MINI-SYMPOSIUM: SOFT TISSUE KNEE PROBLEMS

(iv) Patellofemoral dysfunction—Extensor mechanism malalignment

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Patellofemoral joint; Patellar instability; Malalignment syndromes; Trochleoplasty

Summary
Anterior knee pain has many causes. When it arises from the knee extensor mechanism, those with normal alignment must be distinguished from those with malalignment. Patellar dislocation is at one extreme of a spectrum of disorders that are due to malalignment of the extensor mechanism of the knee. This article discusses important aspects of extensor mechanism malalignment and a logical approach to operative treatment for patients with failed conservative therapy.

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Introduction

The patella is a sesamoid bone that acts as a marker for the extensor mechanism of the knee. Patellofemoral dysfunction comprises a number of disorders of the extensor mechanism of the knee. There are two main presentations: anterior knee pain, and abnormal patellar movements, but both may be present at the same time. The disorders presenting as anterior knee pain are listed in Table 1.

Abnormalities of patellar movements range from permanent dislocation through subluxation to a tight lateral retinaculum.

Anatomy

The patellofemoral joint includes the entire extensor mechanism of the knee, i.e. the quadriceps tendon, patella and patellar ligament. The trochlear groove and an arch of articular cartilage around the intercondylar notch make up the femoral side of the joint. It is important to remember that the tibial articular surface comes into contact with a different part of the femur to the patella, except at the tibial spines. It is also important to remember that intercondylar notch osteophytes usually arise from patellofemoral disease.

The movements of the patellofemoral joint are complex. In full extension only the distal part of the patellar articular surface is in contact with the femoral groove. As flexion proceeds, the contact area on the patella sweeps proximally until at 90° flexion the proximal part is in contact with the distal groove. From 90° flexion the odd facet (the most medial) articulates with the lateral edge of the medial femoral condyle, and the lateral facet articulates with the medial edge of the lateral femoral condyle. The medial facet lies in contact with the synovium overlying the anterior cruciate ligament.

There are synovial folds that fill in any space between the non-contacting articular surfaces of the patella and femur.2
In full extension the patella rests on the synovium of the supracondylar fat pad. This has a leading edge that moves 2–3 mm distally in the first 20° of knee flexion. As the contact area on the patella moves proximally, progressively more of the supracondylar fat pad lies in contact with the quadriceps tendon. In the inferior part of the patellofemoral joint the synovial folds are more complex. As the knee flexes, the inferior articular surface of the patella becomes more progressively covered by the alar folds of the infrapatellar fat pad. Initially the alar folds face inwards, but beyond 90° flexion the alar folds move away like opening curtains to face away from each other (the way they are typically depicted in anatomy textbooks). The movement of the synovial folds sweeps the articular cartilage and may be important for joint lubrication and nutrition.

**Clinical features**

Pain is typically felt at the front of the knee around the patella. It is worse with exercise, on squatting or getting out of a chair, and on going upstairs. Increased pain on going downstairs is more typical of medial tibiofemoral pathology (medial meniscal tear or arthritis). Patients may complain of the knee locking, despite there being no mechanical block to extension. This pseudo-locking occurs when the patellar and trochlear lesions come into contact causing pain which inhibits knee movement. Feelings of instability and giving way are also typical, either because the quadriceps is weak from pain, or due to extensor mechanism malalignment.

