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REVIEW ARTICLE

Current clinical, radiological and treatment perspectives of patellofemoral pain syndrome

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ABSTRACT

Anterior knee pain in active young adults is commonly related to patellofemoral pain syndrome, which can be broadly classified into patellar malalignment and patellar maltracking. Imaging is performed to further elucidate the exact malalignment and maltracking abnormalities and exclude other differentials. This article details the role of the stabilizers of the patellofemoral joint, findings on conventional and multimodality imaging aiding in patellofemoral pain syndrome diagnosis and characterization, and current perspectives of various treatment approaches.

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is the most common cause of anterior knee pain in active young adults. PFPS is defined as anterior knee pain involving the patella, retinaculum and adjacent soft tissues, after excluding intra-articular pathology of the knee. It is a chronic disease caused by overuse and misuse, rather than acute trauma and is broadly classified into two categories, patellar malalignment and patellar maltracking.¹ PFPS is a challenging diagnosis for clinicians and radiologists alike, and many differential considerations exist. Radiographic, CT and MRI evaluations are commonly employed to further elucidate the PFPS-related lesions^{2,3} and exclude other related differential diagnoses, such as lateral meniscus tear, extensor tendon tear, anterior tenosynovial giant cell tumour and plica syndrome. This article comprehensively discusses the role of many static and dynamic stabilizers involved in the biomechanics of the PF joint, findings on conventional radiography and cross-sectional imaging that aids in the diagnosis and characterization of PFPS, and current perspectives of various management (conservative and surgical) approaches.

ANATOMY AND BIOMECHANICS

The patella is a sesamoid bone within the substance of the quadriceps tendon and acts as a fulcrum for the extensor mechanism of the knee joint, increasing the quadriceps

power by 33–50%.⁴ Related to considerable load bearing capacity, patellar articular cartilage is the thickest in the body, measuring up to 4–6 mm in a young healthy adult. At rest, the upper three-fourth of the posterior patella articulates with the femoral trochlear sulcus while its contact area with trochlea changes throughout its range of motion. It rests laterally in full extension, engages in the trochlea at 30° of flexion, and moves more distally with increasing flexion. The lateral femoral condyle is larger than the medial condyle in anteroposterior (AP) dimensions, which prevents the lateral translation of the patella acting as a static stabilizer. Surrounding the patella, are three distinct fat pads (Hoffa's, quadriceps, and pre-femoral fat pads) and three distinct bursae (pre-patellar, superficial infrapatellar and deep infrapatellar bursae). Anatomic and developmental variations of patellar shape and height are common and these include variations in size of patellar facets (Wiberg types), odd facet, which is an additional medial facet (innermost) that articulates with the femur beyond 120°,⁵ and inferior pole elongation.⁶ Bipartite patella represents an accessory ossicle, which may be present along its superolateral, inferior or medial borders. Generally, thicker the patellar facet, thicker the overlying cartilage. Therefore, the lateral facet (Wiberg Type II and III) usually has the thickest cartilage while odd facet exhibits the thinnest cartilage.

Patellar stability mainly relies on soft tissue constraints around the anterior knee. From 0 to 30° of flexion, the

quadriceps tendon, the medial and lateral retinaculae, and the patellar tendon act as the static stabilizers, supported by vastus medialis obliquus muscle, which provides dynamic stability limiting the maltracking.⁷ The medial retinaculum has central thickenings, which are named according to structures they connect along its craniocaudal direction, *i.e.* the medial patellofemoral ligament (MPFL), medial patellomeniscal ligament and medial patellotibial ligament.⁷ The MPFL is the most important soft tissue static constraint to lateral displacement of the patella contributing about 53%.⁸ At >30° of flexion, the stability relies mainly on bony constraints.⁹ As the knee flexes, the primary restraint is the height and slope of the lateral femoral condyle. Increasing trochlear dysplasia is associated with lesser energy required for lateral dislocation of patella.¹⁰

PATHOPHYSIOLOGY

The exact genesis of pain in PFPS is still unclear. The pain is hypothesized to be generated at the insertions of the extensor muscles, retinacula, Hoffa's fat pad and subchondral bone.^{11–14}

