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REVIEW ARTICLE

Modern management of patellar instability

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Abstract Recurrent patellofemoral instability is a disabling condition, attributed to a variety of anatomical aetiologies. Trochlear dysplasia, patella alta, an increased tibial tubercle trochlear groove distance of greater than 20 mm and soft tissue abnormalities such as a torn medial patellofemoral ligament and inadequate vastus medialis obliquus are all factors to be considered. Management of this condition remains difficult and controversial and knowledge of the functional anatomy and biomechanics of the patellofemoral joint, a detailed history and clinical examination, and an accurate patient assessment are all imperative to formulate an appropriate management plan. Surgical treatment is based on the underlying anatomical pathology with an aim to restore normal patellofemoral kinematics. We summarise aspects of assessment, treatment and outcome of patellofemoral instability and propose an algorithm of treatment.

Introduction

Recurrent patellofemoral instability is a common problem, with reported rates as high as 44 % following initial non-operative management of a primary incident [1]. Patients present with symptoms of anterior knee pain and episodes of mechanical instability. The relationship between the separate phenomena of subjective "unstable" symptoms and objective patellar dislocation, although inevitably interrelated, has been particularly confusing [2, 3]. In order to differentiate these interpretations of instability, Dejour et al [4] defined objective instability to include patellar maltracking, subluxation or dislocation. Since then, studies have focused primarily on advancing our knowledge of the anatomy and biomechanics of the patellofemoral joint (PFJ), and the treatment of objective patellar instability. Nevertheless, it still remains a difficult condition for clinicians to manage, and lacks a common consensus on management strategies.

This article reviews the anatomy, biomechanics, assessment and current treatment options used to manage "objective" patellar instability.

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Anatomy and biomechanics of patellar instability

The patella is the largest sesamoid bone and is located within the complex of the quadriceps and patellar tendon. It serves as a biomechanical lever, magnifying the force exerted by the quadriceps on knee extension, as well as centralising the divergent forces of the quadriceps muscle and transmitting the tension around the femur to the patellar tendon [5]. Through its articulation with the femoral trochlea, the PFJ forms a highly complex unit with potential for joint instability. PFJ stability is multifactorial and can be categorised into static and dynamic stabilisers.

Static stabilisers

Medial anatomical structures

Static stabilisers provide fixed inhibition to lateral translation of the patella. Absence has been demonstrated to cause up to 49 % reduction in lateral stability at zero degrees of flexion. In addition, lying beneath are three ligaments; the patellofemoral (MPFL), patellomeniscal (MPML) and patellotibial (MPTL). These are the primary ligamentous structures constraining lateral patellar motion, of which the MPFL is the most notable. The MPFL is a continuation of the deep retinacular surface of the vastus medialis obliquus (VMO). It runs transversely between the proximal half of the medial border of the patella to the femur between the medial epicondyle and the adductor tubercle, forming the second layer between the superficial medial retinaculum and the capsule [6]. Studies on cadaveric specimens have shown that the MPFL with a tensile strength of 209 N contributes on average 50–60 % of the total restraining force against lateral patellar displacement [7-10]. Isometry of the MPFL has also been studied to determine whether it influences the angle of immobilisation after reconstruction. Steensen et al determined that the most isometric point of the MPFL is the inferior portion of its patella attachement to the superior portion of the femoral attachment [11]. With this in mind authors have suggested that the key to reconstruction is the position of the femoral insertion to restore isometry [12].

Lateral anatomical structures

The anatomy of the lateral side is more complex. The superficial layer consists anteriorly of the fibrous expansion of the vastus lateralis and the superficial oblique retinaculum further posteriorly. The deep layer mirrors the medial structures and consists of the epicondylopatellar ligament, the deep transverse retinaculum and the patellotibial band which attaches directly to the distal pole of the patella and sends fibres both into the lateral meniscus and into the underlying tibia [13]. The epicondylopatellar ligament, often referred to as the lateral patellofemoral ligament, is not attached to the femur except indirectly via the proximal and distal attachments of the iliotibial band (ITB). Thus the tightness of the ITB (dynamic stabiliser) will influence the lateral stability force inferred by the lateral retinacular structures. The medial and lateral retinacular structures are therefore most effective within the range of 20 ° flexion and full extension, during which the PFJ is most vulnerable due to the lack of resistance offered by other stabilising structures.