<table>
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<th>Table 1</th>
<th>The causes of anterior knee pain.</th>
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<td>Adolescent anterior knee pain (Painful patella syndrome)</td>
<td>Patellar malalignment syndromes including dislocation</td>
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<tr>
<td>Patellofemoral pathology</td>
<td>Patellar malalignment syndromes</td>
</tr>
<tr>
<td>• Patellofemoral arthritis</td>
<td>• Patellar tendinitis (Sinding-Larsen, Osgood-Schlatter’s)</td>
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<tr>
<td>• Infections</td>
<td>• Quadriceps tendinitis</td>
</tr>
<tr>
<td>• Tumours</td>
<td>Tibiofemoral pathology</td>
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<tr>
<td>• Complex regional pain syndromes</td>
<td>• Medial meniscal tear</td>
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<tr>
<td>Extensor mechanism pathology</td>
<td>• Lateral meniscal tear</td>
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<tr>
<td>• Patellar tendinitis (Sinding-Larsen, Osgood-Schlatter’s)</td>
<td>• Osteochondritis dissecans</td>
</tr>
<tr>
<td>• Quadriceps tendinitis</td>
<td>Hip pathology</td>
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<tr>
<td>Tibiofemoral pathology</td>
<td>• Osteoid osteoma</td>
</tr>
<tr>
<td>• Medial meniscal tear</td>
<td>• Osteosarcoma/Ewing’s</td>
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<tr>
<td>• Lateral meniscal tear</td>
<td>Postural abnormalities</td>
</tr>
<tr>
<td>• Osteochondritis dissecans</td>
<td>• Tight quadriceps/hamstrings</td>
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<td></td>
<td>• Hyperlordotic lumbar spine</td>
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<td></td>
<td>• Pronated feet</td>
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<tr>
<td>Psychological problems</td>
<td>Highlighted conditions covered in article.</td>
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</table>

Clinically if the patient can squat easily, and duck waddle (move about in the squatting position), there is unlikely to be serious pathology within the knee. The clinical signs that should be noted are listed in Table 2.

**Patellofemoral syndromes**

**Adolescent anterior knee pain**

Adolescent anterior knee pain (AAKP) has many synonyms. It is common; in a case series of 446 children, 30% both boys and girls experienced it. Of these only 10% of the boys, and 30% of girls presented to doctors. There was no association with any anthropometric measure (although benign joint laxity syndrome was not recognised at that time), but it was associated with sporting activity. In a mean of 16 years follow-up of girls 71% were symptomatically improved, 88% took no painkillers, 90% played regular sports, and 25% had intermittent significant symptoms after 20 years.

Chondromalacia patellae is a commonly used synonym. However, it is an arthroscopic diagnosis and can be inferred from an MRI scan. It should only be used when the macroscopic state of the articular cartilage of the patella is softened. However, it can be present secondary to chronic trauma, notably in trochlear dysplasia (see below), which is not AAKP.

My view is that AAKP is result of chronic overload of the extensor mechanism in the growing sporty child. It occurs because the femur and tibia are growing faster than the soft tissues of the extensor mechanism, and therefore causes a relative overload during sports. The typical age of onset is around 12 years old. The pain is worse with exercise, and eases with rest. It usually resolves over 4–5 years. It is not a disease, and should not be treated operatively, but it is important to exclude other causes of anterior knee pain, most notably extensor mechanism malalignment with trochlear dysplasia.

**Patellar malalignment syndromes**

The literature on the management of patellar instability is confusing. There is no standardisation of diagnoses, e.g.
patients with patella alta are often lumped with patients with lateral subluxation in extension. Many reports are of the results of a single operative technique used for a variety of conditions. Consequently operations for patellar instability have a relatively poor record. What is clear is that while the patella is stabilised, operated patients have a higher rate of osteoarthritis than non-operated patients.

Classification of patellar instability

The traditional classification of instability includes:

- congenital
- traumatic
- habitual
- obligatory
- subluxation and dislocation.

Dejour described a system based on clinical symptoms and on the radiological abnormalities found (Table 3). The radiological abnormalities are important to note. If they are present in a patient with anterior knee pain, then the cause is an extensor mechanism malalignment, and not classical AAKP. The latter may have a surgical option in the management, the former does not.

Imaging the extensor mechanism

Although the patella has three degrees of freedom, in practice the important malalignments occur in the sagittal and frontal planes, and longitudinal axis. These are assessed on a lateral X-ray, a CT scan, and a tangential patella (or skyline) X-ray, respectively. These images give a static two-dimensional analysis of the problem. Three-dimensional ‘moving’ images using MRI are possible, although this is not routinely available.