Central mechanisms may also contribute to pain in PFPS. A decreased pain threshold and abnormal sensory mechanisms have been found to play a role in pain genesis.^{15,16}

Psychological contributions to pain in PFPS such as high levels of mental stress, altered pain experience and coping mechanisms have also been shown to play an important role.^{17,18}

Secondary gain in underperforming young athletes has been identified as a causative factor.¹⁴

PATELLOFEMORAL DISORDERS AND CLINICAL FEATURES

Patellofemoral (PF) malalignment refers to the relationship between the patella and the trochlear groove in the static position which is not centrally congruent, but becomes lateral or medial, or

abnormally high or low position of the patella, namely patella alta and baja, respectively. PF maltracking refers to abnormal translation of the patella with respect to the trochlea on extension or flexion—similar to malalignment, but in a dynamic position. It usually occurs laterally due to the greater pull exerted by the quadriceps on the lateral aspect (tut vastus lateralis obliquus), but can sometimes be medial as well. PF impingement refers to abnormal contact of the patella with the femur leading to friction with the fat pads and subsequent cartilage loss. The most common height abnormalities are patella alta and baja.^{1,2} Patella alta refers to a high-riding patella, which can be associated with lateral patellar subluxation and tilt, as the elongated patellar tendon allows increased mediolateral translational mobility and axial rotation of patella due to suboptimal engagement in the apex of trochlear sulcus. It also predisposes to chondromalacia patellae, stripping of patella along its anterior surface (enthesopathy) and patellar tendon rupture. A low-riding patella (patella baja) is seen in the settings of quadriceps tendon rupture, neuromuscular disorders, achondroplasia and after surgical realignment of the tibial tuberosity. The other abnormalities include excessive patellar tilt, painful bipartite patella, tight lateral retinaculum and excessively loose medial retinaculum.

The typical clinical presentation is an active young adult with gradual onset of anterior knee pain associated with a grinding sensation perceived on movement. The pain is often bilateral, usually more on one side, and is typically worsened by climbing or squatting activity, described by the patient “giving away or slipping”, which is due to the inhibition of the quadriceps.¹⁹ It is difficult to localize and the patient may just place their hand on the knee or circumscribe the patella, referred to as the circle sign.²⁰ A locking or catching sensation after prolonged flexion of the knee (rising from a seated posture) is observed, referred to as the “movie theatre sign”.^{13,21}

On physical examination, one may identify several deformities, which can cause malalignment anatomy and PFPS. The typical

Table 1. Commonly used patellofemoral joint measurements

Measurement	Normal value	Definitions
Insall-Salvati ratio	0.8–1.2	The ratio of the patellar tendon height (inferior pole of patella to middle to tibial tubercle notch) to the patellar height (oblique distance including the whole patella and exclusion of the osteophyte).
Blackburne-Peel ratio	0.8–1.0	The ratio of the distance measured from the inferior patellar articular surface to the horizontal line along the tibial plateau to the height of patellar articular surface.
Patellar tilt	<8°	The PF angle formed between the lines drawn along posterior condyles of the femur at the level of thickest trochlear cartilage and the lateral patellar facet.
Patellar subluxation	<2 mm	The lateral or medial displacement of the patella with respect to the trochlear groove, >2 mm distance between the margins of medial pole of patella and medial trochlear facet; or median ridge of patella with respect to apex of the trochlear sulcus.
Lateral trochlear inclination	>11°	The angle formed between the lines drawn along posterior condyles of the femur at the level of thickest trochlear cartilage and the lateral trochlear facet.
Trochlear depth	>3–5 mm	The depth of the trochlear groove, best measured at 3 cm above the tibial plateau or at the femoral physeal scar.
TT–TG distance	<9 mm	Distance from centre of tibial tubercle to the apex of trochlear groove parallel to the tangential lines drawn through the posterior femoral condyle.
Sulcus angle	138 ± 6°	The angle formed between the lines along the anterior tips of the medial and lateral femoral condyles to the deepest point of the intercondylar sulcus.

TG, trochlear groove; TT, tibial tubercle.

Figure 1. Insall-Salvati ratio: patellar tendon length/patellar length (a/b). (c) Modified Insall-Salvati ratio: c/d. Normal value: 0.8–1.2.

