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REVIEW ARTICLE

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Imaging assessment of anterior knee pain and patellar maltracking

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Abstract Anterior knee pain is a common complaint in the orthopaedic clinic. The differential diagnosis is wide and the principal goal of initial assessment is to detect remediable causes. The majority of patients do not have a specific disease and increasingly interest has focused on the role of patello-femoro-tibial morphology and of patellar maltracking in the aetiology of anterior knee pain. Classification in this group of patients is poor and there is no uniform agreement on which patient groups benefit from treatment and which treatment is best. Much of the literature involves relatively small numbers of patients, is poorly controlled and there is little agreement on outcome measures [1, 2]. The purpose of this review is to outline the current status of the imaging assessment of recalcitrant anterior knee pain with particular reference to patellar maltracking.

Keywords Magnetic resonance imaging · Knee joint · Patellar movement · Kinematic studies · Biomechanics

Introduction

Anterior knee pain (AKP) may affect up to one third of adolescents at any time [3]. The majority of patients are female and the symptom most commonly occurs in the second and third decades. The increase in prevalence has been attributed to the rise in sporting activity in schools[4]. Sports which involve persistent knee flexion associated with jumping, such as basketball, athletics, skiing and cycling, are particularly susceptible. The pain is often described as being worse on compression of the patello-femoral joint, such as occurs during ascending or descending stairs or rising out of a chair. In many cases the symptom is self-limiting although it may follow a prolonged and unremitting course lasting several years.

Clinical examination in the patient with AKP is directed at determining remediable causes. Particular attention is paid to the anterior structures, patellar tendon, quadriceps tendon, Hoffa’s fat pad and the anterior portions of the menisci [5]. The examination should also be extended to include the hip and foot.

Clinical context

A list of causes of AKP is shown in Table 1. Of these the commonest are chondromalacia and focal patellar tendinopathy, with patellofemoral osteoarthritis (OA) becoming more prevalent in the older population. Many patients do not demonstrate these conditions and there is increasing interest in the role of patellar malalignment and maltracking. Two distinct subgroups can be identified. The first is transient patellar dislocation, where the patellar has subluxed following trauma and then has spontaneously reduced. Although a history of trauma is nearly always present, patients are not always aware that the patella had dislocated. The associated soft tissue disruption that accompanies the dislocation, principally tears of the medial retinaculum, may predispose to further episodes of dislocation, in a similar manner to recurrent dislocation of the shoulder. This has also been called acute patellar dislocation or acute reduced patellar dislocation. The second distinct entity is chronic patellar maltracking. In these cases there is no history of trauma and, in the majority, the patient is unaware of abnormal patel-

Table 1 Differential diagnosis of anterior knee pain

Patellar tendon	
	Tendinopathy
	Rupture
	Osgood Schlatter's disease
	Sindig Larsen's disease
Quadriceps tendon	
	Tendinopathy
	Rupture
Patella	
	Chondromalacia
	Patello femoral osteoarthritis
	Stress fracture
	Frank fracture
	Painful bipartite patella
	Osteochondritis patella/femoral groove
	Transient patellar dislocation
	Chronic patellar maltracking
Hoffa's fat pad	
	Hoffa's ganglion
	Synovitis
	PVNS
	Osteochondromatosis
	Hoffa's impingement syndrome
	Synovial haemangioma
	Gout
	Chondroma
	Sarcoma
Miscellaneous	
	Anterior meniscal tear
	Meniscal cyst
	Neuroma of infrapatellar nerve
	Pre/infra-patellar bursitis

lar movement. Patellar subluxation is assessed clinically with the knee fully extended. The patella is gripped between thumb and forefinger and the examiner attempts to displace it laterally. Displacement of greater than 25% of the patellar diameter constitutes a subluxable patella. Reports on the accuracy of clinical examination in the detection of patellar maltracking are sparse. Fithian et al. [6] used a mechanical device to assess patellar motion and were able to differentiate between control patients and those with transient patellar dislocation. There are no studies of the accuracy of clinical assessment in patients with chronic patellar maltracking though it is generally recognised that many cases are overlooked.