Routine plain X-rays should include a strict lateral X-ray with the posterior condyles of the femur overlapping precisely. A skyline view (tangential patella) is essential. A sulcus angle of greater than 140° is strongly associated with other abnormalities that lead to patellar dislocation. It may also show a medial “ossicle” which is pathognomonic of a previous dislocation. See Figs. 1 and 2 for the typically measured angles on skyline views, although these are not for deciding on operative management as they change with knee flexion. Standardising images for knee flexion is very difficult within a department.

![Figure 1](image1.png) Lateral patellofemoral angle on skyline X-ray.

![Figure 2](image2.png) Sulcus and congruence angles on skyline X-ray.

Table 3: Dejour’s classification of extensor mechanism malalignment.

<table>
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<tr>
<th>Major patellar instability</th>
<th>Objective patellar instability</th>
<th>Potential patellar instability</th>
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<tr>
<td>More than one documented dislocation</td>
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<tr>
<td>One dislocation with associated anatomical abnormalities</td>
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<tr>
<td>Patellar pain with associated radiological abnormalities</td>
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![Figure 3](image3.png) The patellar height: Caton–Deschamp method on lateral plain X-ray. Arrow shows posterior condyles strictly overlapping.

On the lateral X-ray the patella height is measured. My preferred method is the Caton–Deschamps modification of the Blackburne–Peel method (TA/PA on the X-ray: 1.0 range 0.8–1.2 is normal) (see Fig. 3). Trochlear dysplasia and
trochlear boss height can also be measured from the plain lateral X-ray (Figs. 4–6). CT scanning, made up of a series of transverse cuts with the knee in extension, allows the patellar tilt angle to be measured using the posterior condyles as the reference line and the long axis of the patella as the measurement line. Normal is less than 20° (Fig. 7).

Also on CT scan the tibial tubercle–trochlear groove (TTTG) distance can be measured. This measures the offset of the tibial tubercle relative to the true trochlear groove and is more accurate than the 'Q'-angle. The normal is 10 mm with greater than 20 mm as abnormal, allowing for errors in the measurement (Fig. 7).

**Surgical procedures for patellar instability**

Most patients with an acute patellar dislocation settle after a period of rest, and physiotherapy. The 10% of patients who have failed conservative therapy, and have significant disability from an unstable extensor mechanism can be considered for surgical treatment. However, the evidence base for operative intervention is very poor.

Traditionally two types of procedure were described: proximal realignment and distal realignment (see Table 4). Proximal operations are soft tissue procedures intended to make the patella track more medially. Distal operations are related to the patellar ligament insertion and tibial tubercle. More recently operations on the groove, trochleoplasty, have come to the fore. Many surgeons take a traditional approach and perform a standard operation for all abnormalities, e.g. lateral release and medial reefing proximally, and a Roux-Goldthwaite distally. There is no doubt that this will stop dislocation in most cases, but may precipitate anterior knee pain (since any trochlear dysplasia has not been addressed), and not have a satisfactory functional outcome.

**Proximal operations**

**Lateral release**

Lateral release may be open or closed (arthroscopic). Traditionally lateral release has been performed on all patients with instability, often as the only operation. The current view is that this is usually not necessary if the medial side is tightened with a medial patellofemoral ligament reconstruction.

![Figure 4](image1.png) The normal groove on: (a) plain lateral X-ray; (b) skyline X-ray.

![Figure 5](image2.png) The Dejour classification of trochlear dysplasia on plain lateral X-ray.
ligament (MPFL) construction (see below) and may increase the risk of medial subluxation. Concerns about increasing the joint reaction force are overcome if a deepening trochleoplasty is included. There is also evidence that a lateral release significantly increases the loads on the patellar ligament.

Medial reefing
Medial reefing is used to correct excessive patellar tilt that develops as the medial structures stretch as part of the evolution of instability. Various techniques have been described that tighten the medial side by a double-breasted reefing. This does not correct maltracking in extension, and itself stretches with time. The vastus medialis obliquus muscle is usually absent in these patients. Efforts to move the existing vastus medialis distally to compensate for this, fail because the muscle becomes functionless.

