the Hughston VAS and improved running.

The Cochrane review by Khan and Miller in 2016 concluded that although there is evidence to support surgical over non-surgical management of primary patellar dislocation in the short-term, the quality of evidence is very low due to bias and imprecision in the effect estimates. They conclude that further well-designed studies and longer-term outcomes are needed to establish a firmer conclusion.

Parikh et al. summarize the outcomes after conservative treatment of first-time lateral patellar dislocations succinctly: one third of patients do well, with return to previous levels of function, one third have recurrent instability and require surgical stabilization, and one third of patients do not suffer recurrent dislocation but do suffer persisting symptoms of pain, apprehension and instability, without return to pre-injury levels of activity.[5]

There thus seems to be an evolving change in direction in the management of acute first-time lateral patellar dislocations. Recent papers by Parikh et al. and Balcarek et al. describe algorithms and severity scores that predict which groups of patients would do well with early intervention following primary dislocation[3-5]. These models have not, however, yet been validated externally, but they do offer pragmatic pathways for guiding the management of this group of patients.

Medial patellar instability

Medial patellar subluxation is almost universally iatrogenically induced. Medial patellar subluxation was described by Hughston and Deese in 1988 as a complication in 30 out of the 60 knees that were referred for failure to improve following arthroscopic lateral retinacular release. This complication in the modern era is unacceptable, as there has been a global shift away from isolated aggressive lateral releases.

Surgery in the skeletally immature patient

The paediatric population, with open physes, requires alternative surgical techniques to avoid iatrogenic growth disturbances. Treatment options in the young patient with open physes might therefore include non-operative management until physeal closure.

The Roux-Goulthwaite procedure has been well-described as a procedure to treat paediatric PFI. This procedure involves a medial transfer of the lateral longitudinal split patellar tendon, without advancement. The procedure improves the TT-TG offset without affecting the physis.

Alm et al. describe the modified adductor sling technique for non-anatomic MPFL reconstruction, first described by Sillanpaa.[29] They report that 87% of their group of 28 patients gained excellent postoperative functional scores. However, there was a re-dislocation rate of 13%.

Sillanpaa et al. published their results of MPFL reconstruction with the adductor magnus tenodesis compared to a distal patellar realignment procedure (Roux-Goulthwaite), and concluded that the adductor magnus tenodesis is a reliable option for treating PFI in children.[30]

Conclusion

Non-operative management of first time patellofemoral instability remains the gold standard initial treatment but individuals that are likely to fail are becoming more readily identified. Certain physiological and anatomical characteristics predispose some patients to recurrence and thus allow treating clinicians to manage expectations better and perhaps intervene surgically sooner. Moreover, in the setting of recurrence, individually tailored stabilization surgery is now firmly evidence based provided the surgeon makes every effort to correct all anatomical abnormalities. Surgeons should be able to carry out all facets of patellofemoral stabilization surgery, as it is preferable for surgery to be performed in a single stage since the majority of patients are young and lead active lifestyles.

Key correctable anatomical abnormalities to identify are loss of MPFL integrity, trochlear dysplasia, patella alta and malposition of the tibial tubercle relative to the trochlear groove or PCL origin. Established and proven surgical techniques exist for all corrections.

Almost all patients will display a degree of joint hypermobility, either local or diffuse, and therefore they must be counselled regarding on going rehabilitation and failure of surgery although failure rates are declining as surgical techniques and patient identification improves. ◆

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