Differential diagnosis of AKP

The list of causes of anterior knee pain is long (Table 1). The imaging diagnosis of the more common conditions is straightforward. Focal proximal patellar tendinopathy, or jumper's knee, so called because of its relationship to sports including basketball and soccer, is easily detected by high-resolution ultrasound or magnetic resonance imaging (MRI). On MRI the patellar tendon is best visualised in the sagittal plane. Patellar tendinopathy is easily seen as an area of tendon swelling and increased signal intensity on T2-weighted or gradient echo T2*-weighted sequences (Fig. 1). Partial tendon tears with high signal intensity without tendon swelling are rare (Fig. 2). In younger patients the adjacent bone may also be involved. This is most common at the tibial insertion, where the condition is called Osgood Schlatter's disease (Fig. 3). Complete patellar tendon rupture is also rare without a predisposing cause, and is most commonly seen following patellar tendon section for anterior cruciate ligament reconstruction. Quadriceps rupture is more common, particularly in the older population, and is also most frequently encountered when there are predisposing conditions such as diabetes, steroid use, connective tissue disease or renal disease. Chondromalacia is fragmentation of the articular surface of the patella (Fig. 4). It has been graded into four types: cartilage softening, fissuring, defect to bony and bony involvement. MRI is best at assessing grades 3 and 4. Reliable detection of grades 1 and 2 probably requires MR arthrography[7]. Chondromalacia must be distinguished from the painless dorsal patellar defect, the occasionally painful bipartite patella [8, 9], the usually painful patellar stress or frank fractures (Fig. 5) and osteochondritis of the patella or patellar groove [10]. In the older patient, retropatellar disease is more often associated with cartilage thinning and subchondral cyst formation on the anterior aspect of the lateral femoral condyle as patello-femoral OA, though crystal deposition disease may also result in considerable destruction of articular cartilage. Osteochondritis may present as anterior knee pain, recurrent swelling, locking or giving way. The most common site is on the lateral aspect of the intercondylar region of the medial femoral condyle. The lateral femoral condyle or patella may also be affected (Fig. 6). Hoffa's fat pad can harbour a number of conditions including meniscal cyst, ganglion cyst (Fig. 7) or inflammatory changes secondary to femorotibial impingement (Fig. 8), termed Hoffa's syndrome. It may also be the primary and initial site for diseases of the synovium including pigmented villonodular synovitis or synovial osteochondromatosis (Fig. 9). Rarer synovial tumours in this location include synovial haemangioma (Fig. 10) and lipoma arborescens (Fig. 11). Synovial plicae have been implicated in the aetiology of anterior knee pain though this is controversial. Plicae are very common in the asymptomatic population, occurring in up to 50% of some post-mortem series. A rare cause of anterior knee pain is post-traumatic neuroma affecting the infrapatellar branch of the saphenous nerve [11].

The diagnosis of chronic patellar maltracking is more problematic and it is this that forms the main thrust of this review.

Aetiology: morphology or biomechanics?

The knee comprises three joints, the patello-femoral articulation and the medial and lateral tibio-femoral joints.


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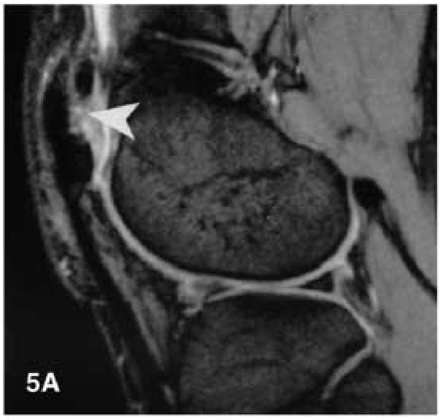
2


3
LEFT KNEE


4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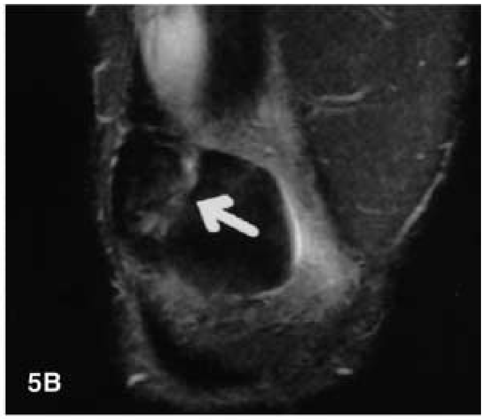
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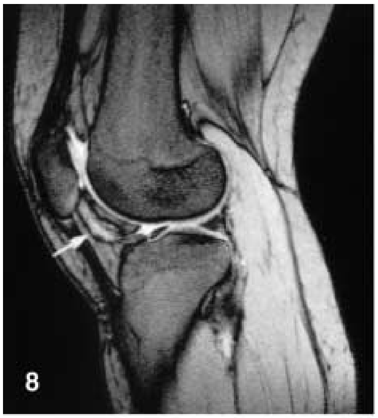

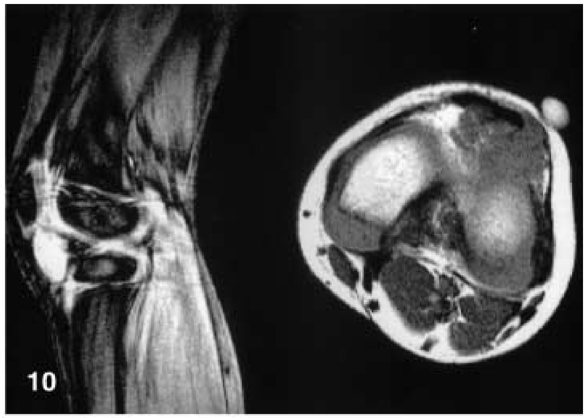

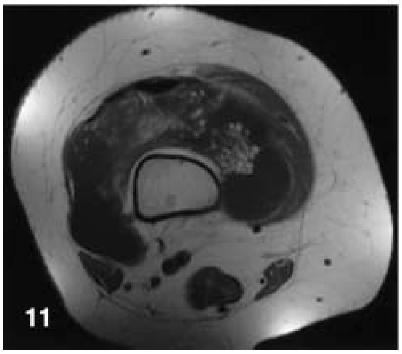

Fig. 8 Calcification (*arrow*) within Hoffa's fat pad secondary to Hoffa's impingement syndrome