Trochlear geometry

Once the patella enters the confines of the trochlea, the bony anatomy allows for inherent stability of the PFJ [14]. The normal shape of the trochlea is a concave trough, with a normal sulcus angle of 138±6° (on Merchant view axial radiographs) [15]. The lateral femoral trochlea extends further anteriorly than the medial side, providing a buttress to lateral patellar subluxation thereby maintaining the patella's centred position in the trochlea. The lateral extremity of the trochlea extends further proximally than it does on the medial side, providing a mechanism for engaging the patella in early knee flexion and deflecting it medially to the centre. Several studies have identified the significance of trochlear geometry, and have demonstrated trochlear dysplasia (both decreased trochlea depth with a low lateral femoral condyle) as an important risk factor for recurrent patellar dislocation [4, 16]

Patella geometry

The patella has a convex articular surface and this congruity between the patella and the trochlea provides some constraint to the PFJ. When the knee begins to bend, the initial contact area is the distal and lateral patella facet. With further flexion the contact area on the patella articular surface moves more proximally until in deep flexion where the medial facet has then made contact. The shape of the patella, however, does not always follow the groove exactly as demonstrated by Wiberg patella variations [17]. A type III patella, representing 25 % of all cases [15], has a small and convex medial facet, leaving only the lateral facet in contact with the trochlear. Bony patella anatomy is unlikely to be of significant relevance and one should consider the overlying cartilaginous shape as a more important factor.

Patella height

Patellar height also contributes to PFJ stability. Trochlear geometry is such that it encourages early "catchment" of the patella during the flexion arc. Engagement of the patella depends entirely on patella height. With patella alta, engagement into the trochlear does not occur in the early phase of knee flexion, thus potentiating instability at the PFJ [4].

Limb alignment

The importance of the "Q" angle is well recognised [18]. This is measured as the angle between the pull of the quadriceps and the axis of the patella tendon. In males, the "Q" angle is 8 to 10° and in females it is 15 ± 5°. An increase in the "Q" angle results in an increased valgus vector to the PFJ. Genu valgum, increased femoral anteversion, external tibial torsion and/or a lateralised tibial tuberosity can all ultimately affect patella tracking.

Dynamic stabilisers

A great deal of patellar stability is conferred actively through the quadriceps complex. Both the VMO and lateralis muscles have distal portions that deviate from the parallel anatomical axis of the femur. The VMO muscle fibres have a pull of 47 ± 5° degrees from the femoral axis and the vastus lateralis obliquus 35 ± 4° lateral from the femoral axis [19]. The obliquely aligned VMO provides a mechanical advantage to promote a medial stabilising force to the patella. This mechanism enhances vastus lateralis efficiency during knee extension. The synergistic relationship is important in maintaining alignment of the patella within the trochlea. The VMO overlies and merges with the MPFL, acting together to provide both active and passive stabilisation of the patella. In vitro studies have found that complete VMO relaxation reduced the patellar lateral stability significantly, especially at 20° flexion where stability was least [16, 20]. In addition, Dejour et al [4] correlated VMO insufficiency to patellar tilt. Lateral patellar tilt (as defined by the angle intersection made from a line along the lateral slope of the trochlea groove and with a line through the widest diameter of the patellar on axial views) greater than 11° proved to be the most sensitive measure and occurred in 93 % of patients with objective patellar instability [21]. As well as influencing the patella in a lateral-medial direction, the vastii muscles also exert a posterior force vector. This force stabilises the patella within the trochlear groove [19].