Repair of the medial patellofemoral ligament
The evidence base for the approach to managing an acute dislocation is sparse. Immediate repair of an acute rupture or avulsion of the insertion of the medial patellofemoral ligament...
ligament as occurs with patella dislocation, has been advocated. My view is that most acute dislocations settle with an orthosis and early physiotherapy, without the need for an acute repair.

Construction of the medial patellofemoral ligament
Recently a number of operations have been devised that act as a check rein between the patella and medial femoral condyle, constructing the deficient MPFL. The isometric points are in the superior half of the medial border of the patella and just proximal to the medial epicondyle of the femur where a ridge is palpable. I use a semitendinosus free graft, passing it through a tunnel in the patella and fixing it to the femur with an absorbable screw as on the femoral side of an ACL reconstruction (see Fig. 8). This stops lateral tracking in extension, and guides the patella into the femoral groove during flexion. I rarely combine this with a lateral release, and now rarely perform a distal re-alignment since the patella tracks in the groove. Semitendinosus tendon is ten times stronger than the normal MPFL and so can overcome any resulting lateral displacement force. If combined with a trochleoplasty (see below), then the groove is moved more laterally. This decreases the TTTG and also means that tibial tubercle osteotomy is unnecessary.

Dynamic semitendinosus transfer
This procedure may be necessary in pre-physeal closure or severe adult dislocation. It aims to create a dynamic force somewhat akin to the effect of the vastus medialis obliquus. I use it in children as a temporising measure until they have stopped growing. They then undergo a definitive procedure depending on the underlying abnormalities.

Distal operations

**Roux–Goldthwaite**
This is a very popular procedure where the lateral half of the insertion of the patellar ligament is passed under the medial half and inserted into the medial plateau. Its effect is therefore medialisation of the insertion of the extensor mechanism. I do not favour using it for three reasons. There is no imaging technique that can measure its effect. Intra-operatively it is difficult to know precisely where to place it and how tightly it should be fixed. Finally, it usually requires immobilisation. In principle joints should not be splinted. It is however a popular operation used by many surgeons.

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<th>Table 4</th>
<th>Operations for patellar instability.</th>
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<tr>
<td>Proximal</td>
<td>Lateral release&lt;br&gt;Medial reefing&lt;br&gt;Medial patellofemoral ligament</td>
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<tr>
<td>Distal</td>
<td>Dynamic semitendinosus transfer&lt;br&gt;Roux–Goldthwaite&lt;br&gt;Tibial tubercle osteotomy</td>
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<tr>
<td>Trochleoplasty</td>
<td>Dejour&lt;br&gt;Bereiter&lt;br&gt;Albee</td>
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Figure 7 The patellar tilt angle and tibial tubercle–trochlear groove distance on CT scan.

Figure 8 Lateral post-operative X-ray of a medial patellofemoral ligament construction; white arrow—patella tunnel, black arrow—femoral pit.
Tibial tubercle osteotomy

Tibial tubercle osteotomy can be imaged and measured. Intra-operative displacement can be predicted, and immediate mobilisation of the knee allowed. Moving the tibial tubercle clearly affects the action of the extensor mechanism. The criticism for any tibial tubercle osteotomy is that it risks non-union, and stress fractures of the tibia. This is certainly true for distalisation (aimed at correcting patella alta). This is unusual in the Elmslie (see Fig. 9) and Fulkerson, which are based on a distal osteo-periosteal flap. The latter brings the extensor mechanism forwards, and therefore reduces the patellofemoral joint reaction force, which is useful if there is a mild trochlear dysplasia. The Maquet has the same effect, but was designed for anterior knee pain. It is not in vogue now, mainly because of its cosmetic effect. The Hauser procedure (not listed in Table 4), repositioned the tubercle posteromedially, but is well documented as leading to early patellofemoral osteoarthritis.

