Disorders of the Patellofemoral Joint

Diagnosis and Management

E. Carlos Rodríguez-Merchán
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Preface

Pathologies of the patellofemoral joint are common and affect a diverse group of patients, from children with patellar instability to sports people with traumatic dislocations and cartilage defects and elderly patients with patellofemoral osteoarthritis. In spite of this, for many years, the patellofemoral joint has been poorly understood. As orthopaedic surgeons, the interventions that we have available to treat patients with patellofemoral pathologies have until recently been limited, and outcomes have been uncertain.

Happily, times are changing. Since the turn of the century, unprecedented steps have been made in increasing our understanding of the patellofemoral joint in normal and pathological states. Anatomical and physiological studies have helped us to understand patellofemoral morphology and function. Improvements in imaging have improved diagnosis and planning of surgical treatments. New procedures, such as trochleoplasty and medial patellofemoral ligament reconstruction, have been introduced and have demonstrated reliable results, and new implants have been introduced, improving outcomes in patellofemoral arthroplasty. A large and growing body of evidence exists to guide us in the treatments we offer and to improve the information available to patients; traditional interventions such as lateral retinacular release and patellectomy have been shown not to have the efficacy to justify their widespread use. The progress that has been made in recent years in the understanding and treatment of the patellofemoral joint is arguably greater than in any other topic in hip and knee surgery.

As a result of this pace of change, the clinician who treats disorders of the patellofemoral joint should be equipped with the latest evidence. The traditional use of simple and universal techniques for treating patellofemoral problems has been overtaken by a more patient-centred, *a la carte* method of treatment based on the patient's anatomy, physiology and functional demands. As a result, surgeons need to be familiar with a large and growing range of techniques.

The aim of this book is to aid surgeons in providing the best, evidence-based treatments for patients presenting with patellofemoral disorders. We have aimed to cover the breadth of the topic from assessment and imaging of adults and children with patellofemoral pathology to management of acute and chronic patellofemoral conditions. We have covered a range of traditional and novel techniques, including methods of nonoperative management, joint preserving surgery and arthroplasty. Each chapter has been produced by authors with direct experience of the condition and its management, and a thorough overview of the evidence for each intervention is presented. We hope that this book will help surgeons to provide the best, evidence-based treatments for patients with disorders of the patellofemoral joint.

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1 Examination of the Patellofemoral Joint

Luke Jones, Adam Fell, and Simon Ball

1.1 Introduction

Despite its apparent simplicity, the patellofemoral joint exhibits a wide variety of pathology with several potentially causative or contributory factors. The examination of the joint can therefore be challenging and must consider those factors intrinsic to the joint as well as those related to other parts of the body. The joint behaves differently in different positions and has both static and dynamic elements that add to its complexity. In addition, patellofemoral joint examination findings are often subtle and poorly reproducible, reinforcing the impression that only an expert can adequately assess it.

Of course, there is no substitute for experience—the clinician must take every opportunity to examine patients in order to understand what is normal and what lies outside this range. The clinician should realise that most tests have poor sensitivity and therefore utilise several different examination techniques to assess the same aspect of the joint. The examination should be used to confirm or refute the diagnosis made from the clinical history and guide the use of specialist investigations. It should never be thought of as isolated from the overall diagnostic process. The history will reveal common presentations (typically pain, giving way and swelling) and will therefore narrow the potential differential diagnosis and allow the clinician to focus on specific aspects of the examination.

Despite this, we suggest that a thorough clinical examination be performed on each patient, allowing the examiner to gain more experience in assessing the subtle examination findings associated with the joint. Here, we outline a structured examination technique that should be performed in a systematic manner. We use this examination structure in our outpatient clinics to allow clear documentation of findings and to facilitate communication between clinicians of differing experience.

The patient is examined in three stages: standing, sitting and supine. In each of the first two stages, inspection is performed both statically and dynamically. In the third stage, palpation and special tests are performed. We believe this structured examination to be the most efficient method of assessing the patellofemoral joint. There is of course flexibility to perform palpation and special tests in the first two stages. Although

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the examination manoeuvres may be adjusted according to individual patients, it is advised to perform it in a systematic manner to avoid missing key findings.

1.2 Standing

The patient's lower limbs are exposed, with the patient wearing high shorts or briefs to allow inspection of the pelvic position. The feet must be uncovered.