Clinical evaluation

The management of patellar instability begins with the identification of risk factors. A detailed history helps differentiate acute from chronic instability, as well as excluding osteoarthritis, osteochondral pathology and anterior cruciate ligament injuries. First time dislocators tend to be female adolescents in the second decade of life, as indicated by the largest prospective study to date [22]. Fithian et al [23] demonstrated that the redislocation risk was highest amongst girls aged ten to 17 years. They found that further risk of instability was more likely in this age group (49 %) compared to first time dislocators on older women (17 %).

Physical examination includes assessment of acute dislocation (deformity and swelling that may mask a persistent lateral subluxation of the patella), lower limb alignment in coronal, sagittal and axial planes, evidence of joint hyper laxity (as objectively measured by the Beighton hypermobility score) and measurement of the "Q" angle [24]. Palpation of the patella may reveal a palpable defect at the medial patellar margin and tenderness along the course or at the insertion of the MPFL. If VMO disruption has occurred, there may be visible atrophy of this muscle. The patella is often small and sits high, with evidence of hyper mobility in the lateral and medial directions [25]. Patella tilt may be produced by laxity in the medial structures or by a tight lateral retinaculum. Patella glide can be assessed at 30 ° knee flexion and should be less than two quadrants in a medial and lateral direction. Excessive lateral retinacular tightness is indicated by limited medial passive patellar glide. Other specific patellar examinations include the patellar grind test and presence of the "J" sign to test for dynamic patellar tracking. These tests are non-specific and have been noted to be absent in most cases of instability. The most reliable test for patellofemoral instability is the apprehension test. The examiner holds the relaxed knee in 30 ° of flexion and manually subluxes the patella laterally. When the test is positive, the patient complains of pain and anxiety, resisting any further lateral motion of the patella.

Radiological evaluation

Different modalities have been described to investigate the PFJ [26, 27]. Standard anteroposterior radiographs, although limited, are necessary to exclude osteochondral fractures, osteoarthritis of the tibiofemoral joint and loose bodies. Lateral radiographs yield information relating to patella height which can be quantified, using the Insall-Salvati [28, 29], Blackburne Peel [30] and Caton Deschamps [31] indices or with using Blumensaats line [32]. Trochlear depth can be quantitatively elucidated from true lateral views, with reports of 85 % sensitivity for this measurement in cases of objective patellar instability [21]. Dejour et al [4] reported that trochlear dysplasia can be defined by the crossing sign (present in 96 % of cases) which is quantitatively expressed by the presence of a trochlear bump greater than 3 mm (present in 66 % of cases) (Fig. 1). The principal radiological method of analysing the trochlear groove geometry is by means of skyline patellar views, pioneered by Merchant [33]. This allows measurement the sulcus angle. the congruence angle of Merchant to identify lateral translation [33], and the lateral patellofemoral angle of Lauren to identify lateral tilt [34].

Computed tomography (CT) can provide a three dimensional view of the PFJ. Images can be created at different degrees of knee flexion, as well as performing dynamic

Fig. 1 Lateral radiograph demonstrating a positive "crossing sign". The base of the trochlear (*arrow*) crosses the line of the lateral femoral condyle

investigation (Figs. 2 and 3). Studies have reported CT scans to be more accurate and sensitive in detecting abnormal tracking, tilt and subluxation [35, 36]. Their main advantage lies in the assessment of lower limb alignment, femoral anteversion, and lateralisation of the tibial tubercle (tibial tubercle to trochlear groove offset) [4]. Tibial tuberosity offset greater than 9 mm has been shown to identify patients with patellofemoral mal-alignment with a specificity of 95 % and a sensitivity of 85 % [37]. A tibial tubercle to trochlear groove distance of greater than 20 mm is virtually always associated with patella instability.