Figure 2. Blackburne-Peel ratio: distance from the inferior patellar articular surface to the horizontal line along the tibial plateau/the height of patellar articular surface: x/y. Normal value: 0.8–1.0.

“miserable malalignment syndrome” refers to the combination of internal rotation or antetorsion of the femur, “squinting” patellae which is due to femoral anteversion causing the patellae to point inwards, proximal tibial varus/external rotation, knee valgus and pes planus. Distal vastus medialis atrophy may be apparent.

The Q angle is the angle between the line joining the anterior superior iliac spine and the centre of the patella, and the second line joining the centre of the patella to the tibial tubercle. It can be measured both at flexion (15–20°) and extension, however, it may not be accurate in extension due to lateral patellar displacement. Traditionally measured with the patient supine and quadriceps relaxed, there has not yet been a standardization of the position and state of muscle contraction while measuring the Q angle.^{22,23} It is an indicator of the net lateral force exerted on the patella by the quadriceps and the patellar tendon.²⁴ Q angle of more than 14° in males and more than 17° in females suggests abnormal lateralization of the tibial tubercle.^{25,26} Dynamic valgus may be observed on one-legged squats. Abnormal foot pronation and altered position of patella, as seen from side and front are helpful clues. The tubercle Sulcus angle can be measured with the patient sitting with knees flexed to 90°. A line perpendicular to the palpable transepicondylar axis is compared to line passing through the centre of the patella and tibial tubercle. An angle >10° is abnormal.

RADIOLOGICAL EVALUATION

Radiography (X-ray)

The initial evaluation typically involves standard AP and lateral views. AP view of both knees primarily evaluates the tibiofemoral joint but may show multipartite patella, gross patella alta and lateromedial subluxation. Patellar height is best assessed on the lateral view and qualitatively, the patellar height should approximate patellar tendon height. The commonly evaluated Insall-Salvati ratio (ISR) and Blackburne-Peel ratio are described in Table 1^{27,28} (Figures 1 and 2). An ISR ratio of >1.2 indicates alta and <0.8 indicates baja. Some literature suggests values of 1.5 and 0.74 respectively.²⁸ The ISR does not account for variations in patellar morphology. To compensate for this, Grelsamer et al described a modified index in which the distance between the inferior articular surface of the patella and the patellar ligament insertion is divided by the length of the patella articular surface, and patella alta, with modified ISR, is defined as a ratio of >2.²⁹ The Blackburne-Peel ratio similarly provides a better representation of the position of the patella and a ratio of >1.0 indicates alta and <0.8 indicates baja.²⁷

Axial radiograph of the PF joint shows patellar translation and axial rotation along with morphology of the trochlea. The Merchant view³⁰ is obtained with the knee flexed at 45° and the X-ray beam aimed caudal 30° from the plane of the femur, making the positioning of X-ray tube easier and the technique more reproducible. It is also easier to perform in the obese or those with large tibial tubercles when other views may not be as informative. A standing, loaded Merchant view has been found to be superior in the evaluation of PFPS due to a more accurate representation of joint kinematics.³¹ Laurin view is obtained

Figure 3. Trochlear inclination: angle between the lines drawn along posterior condyles of the femur at the level of thickest trochlear cartilage and the lateral trochlear facet. Normal value: $>11^\circ$.

Figure 4. Trochlear depth: the depth of the trochlear groove, best measured at 3 cm above the tibial plateau or at the femoral physal scar. Normal value: $>3-5$ mm.

with the knee flexed at 20° and, even though difficult to obtain, detects not just severe abnormalities but also subtle changes in patellar tracking.³² Patellar translation measurement is described in Table 1^{1,33} and more than 2 mm is abnormal. The congruence angle is another less frequently used measurement to evaluate patellar translation. It is formed by a line drawn from the median ridge of the patella to the deepest point of the intercondylar sulcus and a line bisecting the trochlear sulcus angle.³⁰ The angle lying towards the medial side is expressed as a negative, with the normal range being -8 to -14 , and $>14^\circ$ suggests lateral subluxation of the patella. Patella can axially rotate especially with tight lateral retinaculum (aka excessive lateral pressure syndrome). Qualitatively, the patellar body and femur condyle should be parallel. The PF angle should open laterally and more than 8° is normal. With increasing patellar tilt, it becomes negative and opens medially.