Trochleoplasty

The earliest trochleoplasty was described by Albee.\textsuperscript{9} This was an elevating osteotomy of the lateral trochlear

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**Figure 9** Intra-operative photograph of medialisation of the tibial tubercle (Elmslie). The tubercle is held in the new position by an awl.

**Figure 10** Before and after the Dejour trochleoplasty: (a) per-operative photograph; (b) CT scans.
facets. In the presence of the hyperplastic type of dysplasia (by far the commonest) this raises the joint reaction force and precipitates patellofemoral osteoarthritis. Despite this, it is useful in a rare condition of lateral condylar hypoplasia, although MPFL construction is my preferred management.

There are currently two types of deepening trochleoplasty. Both remove subchondral bone approached from above. The Dejour10 (see Fig. 10) has a thicker resulting osteochondral flap compared to the Bereiter11 which creates a thin flexible flap. The Dejour uses screws or staples to anchor the flaps. The Bereiter uses a vicryl tape to create the new groove. The latter is only suitable with intact articular cartilage. It is an elegant operation suitable for the milder dysplasias. These operations are still in their infancy, and it is not yet known whether that truly improves the functional outcome or reduces the risk of later osteoarthritis.

Summary of surgical options
The advent of construction of the MPFL construction means that, for those surgeons who have taken it up, it is the most common operation that they do. Its strength and mechanism of action means that all other proximal and distal operations appear to be unnecessary for the vast majority of patients. The necessity for lateral release is contentious. Trochleoplasty is even more contentious, even though logical. Until the results of robust clinical trials are available to inform surgeons as to best practice, the majority of general orthopaedic surgeons (particularly in the USA) are likely to continue with lateral release, medial reefing, and some with Roux–Goldthwaite, Elmslie or Fulkerson.

Postural abnormalities
Anterior knee pain may be the result of postural abnormalities, most commonly rotational abnormalities of the lower limb either persistent femoral anteverision or external tibial torsion. Tightness of the lower limb muscles (quadriiceps, hamstrings or gastrocnemius) may present with anterior knee pain.

Additionally, there are two postural patterns that may be seen, especially in adolescents. Firstly, the hyperlordotic lumbar spine with squinting patellae where the symptoms are bilateral. Secondly, standing in the pelvis slouch position, with weight-bearing on one leg. The bent resting knee is the symptomatic one. The weight-bearing leg is being loaded through the iliotibial band. It may be that the iliotibial band is tight in these cases. This area needs further research.

Psychological problems
Finally, it is important to realise that many patients present with anterior knee pain (AKP) secondary to psychological problems. In children they fit in with a pattern of headaches and abdominal pain. Nowadays operations are avoided as MRI scans confirm that the knee is normal (having checked the hips and spine).

Many adolescents present with AKP who are athletic. Beware the parents who say that their child is at national or county level but are struggling because of the pain. Sometimes the parents are basking in the reflected glory of the child, but the latter does not want to continue the sport!

There is a small group of patients where the presentation is secondary to severe abuse (physical or sexual). The typical presentation is a girl with bilateral knee pain where both parents attend the clinic. The history is that the pain is severe, they are unable to run, and are taking time off school. On examination there is diffuse pain to light touch. All routine imaging is normal. If they are put on a waiting list (nowadays for an MRI scan), within a few days the family doctor rings asking that this is performed urgently as the child has deteriorated to being in a wheelchair and unable to go to school. Involvement of a paediatrician is mandatory. A psychiatrist will be needed to treat the child if suspicions are confirmed.

Conclusion
Patellofemoral dysfunction is common and has many causes. It presents as anterior knee pain, or patellar instability. Surgery aims to correct extensor mechanism malalignment in patients if conservative therapy fails. This requires proper imaging to define the abnormalities, and operations targeted at correcting them. The two new operations that are being popularised for this are MPFL construction and trochleoplasty. It has yet to be confirmed that these have improved functional outcomes over traditional operations.

References
Further reading