Magnetic resonance imaging (MRI) scans should be considered the gold standard investigation. As well as providing reliable images of soft tissue and articular surface, studies and measurements similar to those made with CT scans can be easily accomplished without exposure to radiation and no need for invasive CT arthrogram. MRI can be helpful in demonstrating chondral defects of the PFJ, patellar and trochlear dysplasia, tilting of the patella, patella height, tibial tubercle offset, the lateral condylar index [38], avulsion fragments, and the integrity of the retinacular or patellofemoral ligamentous structures (predominantly the MPFL) [39]. Sallay et al [40] demonstrated that the rupture of the MPFL from the femur could be clearly seen on both sagittal and axial T2-weighted views, more so with the advent of high resolution MRI [41]. Studies have shown that the articular cartilage contour is different from that of the underlying bony contour, especially in cases of patellofemoral dysplasia, making MRI a useful adjunct especially when planning surgery [42, 43].

Conservative management

Patellar instability is generally perceived as a difficult condition to treat, despite the improved understanding of the extensor mechanism and the PFJ. Many surgical procedures have been described for the treatment of instability, but surgical intervention should be reserved until conservative measures have failed and the chronic recurrent nature of the disease has caused significant functional impairment. In the acute phase, the immediate goals are to reduce inflammation, relieve pain and limit activities that place excessive loads on the PFJ. Acute phase management should involve anti-inflammatory analgesia, ice therapy, elevation and a period of immobilisation. A study by Mäenpää and Lehto [44] suggested that a period of immobilisation may be beneficial. In their study of 100 acute dislocations, they found fewer re-dislocations in patients who had a period of immobilisation; the authors suggested a period of three weeks to avoid muscle atrophy and joint restrictions. The study is limited, however, by being retrospective and non-randomised. It is the authors' opinion that immobilisation of more than a few days can, in fact, have a devastating effect on quadriceps muscle function, necessitating further rehabilitation. Others have advocated the beneficial use of patellofemoral braces to allow weight bearing as much as pain allows [45-47]. The goal of bracing is to restore proper alignment and protect against re-dislocation and subluxation, while at the same time allowing for quadriceps strengthening during the rehabilitation programme. Muhle et al [45], however, demonstrated no significant effect on patellar tracking when bracing was used. Other methods of stabilising the patella include patellar taping (McConnell method) [48, 49]. Although there is yet to be a randomised controlled clinical trial regarding efficacy of taping, the theory is to restore proper alignment and shorten the medial retinacular tissue and MPFL, providing stability for the disrupted tissue [49]. Taping the patella has also been found to activate the VMO earlier than vastus lateralis, and such timing changes have beneficial effect on patellofemoral mechanics, promoting movement of the patella into the trochlea groove early in flexion [48].

Fig. 2 CT arthrogram demonstrating trochlear dysplasia

Conservative management seems to be the treatment of choice in patients with acute patellar dislocation, provided that the generally accepted indications for surgery, such as evidence of osteochondral fragments and major defects of the parapatellar ligament complex are excluded. However, the lack of bony restraint in some cases, make conservative muscle rehabilitation very difficult, so surgical assistance to improve the passive stability of the joint may be required.

Surgical management

Operative intervention is appropriate for those recurrent patellar subluxations or dislocations, and in those where conservative treatment has failed. In acute circumstances, indications for surgery include complicated dislocations