Trochlear morphology affects PF joint stability. Shallow trochlear groove and/or prominent lateral ridge can result in malalignment.³⁴ Qualitatively, a triangle of trochlear facets should be seen on axial view and the patella should fit within the apex of the trochlear sulcus. The lateral trochlear facet should not be more than 60% of the overall anterior trochlear articular width. While measurements of trochlear inclination and depth have been described (Table 1) (Figures 3 and 4), a simple measurement is the “sulcus angle”, drawn between the lines along the anterior margins of the trochlear facets to the deepest point of the intercondylar sulcus. The normal angle ranges from $138^\circ \pm 6^\circ$, and an angle measuring $>144^\circ$ indicates trochlear dysplasia.³⁵ It allows greater reproducibility as it is reasonably insensitive to the angulation between the beam and the femur. A trochlear depth $<3-5$ mm also indicates dysplasia.^{33,34}

Figure 5. X-ray demonstration of various patellofemoral and extensor compartment abnormalities. (a) Patella alta, (b) lateral patellar tilt, (c) inferior bipartite patella, (d) patellar dislocation, (e) quadriceps tear, (f) patellar tendon tear, (g) patellar dislocation with avulsion fracture and (h) patellar fractures.

Figure 6. Spectrum of patellar cartilage abnormalities on MRI. (a) Chondromalacia and bipartite patella, (b) cartilage fissures and small defects, (c) large cartilage lap, (d) delamination, (e) large full-thickness defect with cartilage fragments in lateral gutter and (f) complete denudation.

When the patella becomes displaced only during active contraction, as in the case of mild to moderate maltracking, static X-rays often fail to diagnose it.³⁶ As the degree of flexion decreases, skyline views become progressively more difficult to obtain and significant abnormalities may, therefore be overlooked.³⁷ Thus, it has been suggested that the skyline view alone should not be used to make surgical decisions.³⁸ Figure 5 shows various PF pathologies commonly seen on plain radiographs.

Cross-sectional imaging

CT and MRI present multiple advantages over radiography and provide both static and dynamic data. Static CT and MR images allow evaluation of patellar and trochlear morphology and above described measurements on two-dimensional and three-dimensional scans, while MRI provides superior assessment of

soft tissues including PF cartilage abnormalities, active anterior patellar enthesopathy, patellar and quadriceps tendinopathy/tears, retinacular assessment including MPFL integrity, friction-related superolateral and pre-patellar fat pad oedema (which is indicative of maltracking), and pre-patellar or deep infrapatellar bursitis^{39,40} (Figures 6–8). MRI is also radiation free and allows evaluation of plica, lateral meniscus and other synovial abnormalities that can mimic symptoms of PFPS. For the required degrees of flexion, the back of the knee may be raised, or devices may be used to bring about passive flexed position. The axial radiograph typically evaluates the inferior portion of the trochlear groove, not where the high-riding patella would articulate. Therefore, trochlear morphology is best assessed on cross-sectional imaging. In addition, the surrogate marker of tibial tuberosity lateralization, *i.e.* Q angle is altered by the patient

Figure 7. MRI of extensor mechanism abnormalities leading to PFPS. (a) Jumper's knee with patellar tendon tear, (b) chronic tendinopathy, (c) symptomatic bipartite patella, (d) acute on chronic enthesopathy, (e) quadriceps fat pad oedema, (f) superolateral and pre-femoral fat pad oedema. PFPS, patellofemoral pain syndrome.