1.2.1 Static Examination

An initial examination of the patient for the "five Ss" (**s**ymmetry, **s**kin changes (bruising and redness), **s**cars (surgical and posttraumatic), **si**nuses (indicating infection), soft tissue **s**welling) is performed with the patient standing with both feet flat on the ground and the feet slightly apart. The examiner kneels in front of the patient, and the patient is asked to turn 90° to their right on four occasions, until a 360-degree inspection has been performed. Firstly, an inspection of overall alignment is performed to assess for varus or valgus alignment. Genu valgum indicates a larger laterally directed force across the patella which may lead to maltracking and patella subluxation. This is formally measured by the Q angle—a measurement of the angle formed by the intersection of the line drawn from the anterior superior iliac spine (ASIS) to the midpoint of the patella and the extension of a line drawn from the tibial tuberosity to the midpoint of the patella. A greater Q angle in women (15–18°) compared to men (12°) may partly explain higher incidences of patellofemoral pain in women due to a larger valgus vector. The Q angle must be interpreted with caution—a laterally subluxated patella will reduce the value, whilst an internally rotated hip will artificially increase it. An assessment of the presence of increased femoral anteversion is then made by inspecting the orientation of the patellae—an inward pointing or "winking" patella confirms this, as does tibial external rotation and a compensatory hind foot valgus.

At this stage, a brief assessment of leg length discrepancy is made with the feet flat on the ground and the knees fully extended. The tilt of the pelvis is noted from the height of the iliac crests. Next, the relative heights of the patellae are noted from their topographical anatomy: patella alta is associated with instability, whereas patella baja is associated with chondromalacia patellae. From the side, an inability to fully extend the knee is assessed—this is associated with patellofemoral arthrosis. Hyperextension of the knee (recurvatum) may indicate a generalised hyperlaxity, in which case at the Beighton scores is determined. Here, a score of 1 is allocated to the ability to bend the thumb to the radial side of the forearm; a score of 1 is allocated to the ability to extend the fifth finger beyond 90°. A score of 1 is allocated for the ability to hyperextend the knee and elbow. Each side is assessed to generate a score of 8, and a further 1 point is allocated to the ability to place the hands flat on the floor with the legs straight. A total score of 4 or more indicates generalised hypermobility [1].

Whilst standing, the posture of the feet can be assessed. Excessive pronation can be seen if the patient is standing in a relaxed position or during normal walking or running. A flattening of the medial longitudinal arch can indicate excessive forefoot pronation, which is associated with internal tibial torsion, and a valgus deformity of the knee. Both of these can increase the stress on the periarticular soft tissues and may cause anterior knee pain [2]. Fortunately, the simple use of orthotics can eliminate this.

1.2.2 Dynamic Examination

The patient is then asked to walk, and the gait is observed from the front and behind whilst walking forwards and then backwards, on the heel and the toes. The latter two elements are general assessment of lower limb function and the L5 and S1 motor nerve roots in particular. Assessment of the gait whilst walking backwards is a way to assess the patient who is suspected of exaggerating symptoms as it is difficult to artificially induce a limp whilst walking backwards [3]. A limping gait may indicate pain, leg length discrepancy or core motor weakness. A Trendelenburg gait will be seen with hip abductor weakness. A quads avoidance gait is seen in those patients with extensor mechanism dysfunction.

Next the patient is placed next to the wall to aid their balance, and double then single leg squat is performed. The attitude of the knee as the patient descends then ascends to 90° is observed. Malalignment may indicate weakness in hip stabilisers or quadriceps (especially vastus medialis obliquus) and may be made worse by poor motor control in the ankle. Although quadriceps weakness has traditionally been associated with poor control of knee position in squat, weakness of the hip abductors and external rotators is likely to play an even more important role. The single leg squat imposes higher mechanical demands than the double leg squat and therefore is more sensitive in the athletic patient when trying to induce compensatory movements such as knee valgus. This is due to the smaller base of support and the increased amount of dynamic control that is required compared to the double leg squat [4].

During double leg squatting, the patella is observed as it tracks in the trochlea for the specific presence of the J sign. The J sign refers to the pathological inverted J-path the patella takes in early flexion (or terminal extension) as the patella begins laterally subluxated and then suddenly shifts medially to engage with the femoral groove [5]. Palpation of the patella during squatting may reveal crepitus or pain, indicating underlying patellofemoral chondrosis.

1.3 Sitting

The patient is now examined in a seated position with the legs hanging over the edge of the examination couch. The table height is such that the feet do not touch the ground. The patient is asked to lean back with the arms extended in the "tripod" position and to hold on to the edge of the couch behind them. This decreases the tension in the hamstrings by allowing the pelvis to tilt posteriorly, meaning that knee extension is less likely to be restricted.