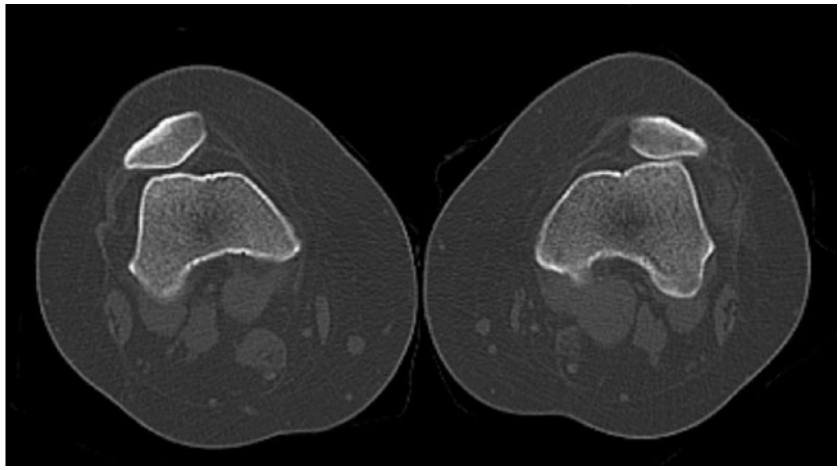


Fig. 3 Axial CT scan of bilateral patellar lateral tilt

with associated osteochondral fractures. Any primary arthroscopic surgery should be conducted with caution. Surgery may address either bony or soft-tissue components, in a proximal or distal procedure, however the gold standard of surgical treatment is yet to be clearly defined in the literature with over one hundred surgical techniques described in the literature.

Lateral release

Historically, lateral retinacular release was commonly performed, but isolated lateral release as a separate procedure for the treatment of instability became popular in the 1970s [50], with the belief that a tight lateral retinaculum predisposed to lateral patellar subluxation or dislocation. Even though some authors have published satisfactory results for this procedure [51, 52], most studies have shown disappointing mid and long-term results [53, 54]. Overzealous or inappropriate lateral release can lead to further medial patellar instability. Often with post-operative scar contraction the lateral retinaculum can be tighter than prior to initial surgery. Isolated lateral release should only be used as an adjunct to proximal or distal realignment procedures or medial retinacular repair [54-56]. Isolated lateral release may however also be used for treating a stable patella with excessive lateral pressure associated with an increase in lateral patellar tilt.

Medial repair

Since the recognition of the importance of the MPFL, there has been increasing interest in different techniques for managing the medial stabiliser. A multitude of surgical options have been described, ranging from repair, imbrication (reefing) or plication of the medial retinacular structures [57-59]. These procedures can be performed in an open, arthroscopic or as an open-arthroscopic technique. A further technique of medial retinacular repair involves radiofrequency thermal reefing [60]. Most of these procedures described are commonly performed in conjunction with a lateral release, and results have been encouraging. Results of these repairs have shown re-dislocation rates of up to 89 % [57-62]

A recent study demonstrated that medial reefing alone yielded similar results to combined procedures of medial reefing and lateral release, with no incidence of re-dislocation or subluxation [63]. Desio et al [8] explains why there is no biomechanical advantage to performing a lateral release. They demonstrated that the MPFL provides 60 % of the lateral displacement restraint, but surprisingly, the lateral retinaculum also provided 10 % of the lateral restraint. This is in agreement with Fithian et al [50] who stated that a lateral release has no role in the treatment of a hyper-lax PFJ and should be used judiciously on a case by case basis.

MPFL reconstruction

More recently, there has been increasing attention towards MPFL reconstruction within the orthopaedic community. Reconstructions using various different soft tissue harvest grafts have been documented, including semitendinosus [64-67], gracilis [68, 69], quadriceps tendon [70], adductor magnus [71-73] and even a mesh-type artificial ligament [74, 75]. The femoral attachment can be secured through a variety of different methods, including a bone block on the graft, screw and washer, or EndoButton™ fixation. A newer technique, using a single soft tissue graft with fixation on the femur without bulky hardware has been described [76, 77]. This technique describes a transverse patella double tunnel technique with femoral fixation using a bio-absorbable interference screw. To date many differing techniques have been described. A systematic review of the literature demonstrates no one technique to be superior. Despite this reconstruction of the MPFL has demonstrated excellent clinical results across a number of series, with low levels of re-dislocations [64, 78-81]. MPFL reconstruction offers an appropriate treatment modality in a chronic situation. The differing techniques all offer satisfactory results with the most likely factor for good outcome being surgical exposure and ensuring appropriate care is taken to tension the MPFL in the flexion arc.