Figure 8. MRI of vastus medialis and patellar retinaculum pathologies. (a) Axial T_1 W image showing vastus medialis atrophy (arrow), (b) Axial T_2 W fat suppressed image showing MPFL tear from the patella (arrow), (c) Axial T_2 W image showing MPFL tear from femur (arrow), (d) Axial T_1 W image showing subacute MPFL tear with haematoma. MPFL, medial patellofemoral ligament.

position, rotation of the limb and the degree of knee flexion. It is better and indirectly assessed on cross-sectional imaging using the tibial tubercle–trochlear groove (TT–TG) distance^{41,42} which can be measured on both axial CT and MRI^{43,44} (Figure 9). The normal TT–TG distance is <9mm, and >20 mm is considered indicative of symptomatic lateralization of tibial tubercle, where surgery can correct it.⁴⁵ It is highly sensitive to the femoral alignment and femorotibial rotation, and errors in measurement are possible if the protocols for obtaining axial images are not standardized.⁴⁶ MRI combines the accuracy of CT with the ability to visualize soft tissues and also directly depicts the articular cartilage lesions,^{1,47} and can aid in individually tailored treatment plan.⁴⁸ Post-operatively, MRI can be used to evaluate the status of the repaired tissue and complications (Figure 10).

In a recent systematic review and meta-analysis by Drew et al, certain imaging findings were shown to have a higher correlation with PFPS than others, namely, an increase in the CT congruence angle, both weighted and non-weighted, when measured at 15° flexion and an increase in the MRI bisect offset when measured under load and with no flexion.⁴⁹ Lankhorst et al concluded that

Figure 9. TT–TG distance: distance from centre of tibial tubercle to the apex of trochlear groove parallel to the tangential lines drawn through the posterior femoral condyle. Normal value: <9 mm

PFPS patients exhibit a larger Q angle, sulcus angle and patellar tilt angle (Figure 11).⁵⁰

Dynamic imaging

Static imaging does not evaluate the effect of active muscle contraction on the patellar position, expected during knee movements. Dynamic imaging allows assessment of the PF joint kinematics and evaluation of real-time interplay of soft tissue and bony constraints.^{2,51,52} However, due to the needed technical expertise and time limitations, dynamic imaging is not routine. It is generally employed to investigate suspected patellar maltracking in patients with PFPS symptoms without, otherwise, evident anatomic malalignment. It is also used to assess subclinical patellar subluxation and the impact of treatment in patients with recurrent subluxations.⁵³ This method requires a good degree of patient compliance and the examination may not be possible in patients with severe pain. Kinematic MRI using gradient echo or steady-state sequences using a surface coil can produce the desired T_1 W or T_2 W contrasts, respectively, and these techniques can produce 3–6 images per second, which can easily capture PF kinematics while patient actively flexes and extends the knee in the MR gantry.⁵⁴ Four-dimensional CT (4DCT) can show similar motion where three-dimensional CT volume acquisitions of the knee are performed during flexion–extension motions. Typically, a 256-slice multidetector CT can generate 16-cm long field of view. Four-dimensional CT has been shown to be feasible in evaluation of PF joint for altered biomechanics and risk stratification for development of osteoarthritis² (Figure 12). However, it involves radiation exposure as opposed to MRI. It remains to be seen, whether widespread use of these advanced techniques can improve patient outcomes.

TREATMENT

The aim of treatment is to address various underlying factors contributing to the patient's symptoms and restore dynamic balance, thereby correcting the improper kinematics and alignment. The treatments are divided into conservative and surgical approaches. Conservative treatment for 3–6 months is the management of choice in the initial stages, but failure of conservative management may necessitate the surgical management.

Figure 10. Spectrum of post-surgical changes related to patellofemoral compartment. (a) Lateral retinacular release, (b) patellectomy, (c) patellar tendon repair with small post-operative ossification, (d) quadriceps tendon repair with remodelling.

Conservative treatment

Patients with PFPS may demonstrate lower hip abduction and external rotation strength, and lower peak knee extension torque.⁵⁰ Conservative treatment options for patients with PFPS include improving the lower extremity biomechanics and modifying lifestyle through enhancing flexibility, correcting gait and retraining with proper techniques and adequate rest, all of which necessitate sufficient pain control.^{55,56} Quadriceps strengthening program is a common rehabilitation technique, which attempts to strengthen the knee extension weakness and has consistently been shown to aid in improvement.⁵⁷ The vastus medialis, particularly obliquus, draws a lot of attention due to its role in the medial stabilization of the patella. There is some evidence that selective muscle strengthening resolves pain and improves knee function, and is also helpful to prevent relapses.⁵⁸ However, it has largely been agreed upon that overall quadriceps strengthening shows no difference in the short-term outcomes.^{56,57,59} Patellar taping (McConnell method) aims to control the patellar tilt, glide and/or spin, and causes an inferolateral PF shift leading to wider distribution of forces.^{60,61} Braces and orthotics are all regarded as adjuvant to PF rehabilitation and quadriceps strengthening. Patellar stabilizing bracing is best used in the “maltracking” patients.⁶² Semi-rigid foot orthotics absorb shock and provide medial longitudinal arch support leading to pain reduction and improved functional