Fig. 9 Osteochondromatosis of the fat pad

Fig. 10 Synovial haemangioma on sagittal GRE (**A**) and axial T1-weighted images (**B**). Slight lobulation on the T1-weighted image provides a clue to the diagnosis in what are otherwise non-specific findings

Fig. 11 Axial T1-weighted image showing a frond-like fat pattern within the suprapatellar bursa: lipoma arborescens

The patello-femoral joint bears little load whilst standing, with the greatest pressure occurring between 30° and 70° of knee flexion, particularly when jumping. The principal components of the extensor mechanism are the quadriceps and patellar tendons separated by the sesamoid patella. Soft tissue support to the extensor mechanism comes from the medial and lateral retinacular structures. The principal constraint to lateral displacement is the medial retinacular complex, the most important component of which is the medial patello-femoral ligament. In addition to these ligamentous structures, the lowermost fibres of the vastus medialis muscle (vastus medialis obliquus) that insert into the upper and medial margin of the patella, are also thought to be important in stabilising the patella during motion.

Although the precise mechanism of maltracking is not fully elucidated, a number of authors have drawn attention to morphological abnormalities of the distal femur, proximal tibia and patella that may predispose to abnormal movement. The two principal relationships are the degree of lateral deviation of the patellar tendon as it advances towards its insertion, and the fit between the patella and distal femur.

The former can be assessed clinically by palpating the anterior superior iliac spine (ASIS), the patella and the tibial tubercle. The angle between the line joining the ASIS and patella and the line joining the patella and tibial tubercle is termed the Q angle. An increased Q angle is usually the consequence of a more laterally positioned tibial tubercle, which exerts a lateral pressure on the patella as the knee is extended. If that force is not counteracted by muscle contraction, usually by the lower oblique fibres of vastus medialis muscle, lateral sublux-

◀ **Fig. 1** Proximal focal patellar tendinopathy with high signal at the patellar tendon origin (*arrow*) on a GRE T2*-weighted image. The tendon itself is swollen

Fig. 2 Partial patellar tendon tear with high signal changes without swelling

Fig. 3 Osgood Schlatter's disease with tendon swelling and abnormal signal at the patellar tendon insertion. GRE T2*-weighted image

Fig. 4 Chondromalacia patellae grade 4 with bone defect (*arrow*) and patella alta

Fig. 5A, B Fracture of the patella not appreciated clinically. The fracture is seen on the sagittal GRE image (**A**) as a poorly defined high signal focus (*arrowhead*). The linear fracture is better appreciated on (**B**) the coronal STIR image (*arrow*)

Fig. 6 Osteochondral defect on the inferior surface of the lateral femoral condyle. A high-intensity line separates the surface fragment from the underlying condyle. An incidental popliteal cyst was noted. GRE T2*-weighted image

Fig. 7 Multiloculated ganglion within Hoffa's fat pad (*arrow*) on a GRE T2*-weighted image ation occurs. Eckhoff and co-workers [12, 13] have demonstrated differences in both femoral anteversion and tibial rotation in patients with anterior knee pain compared with asymptomatic controls. The symptomatic group had 7° of relative external rotation of the tibia and 5° of femoral anteversion. They concluded that it is these rotational anomalies that most influence the Q angle and trochlear-tubercle distance (TTD).

There is some variation in the reported normal Q angle, with ranges between 10° and 22°. There is also disagreement on the significance of the Q angle in the aetiology of anterior knee pain. In a cohort of school children with anterior knee pain, no difference between the symptomatic and asymptomatic sides was detected. Patients with unilateral pain are often found to have similar Q angles on both sides [14] when assessed by clinical examination. Fairbank et al. [4] compared lower limb morphology in 310 UK school students without anterior knee pain with 136 of their contemporaries with anterior knee pain. Joint mobility, the Q angle, genu valgum and anteversion of the femoral neck were not significantly different between those pupils with and those without anterior knee pain . These and other studies have cast doubt on the relevance of the Q angle in patients with anterior knee pain alone. When anterior knee pain is associated with patellar malalignment, there is better evidence of causation. Ando et al. [15] found significant differences between patients with recurrent patellar dislocation and normal controls, suggesting that an increased Q angle may predispose to patellar dislocation during injury. McNally et al. [16] have shown that there is an increasing likelihood that maltracking will occur as the Q angle, as measured on MRI, increases.

Other morphological abnormalities that predispose to maltracking include a shallow femoral groove, poor congruency between patella and femoral groove and lateral femoral condylar dysplasia. Poor congruency can occur as a result of a shallow femoral groove or an abnormally flat retropatellar surface. Wiberg [17] has classified retropatellar shape into three types. The commonest is type 2, which is characterised by a lateral facet larger than the medial. The type 1 medial facet is similar is size to the lateral. These shapes encourage good congruency between patella and femur. Least common is type 3, where the medial facet is tiny and the large lateral facet is rather flat. Thus the patella is less well contained within the femoral sulcus and subluxation occurs more easily. Whether patellar shape is the primary defect or the consequence of a deficient notch or patellar position is not clear.

Patello-femoral congruency can be measured using a variety of lines and angles. These are summarised in Fig. 12. Whilst variations in retropatellar shape are relatively rare, morphological abnormalities of the intercondylar groove are more common, and include a shallow flattened groove[18] and lateral condylar dysplasia.