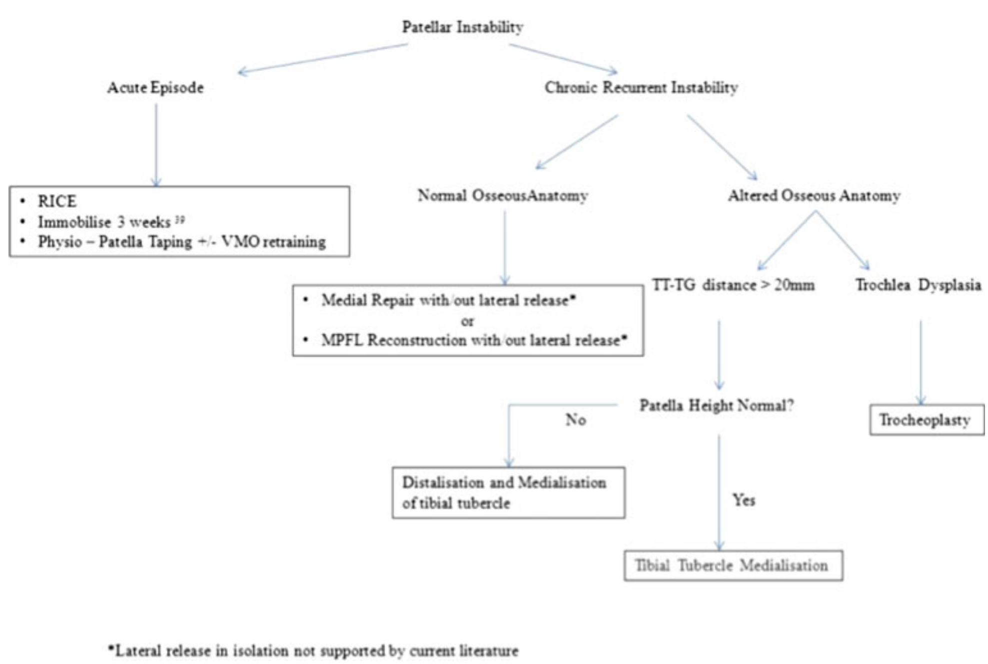
Bony realignment procedures

Several tubercle realignment procedures have been described. A common form of malalignment is a large Q angle or increased tibial tubercle to trochlear groove offset. Reducing the Q angle by medialising the tibial tubercle insertion has long played a role in patellar realignment surgery. The Elmslie-Trillat procedure [82] involves lateral retinacular release, medial capsule reefing and medial transposition of the anterior tibial tubercle hinged on a distal periosteal attachment. Such proximal and distal combined techniques have been reported to have excellent outcomes [83-85]. Despite the overall results of the Elmslie-Trillat procedure being satisfactory and effective in resolving patellar instability, it is not as successful for patients whose main complaint is anterior knee pain [86-89]. Furthermore, its clinical results are believed to deteriorate with time, with a concomitant increase in the incidence of PFJ arthritis [90]. Carney et al [84] found the prevalence of recurrent subluxation (7 %) in patients with patellofemoral malalignment who underwent Elmslie-Trillat procedure to be similar at three and 26 years, lower than the previous documented rate of 13 % at a mean follow-up of 13.5 years reported by Nakagawa et al [90]. However, the same study also identified that the long term functional outcome of the study population declined. At 26 years, 54 % of patients rated good or excellent functional scores compared to 73 % at three years [84]. It has also been suggested that Elmslie–Trillat procedures may lead to overloading of the medial patellar articular surface, leading to patellofemoral arthritis [90, 91]. When one considers that this surgery is conducted in young patients, long term follow-up of 20–30 years to categorically clarify whether these procedures are worthwhile is unavailable.