performance.⁶³ Lower baseline functional scores, increased midfoot mobility, reduced ankle dorsiflexion and the use of less supportive shoes are all predictors of positive response with the use of orthotics.^{63,64} Cryotherapy, ultrasound, phonophoresis, iontophoresis, neuromuscular electrical stimulation etc. for pain control have been not been found to have any significant benefit in PFPS.⁶⁵ Patients with unilateral symptoms, low body height and young age tend to respond better to the conservative treatments.⁶⁶

Surgical treatment

Surgical treatment may be considered when there is a clear identifiable or correctable lesion and if the patient exhibits no improvement after strict adherence to conservative therapy for >6 months. A “tool-box” approach is typically followed with treatment tailored as per every individual patient's needs, which, along with patient selection, is important to ensure a successful outcome with minimum complications. To consider surgery, one of the following documented findings must be present apart from failure of conservative management: malalignment (abnormal Q angle or increased TT-TG distance), tight lateral retinaculum (patellar tilt/translation), or articular cartilage lesions. Arthroscopy is used prior to the definitive procedures to localize and quantify chondral lesions, isolate and debride chondral flaps, identify and resect plica, and to rule out other intra-articular pathologies. Lateral release is indicated for truly tight and symptomatic lateral retinaculum (lateral patellar compression syndrome). While technically simple, it has gradually fallen out of favour as an isolated procedure as it does not produce lasting effects.⁶⁷ Tibial tubercle realignment is a more favoured procedure in skeletally mature patients to offload the lateral PF joint and different techniques exist (Table 2).^{68–71}

Figure 11. Patellar tilt: angle between the lines drawn along posterior condyles of the femur at the level of thickest trochlear cartilage and the lateral patellar facet. Normal value: <8°

In symptomatic patients with an insufficient MPFL, it can be reconstructed by multiple techniques. However, some controversies do exist regarding graft selection, fixation, position and tension and there is, yet, no consensus on the best approach. Fixation of auto- or allograft to the patella is the main challenge, which can be done by sutures, suture anchors or bone tunnels. Anatomic placement of the graft is ideal.

Figure 12. 4DCT of Knee with cine captures showing patellar maltracking. Patient 1: (a) extended position showing bilateral patellar tilt and subluxation, (b) flexed position showing near normal alignment, right > left. Patient 2: (c) extended position showing bilateral patellar tilt and subluxation, (d) flexed position showing near normal alignment of the right knee, and further patellar dislocation of the left knee. 4DCT, four-dimensional CT.

Table 2. Tibial tubercle realignment procedures

Procedure	Direction of TT transfer	Result	Remarks
Elmslie-Trillat–transverse osteotomy	Medial	Restores TT–TG	Contraindications: medial facet chondral injury, varus knee, medial compartment OA, medial meniscectomy
Maquet–Long transverse osteotomy, using bone graft	Anterior	Unloads PF joint	Suited for: PFPS, OA
Fulkerson–oblique osteotomy	Anterior + medial	Combined	Suited for: PF instability with lateral/distal chondral injuries
Hauser (historical)	Posterior + medial	Overloads PF joint Due to posterior displacement	

A recent systemic review identified the complication rate of MPFL reconstruction at 26.1%. The major complications were patellar fracture, postoperative instability, flexion loss and persistent pain.⁷²

CONCLUSION

Anterior knee pain due to PFPS is a common problem among the young. Its definitive diagnosis and treatment are challenging due to the complex interplay of multiple anatomical and developmental variations. Good clinical and radiological evaluation is

integral to its management and the treatment must be individualized to the patients.

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AC: Consultant ICON Medical, Royalties: Jaypee, Wolters.

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