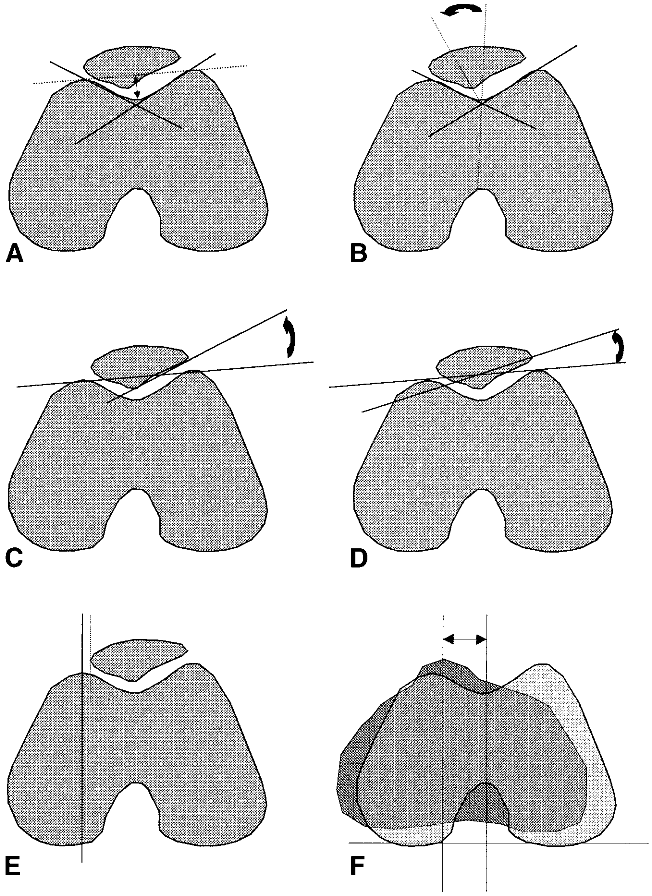

Fig. 12 **A** The sulcus angle is the angle formed by the medial and lateral walls of the intercondylar groove (*continuous lines*). Sulcus depth is also shown (*double arrow*). **B** The congruence angle formed between a line bisecting the sulcus angle and a line joining the nadir of the groove and the apex of the patella (*arrow*). **C** Lateral patellar angle, between the lateral retropatellar facet and a line joining the tips of both femoral condyles (*arrow*). **D** Patellar tilt angle measured between a line drawn between the anterior tips of both femoral condyles and a line bisecting the medial patella and the tip of the lateral facet (*arrow*). **E** Patellar lateralisation, the distance between the medial margin of the patella and medial femoral condyle. **F** The tibial tubercle distance (*double arrow*) is calculated as the distance between two sagittal lines, the first through the deepest portion of the femoral groove, the second through the apex of the tibial tubercle

A shallow femoral groove is characterised by an increased sulcus angle (>150°) and a decreased sulcus depth (<5 mm). The position of the patella within the groove is given by either the congruence angle (8–13°) or the lateral patellar distance. A laterally positioned patella (negative congruence angle or deviation >5 mm.) is associated with a high specificity for maltracking, though tracking disorders can also occur when these values are normal. Patellar tilt is assessed by the lateral patellar tilt angle (22–27°) or lateral patellar angles (6–10°). Some doubt has been cast on the reliability of patellar tilt measurements for predicting maltracking and these angles are often found to be unchanged following successful re-alignment surgery.

Although abnormal morphology appears to predispose to maltracking, others have stressed the importance of abnormal biomechanics, which can cause maltracking by themselves or augment the effects of abnormal anatomy. Overuse is the cause cited in these instances, with blame attributed to the rise in school sports. Incoordination in various muscle and tendon groups has been implicated, with most attention directed at the role of a weak vastus medialis obliquus (VMO). It has been argued that VMO weakness allows the patella to track laterally [19], although not all agree that this is important clinically. VMO strengthening exercises are generally recommended as one of the early conservative treatments, though it has been argued that the VMO is difficult to isolate and train separately from the remainder of the quadriceps mechanism and most patients find general quadriceps strengthening easier to accomplish [20]. Other musculotendinous units that are considered important in the aetiology of maltracking are a tight ilio-tibial tract, hamstrings and hip adductors.

Imaging assessment

Plain radiography

Standard plain radiographs play little part in the assessment of patello-femoral maltracking. The lateral view does not demonstrate the patello-femoral joint in profile unless care is taken to angle the beam properly [21]. They can be used to assess the height of the patella with respect to the patellar tendon. The patella/ patellar tendon ratio (PTR) is used to determine patella alta (Fig. 4) or baja. Patella alta is associated with anterior knee pain [22], patella subluxation and dislocation. Normal values for PTR depend on its mode of calculation. On plain radiographs, the ratio used is PT length to the bony height of the patella, which is usually less than 1.3. Higher ratios result if only the cartilage containing the portion of the patella is used for measurement, a method which clearly only applies to MRI.