Other surgical intervention on the tibial tubercle include distalisation in cases of patella alta with instability [92-94]. Distalisation of the tibial tubercle during the procedure can inherently induce medialisation due to tibial torsion, and thus can result in over medialisation [95]. This phenomenon should be included in the calculations for the desired correction in order to avoid excessive medialisation. Tracking should also be checked intra-operatively to avoid excess correction. A modification of the Elmslie-Trillat procedure has also been described where patellar ventralisation is also conducted in addition by 2–2.5 cm. This confers the advantages of bone graft been consolidated quickly with a minimal requirement for osteosynthesis [96].

To avoid potential loading of the medial patellar facet, there is increasing popularity of the Fulkerson procedure. This entails medialisation of the tibial tubercle in order to correct the Q angle with anteriorisation of the tubercle. The anteromedialisation of the tibial tubercle elevates the distal pole of the patella, which in turn reduces contact on the distal patella during early knee flexion, thus potentially alleviating anterior knee pain symptoms and preventing arthritic progression. Fulkerson and associates reported 93 % good and excellent results subjectively and 89 % good and excellent results objectively [97]. A review of their results demonstrated an overall 74 % of their 42 patients as having good or excellent results at an average of 8.2 years

Fig. 4 Algorithm for managing patellar instability



postoperatively [98]. More recently, Tsuda et al reported a significant improvement in Fulkerson and Kujala scores in 62 knees that underwent Fulkerson procedure with or without lateral release [99]. At an average follow up of 120 months, median Fulkerson scores improved from 65 to 95, and the median Kujala score from 68 to 92 [100]. Potential disadvantages of this procedure, however, include the more invasive nature of the operation, a larger osteotomy, more reports of tibial fracture, and a prolonged rehabilitation including a period of protected weight bearing [101].

Trochleoplasty

Trochleoplasty is a very technical and demanding procedure with variable outcome. Authors have suggested that in most cases, trochlea dysplasia is mild and well tolerated by patients [4]. This technique is indicated in severe dysplasia with a trochlear bump of greater than 6 mm, trochlear dome, abnormal patellar tracking and/or failed previous surgery [95]. More recent in-vitro analysis provides objective biomechanical data to support the use of trochleoplasty in the treatment of patella instability for trochlea dysplasia [102]. Many methods of deepening trochleoplasty have subsequently been described (lateral facet elevating and sulcus deepening) although results are largely variable and discouraging [68, 103-105]. These procedures also have short follow-up and represent a fairly major insult to trochlear anatomy. The technique of trochleoplasty has been shown to prevent recurrent instability, but concerns remain about ongoing pain due to damage of the articular cartilage, trochlear necrosis, arthrofibrosis and incongruence of the patella [106]. In one of the largest studies on trochleoplasty to date, Von Knoch et al reported that ten (23 %) cases of 35 had osteoarthritic changes in the PFJ and 15 (33 %) had worsening patellofemoral pain [107]. This technique (Berieter technique) currently remains the gold standard of treatment.

Patellar osteotomy

With a dysplastic patella the possibility of conducting a longitudinal patella osteotomy exists. Lateral positioning of the patella can result in increases in patellar pressure [108]. By performing a lateral osteotomy the medial facet can improve the medial contact of the facet in the trochlear groove and has been reported to have good analgesic effect in the literature [109, 110]. This procedure, however, is a relatively rare surgical technique.

Conclusion

Patellofemoral instability is a combination of several anatomical abnormalities. Accurate assessments, understanding of biomechanics and anatomy and appropriate investigation to quantify the pathology are imperative to help the surgeon plan an appropriate treatment strategy. Treatment of patellofemoral instability is difficult especially when determining choice of surgical intervention. Review of the literature recommends that non-operative modalities remain the predominant form of treatment for both acute and recurrent cases. In cases where surgical treatment fails the surgical strategy should aim to restore normal anatomy of the joint and will often involve a combination of techniques addressing both soft tissue and osseous anatomical abnormality. We have summarised the most common procedures based on current available literature and propose a treatment algorithm to facilitate clear cut guidelines for this interesting and difficult topic (Fig. 4).

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