More useful is the skyline view taken with the knee in flexion. Various angles of flexion have been proposed, with 20°–30° degrees the most popular as this is the angle at which the lateral retinaculum is at its greatest tension and the patella is most at risk of subluxation[23, 24]. It is also the minimum flexion angle at which this view can be obtained. Static radiographic examinations have good sensitivity for patellar malalignment in patients with previous dislocation [25] but may fail to demonstrate more moderate patellar maltracking[26], where the patella becomes displaced only during active contraction. A further difficulty with skyline views is that they cannot be acquired with the knee in flexion of less than 30° [27] when the patella lies outside femoral groove. Thus the bony stabilisers (sulcus depth, angle and congruence) can be assessed but the dynamic soft tissue stabilisers cannot. Significant abnormalities may therefore be overlooked[28]. Using MR, Koskinen et al. [29] also demonstrated better reproducibility of congruency measurements nearer to 0° of flexion . This and other studies have led Walker et al. [27] to conclude that the skyline view has no role in the assessment of maltracking and surgical decisions should not be based upon it.

Cross-sectional imaging

Static images

The MR appearances of transient patellar dislocation are easily recognised. In the majority of cases the patella has reduced spontaneously by the time the patient seeks medical advice and in many cases the diagnosis is unsuspected clinically. Kirsch et al. [30] reported the MR features in 26 patients with patellar dislocation and found disruption or sprain of the medial retinaculum in 25 (96%), lateral patellar tilt or subluxation in 24 patients (92%), lateral femoral condyle contusion in 21 patients (81%), osteochondral injury in 15 patients (58%) and joint effusion in all 26 patients (100%) (Fig. 13).

In patients with chronic maltracking, static images are often normal. Measurement of the Q angle can be made directly by CT by acquiring a full-length scout view[15]; this is more difficult with MR. The Q angle cannot be measured directly on axial cross-sections, but an equivalent measurement, the trochlear-tubercle distance (TTD) can be calculated using MRI or CT[31]. The TTD is defined as the distance between a sagittal line drawn through the nadir of the intercondylar groove and a parallel line that bisects the tibial tubercle (Fig. 12). McNally et al. showed that a TTD of 2 cm or greater has a high specificity but poor sensitivity for maltracking (Fig. 14). Other anatomical measurements that have high specificity but poor sensitivity for maltracking include a femoral groove less than 5 mm and displacement of the lateral margin of the patella 5 mm or greater beyond the lateral femoral condyle. Patellar lateralisation is relatively uncommon in the normal population [32, 33].

Patellar shape shows some correlation with anterior knee pain [34] but a correlation with maltracking has not been demonstrated. The relative rarity of the type 3 flat retropatellar surface may obscure this relationship. Patella alta predisposes to Osgood Schlatter’s disease [35], anterior knee pain [22] as well as maltracking. A ratio on MR of greater than 1.3 is significant [36] though caution should be exercised with variation on the common type II patellar shape [34]. Ratios calculated using plain films which compare the bony patellar height with the tendon length are often higher; Simmons and Cameron [37] found a mean ratio of 1.6 in a group of patients with recurrent pa-

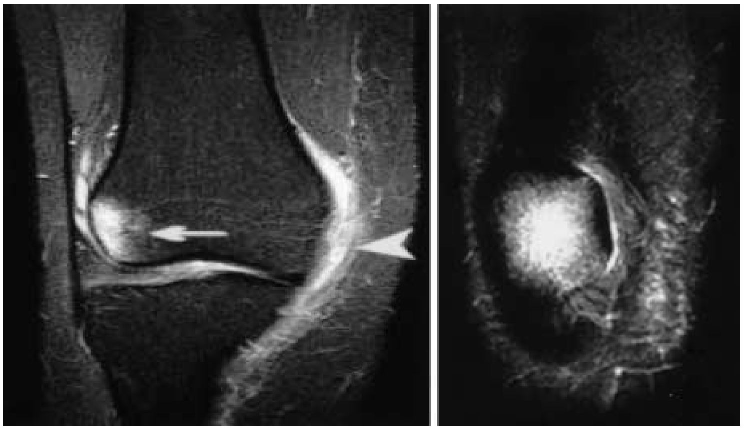

Fig. 13 Transient patellar dislocation with trabecular microfracture on the lateral femoral condyle (*arrow*) and medial retropatellar facet (*arrow*) and disruption of the medial retinaculum (*arrowhead*)

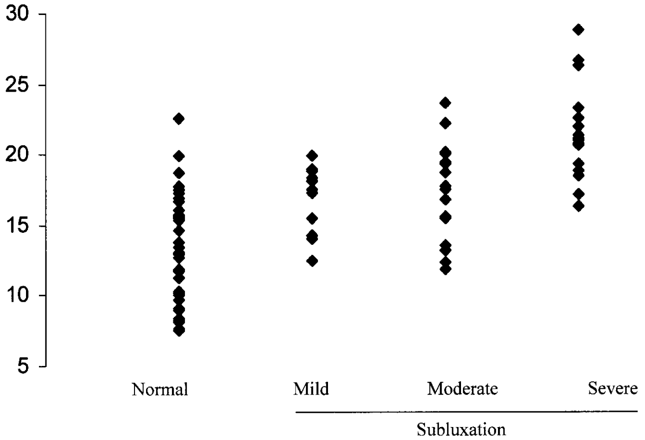

Fig. 14 Relationship between increasing tibial tubercle distance (TTD) and patellar maltracking. The majority of normal patients and those with mild maltracking had a TTD of less than 20 mm

tellar dislocation. This marked difference probably reflects the different populations being studied, as patients with recurrent dislocation might be expected to have more severe derangement. A relationship between anterior knee pain and a progressive increase in patellar tilt has been demonstrated by Pookarnjanamorakot et al. [38] who have shown a mean angle of 13° in patients with anterior knee pain compared with 6° in an asymptomatic group. Maltracking has also been associated with increasing patellar tilt.

Axial MR and CT can also be used to calculate femoral anteversion and tibial torsion. Axial sections through the femoral neck, femoral condyles and proximal tibia are used to make these estimations. Both sides should be included for comparison.

Dynamic assessment

Dynamic MR provides an apparently sensitive and reproducible technique for demonstrating normal and abnormal patellar motion, both before and after realignment surgery [39]. Designing a gold standard is not straightforward. There are no direct studies comparing clinical assessment and MRI, though it is generally recognised that clinical examination does not detect all cases; in particular, accurate clinical examination of patellar motion is difficult when the bony landmarks are difficult to feel. There is better correlation between MR and arthroscopic detection of maltracking, though it is doubtful that an assessment carried out under general anaesthesia, with a tourniquet in place in a knee distended by saline as it is for arthroscopy, is a true reflection of the normal physiological status.

There are two methods for studying patellar tracking, with most of the recent literature supporting the use of true dynamic or kinematic methods [40] – though not all agree [41]. Earlier studies used the system of static scans followed by incremental movement and re-scan, which has been termed “static-dynamic”. The principal problem related to this approach was that muscle relaxation between each movement, when the images are acquired, allowed the patella the opportunity to return to its normal central position, resulting in a false negative examination. True kinematic studies require that the images are obtained during active extension, preferably against a loaded quadriceps. This has led to the development of a number of CT- or MR-compatible motion devices. A variety of designs have been proposed but the principle of these devices is relatively constant. They allow a range of motion between approximately 40° and full extension with free and unconstrained patellar movement. Advantages of a restraining device include its ability to reduce lateral or rotary motion of the femur during extension while allowing unconstrained movement of the patella and the patellar tendon [42]. Whilst lateral movement of the knee joint does not obscure patellar maltracking the relatively fixed position of the femur makes diagnosis easier. Inadvertent fixation of the patella will obscure abnormal movement and should be avoided. This is particularly important with techniques that examine the patient in the prone position when the knee must be elevated sufficiently to allow full and free patellar movement. The restraining devices also allow for the attachment of motion triggering devices. Various motion-triggering devices have been described [43, 44], the principal ones using either the intrinsic ECG or respiratory gating mechanisms within the magnet itself. These can then be preprogrammed to trigger images at particular points in the flexion-extension cycle. Disadvantages of motion devices include their relatively high cost.

With newer faster imaging techniques, motion triggering and restraining devices are less necessary. In the technique used by the author, the knees are supported on a foam cushion, which allows approximately 30° of flexion. The knees are loosely constrained by strapping them together, which prevents excessive lateral motion. Quadriceps loading is achieved by placing an inflatable ball between the patient's ankles and the roof of the magnet. The ball is sealed by a valve situated at the end of a long plastic tube, which can be opened at the start of the manoeuvre. When ready, the patient releases the valve and slowly extends the knee against the resistance of the deflating ball. During extension a series of fast gradient echo sequences are obtained, using a TR of 11 ms, a TE of 4.2 ms and a 15° flip angle. Image degradation by motion artefact is minimal using this technique. A sequence of seven 5 mm slices, six axial and one sagittal, are acquired in 8 s on a 480×580 matrix. The axial slices are positioned to include the full proximal excursion of the patella as the knee extends. The sagittal image is orientated along the long axis of the patella. This sequence is repeated 15 times giving a total imaging time of 2 min. Post-processing involves selecting the axial slice closest to the centre of the patella in each of the 15 sequences and compiling these into the final image set, which is viewed using a cine-loop facility.

Assessing patellar motion

Patellar tracking can be assessed in two ways. The first involves serial measurement of various parameters that reflect the relative position of the patella with respect to the femur, at each point throughout the full range of motion. Many of the usual measurements that have been described above can be used. These include lateral patellar angle, congruence angle, lateral patellar deviation and tilt. The principal difficulty with angle and distance measurement is their application to a method where the interosseous relationships change during the examination. As the knee extends the patella rides up the femoral notch. This makes relating measurements on the patella to a fixed point on the femur difficult. Attempts have been made to reduce these errors by standardising both the examination and analysis techniques. Powers et al. [45] encourage patients to extend at a rate of 9 deg/min, which

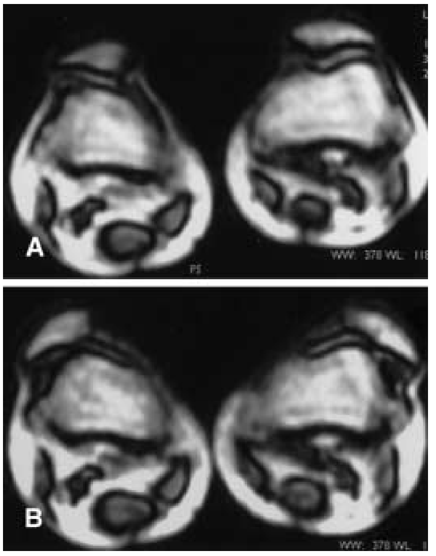

Fig. 15 First (**A**) and last (**B**) section from a dynamic tracking study. Note the marked lateral subluxation and tilt of the patella on full extension

yields standard images at known degrees of flexion; however, not all patients can manage this rigorous protocol and in particular find rotation difficult to control. A further difficulty with angle measurement is that of the quality of the images produced during the dynamic study, as fine detail is not as good as on static images and consequently reproducibility is impaired.

The alternative is to visually assess the tracking study on a cine-loop facility (Fig. 15). Using the technique described in the previous section, the loop is generated by a serial display of the axial section closest to the patellar waist from each of the 15 repetitions. Once created, the loop can be viewed on a workstation. Normally the patella remains centrally positioned within the femoral groove as the knee extends. Various patterns of maltracking have been described. The most common of these is lateral subluxation which can be graded as: 1, minor perceptible lateral deviation or tilt; 2, obvious lateral deviation or tilt; and 3, gross patellar subluxation. As it subluxes, there is also a tendency for the patella to tilt laterally, presumably due to a rotatory force induced by quadriceps contraction.

The advantage of the visual assessment method is that it can be carried out quickly and does not require complex measurements using a workstation. Disadvantages are that it is more subjective than direct measurement, though in practice the significant grades are easily distinguished and inter-observer variation seems to be low.

Lateral patellar tilt may occur without lateral patellar movement. On dynamic MR, this is seen as a reduction in the lateral patellar angle as the lateral patellar facet and the lateral femoral condyle approximate. Some authors have referred to this movement anomaly as EPLS

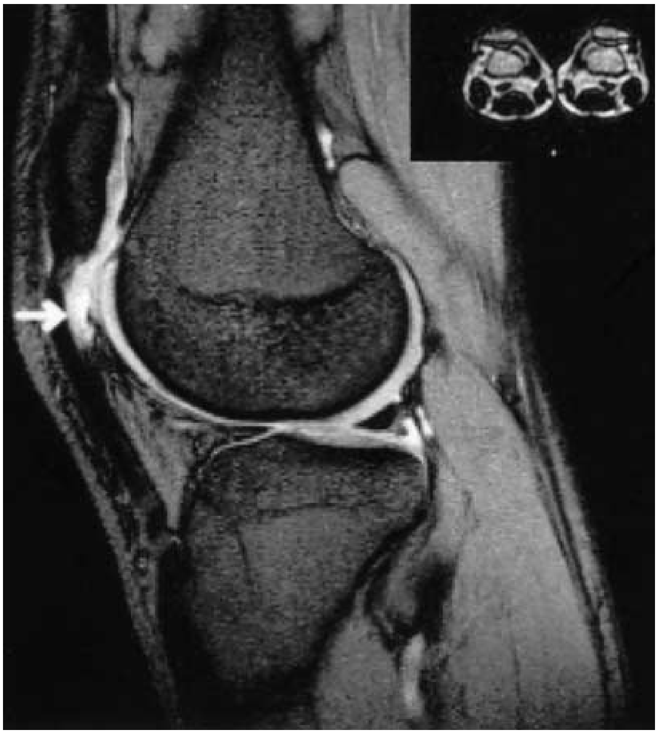

Fig. 16 Variant of patellar tendinopathy in a patient with patellar subluxation (*insert*). Note the proximity of the patellar tendon with the lateral femoral condyle

Table 2 Prevalence of three grades of patellar maltracking in patients with anterior knee pain and normal volunteers

	Anterior knee pain	Normal
1	51%	31%
2	39%	9%
3	10%	0

or excessive lateral pressure syndrome. More complex grading systems have been advocated to take this into account, with patients separated into different groups including those with subluxation only, those with tilt only or those with both subluxation and tilt. The clinical significance of making these distinctions has not been firmly established. The contribution of lateral retinacular tension to subluxation and tilt is also unclear. The assumption that a tight retinaculum contributes to maltracking has formed the basis for operative release, though in the majority of patients with maltracking on dynamic MR, the lateral retinaculum appears lax. Medial patellar subluxation is rare on MR, though medial deviation has been reported as normal phenomenon during walking [46].

Patellar subluxation is common and is a disorder of young active people in the third and fourth decades. Using visual assessment grades, maltracking was found in 40% of a cohort of 500 patients with anterior knee pain studied by McNally et al. [16]. Half of these showed minimal lateral deflection only (grade 1 subluxation). This finding was also present in 30% of a group of normal volunteers (Table 2). This suggests that patellar motion that is not obvious on visual assessment is unlikely to be clinically significant. Moderate subluxation was detected in 40% and severe subluxation in 10% of patients in the same study. Moderate subluxation was uncommon and severe subluxation did not occur in the control population.

Patellar subluxation has been linked with both chondromalacia and patellar tendinopathy. We have also identified a variant of patellar tendinopathy that is particularly associated with patellar subluxation. This variant is characterised by inflammatory changes in the lateral peritendinous structures, close to the origin of the patellar tendon. The extensor mechanism appears to be positioned more laterally and the proximal patellar tendon abuts the lateral femoral condyle. The inflammatory changes lie between the femoral condyle and the patellar tendon (Fig. 16).

Treatment and outcomes

A number of outcome studies have shown that the majority of patients with anterior knee pain follow a self-limiting course with less than 25% having chronic pain [47]. Patients with chronic pain are usually young and no reliable predictors have been established to help differentiate those whose symptoms will persist. The absence of patellar pain and crepitation, unilateral symptoms during the follow-up period, low body height, and young age are associated with good long-term outcome [48]. There are no reliable studies on the prognosis of patellar subluxation though long-term uncorrected subluxation may predispose to OA [49].

The conservative management of anterior knee pain comprises a combination of orthosis, physiotherapy, taping and NSAIDS. Kannus et al. [50] reported that many patients respond to these methods though a high proportion were left with some degree of anterior knee pain at final follow-up. Patients in whom there is a defined cause, such as overuse, have a better prognosis [51].

Patients who do not respond to conservative measures may be offered one of a variety of surgical procedures. Much of the literature on these procedures involves relatively small numbers of patients, is poorly controlled and there is little agreement on outcome measures [1, 2]. One of the more common is surgical division and release of the lateral retinaculum. Good results in correcting subluxation [52] and relieving symptoms [53, 54, 55, 56, 57] have been reported, but not in all cases [58]. Although reports on lateral release are generally favourable, the majority of studies are not randomised and poorly controlled. There is also a perception that the procedure is carried out too frequently in patients with anterior knee pain with little thought to pre-operative assessment. Fu and others warn against this [59] and of the high complication rates that are reported in some studies [60]. Its efficacy in patients with transient patellar subluxation has also been questioned. In a long-term follow-up study over 8 years, Aglietti et al. [58] found that 40% of patients undergoing lateral release had recurrence of patellar dislocation. There are no studies that examine its role in patients with chronic maltracking. Shea and Fulkerson [55] retrospectively classified patients into groups according to the presence of CT-proven patellar tilt on static images. The group with CT-proven tilt had a significantly better outcome from lateral release than patients with normal CT findings. The predictive value of other morphological abnormalities including patella alta and an increased TTD, or of the presence of tracking abnormalities on dynamic testing, is not known.

Another popular procedure is tibial tubercle transfer. This involves the excision of a block of bone containing the insertion of the patellar tendon and its re-insertion onto a more medial location with the aim of restoring the alignment of the quadriceps mechanism and tubercle. Nagamine et al. [61] recommend a displacement of approximately 1 cm. Uncontrolled studies suggest a favourable outcome[61, 62, 63] but once again overuse of this procedure has been criticised and Post and Fulkerson [64] have recommended that surgery should only be carried out when malalignment is confirmed on imaging. Bellemans et al. [63] also noted improvement in function scores when patients with anterior knee pain were selected based on their pre-operative congruence and tilt angles, though not all studies have shown that these particular measurements improve following surgery. Patients with transient patellar dislocation undergoing tibial tubercle reimplantation had a much lower risk of redislocation (4%), but up to a third suffered post-operative pain, swelling and crepitus. A further third did not improve their patellar-femoral relationships after surgery and Aglietti et al. concluded that although transposition of the tuberosity was appealing, clinical advantages are less evident [58]. A proportion of patients with marked lateralisation may require tibial de-rotation osteotomies in place of, or occasionally in addition to, re-implantation procedures. Outcomes in patients with chronic maltracking undergoing tubercle reimplantation have not been reported.

The mixed results from the variety of surgical procedures has led to the suggestion that patients need to be more accurately classified before surgery is undertaken. Holmes and Clancy [65] suggest dividing patients into three groups: (1) patellofemoral instability, i.e. subluxation or dislocation; (2) patellofemoral pain with malalignment but no episodes of instability; and (3) patellofemoral pain without malalignment . The combination of static and dynamic MRI can assist with this differentiation.

Conclusions

Anterior knee pain is a common symptom affecting young people. Patients with this symptom are not a single homogeneous group; some have a recognised definable remediable cause while others do not. Plain films are often the initial radiological investigation though they are of limited value. The combination of static and dynamic MRI allows patients with anterior knee pain to be more accurately assessed. Static images are used to exclude remediable causes including patellar or quadriceps tendon disease, osteochondral disease of the patello-femoral joint, diseases of Hoffa's fat pad and anterior meniscal tears. The sequelae of transient patellar dislocation should be specifically sought. Static images using thin sections and multi-planar reconstruction are used to detect and measure the morphological relationships between the distal femur, proximal tibia and patella. Specific measurements that should be included in the radiology report are the sulcus angle, sulcus depth, congruence angle, lateral patellar distance, lateral patellar tilt, lateral patellar angles, PTR and TTD. A comment on patellar shape should be included, particularly if it is type 3. Although some of these measurements on radiographs and static cross-sectional images predict maltracking they are insensitive. Dynamic MR provides an apparently sensitive and reproducible technique, though it is difficult to define a gold standard. The combination of static and dynamic MR can correctly classify patients into three subgroups. These groups are anterior knee pain only, anterior knee pain and abnormal morphology, and anterior knee pain, abnormal morphology and maltracking. The future hope is that correct classification may lead to more appropriate surgery and better outcomes.

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