1.3.1 Static Examination

A second inspection is made, for any differences in quadriceps bulk. A formal examination of the muscle bulk is made with a tape measure at a point 20 cm proximal to the most prominent point of the tibial tubercle. Next a further assessment of the attitude of the patella is made. If the patella is tilted laterally (the grasshopper eye sign [3]), it may indicate an underlying weakness of vastus medialis and an increase in lateral tilt. From the side, the patella height is determined, with the proximal pole of the patella normally found at the same height as the anterior cortex of the distal femur in the seated position. The tibial tubercle sulcus angle is then determined by drawing a vertical line from the centre of the patella tendon to the centre of the tibial tubercle. A line is then drawn perpendicular to the femoral epicondyle axis. The angle is determined where these two lines subtend each other. At 90° of flexion, the patella should be centrally located in the femoral sulcus, and the tibial tubercle sulcus angle should be zero [6].

1.3.2 Dynamic Examination

Active and passive range of motion of the knee is assessed and compared to the contralateral side. A decrease in active extension compared to passive extension is known as an extensor lag and can represent disruption to the extensor mechanism. This must be distinguished from pain limiting full extension, and often this can be accurately determined by administering an intraarticular local anaesthetic injection. In the post arthroplasty knee, an extensor lag may indicate the joint line being erroneously raised and the extensor mechanism losing its mechanical advantage. A decrease in the passive range of movement may be related to a tightness in any of the muscles that extend across the knee joint. Next, quadriceps and hamstring strength are compared with the contralateral side.

During active range of movement, the hand is then placed over the knee to assess for patellofemoral crepitus. Crepitus alone is a nonspecific finding and is not specific for chondral damage. It may be due to the impingement of the peri-patellar soft tissues such as the anterior fat pad, synovial plica or synovial hypertrophy [7]. Up to 40% of asymptomatic females are known to have patellofemoral crepitus on active knee extension and therefore the finding should be considered of most interest when it is new, painful and asymmetrical. Placing the knee through a range of motion whilst applying compressive force to the patella assesses whether articular pain can be elicited and can localise cartilage defects to positions on the trochlea. Unless the patient's symptoms of anterior knee pain are reproduced by patella compression, then the pain should not be attributed to the chondral surfaces.

To complete the sitting examination, a formal assessment of the "J" sign is performed. The patella is normally in a slightly lateral position when the knee is fully extended. As the knee flexes, the patella engages in the trochlea groove and can be seen to move medially. A "J" sign is therefore produced as the laterally subluxated patella centralises in the sulcus. The patella normally centralises in the sulcus at 10–30° of flexion. Normal lateral displacement is seen only at terminal extension, and patella centring occurs at greater degrees of patella flexion in patients with lateral patella instability or patella alta. The lateral pull test evaluates dynamic quadriceps imbalance by asking the patient to contract the quadriceps with the knee fully extended. If lateral displacement of the patella occurs, then excessive dynamic lateral forces are causing lateral subluxation.

1.4 Supine

The patient is then asked to lie supine with the examination couch positioned to allow approximately 20° of flexion at the waist. This is more comfortable for the patient than lying completely flat. A pillow is placed under the head to relax the core muscles. The presence or absence of an effusion is important to rule out an intraarticular process. In an acute dislocation, a tense hemarthrosis may be found. In the recurrent dislocator, an effusion may indicate an underlying loose body related to osteochondral injury in the patella femoral joint. The preferred validated assessment of effusions used by the authors is the Delaware Grading System [8].

The knee is now palpated. The patient is asked where, if any, pain is located in the knee. Palpation begins away from this point to engender confidence. The knee is flexed to 90° initially, and the foot is stabilised under the thigh of the examiner who sits on the edge of the couch. This allows the patient to relax the hip flexors and thigh muscles. Palpation is performed with a single finger with observation of the patients face at all times to determine subtle signs of pain in the stoical patient. Again, a logical stepwise approach is necessary to avoid missing any key clinical signs. Palpation commences along the extensor mechanism proximal to distal. The quads tendon and its insertion to the patella may be tender with quads tendinopathy. A palpable gap is diagnostic of quadriceps rupture. Tenderness over the patella body itself suggests fracture or a bipartite patella. The patella tendon and its insertion to the inferior pole are then palpated. It can be difficult to elicit subtle tenderness here, and therefore two manoeuvres are performed. Firstly, the knee is extended, and the inferior pole is palpated. With the extensor mechanism relaxed, tenderness is often more pronounced. Secondly, the superior aspect of the patella is pushed backwards, tilting the inferior aspect forwards, making it easier to palpate. Patella tendinopathy is suggested by tenderness, swelling and warmth in this area. Tenderness or swelling along the patella tendon itself again suggests tendinopathy or inflammation of either the prepatellar or infrapatellar bursa. Tenderness over the tibial tuberosity in a skeletally immature patient may indicate Osgood-Schlatter's disease or, in the older patient, an ossicle remnant from the condition in their younger years.

Next attention is turned to the anterior joint line, and the medial and lateral fat pad is palpated against the femoral condyles. Tenderness here on compression and flexion and extension of the knee suggests inflammation and scarring of the fat pad. The medial and lateral retinacula are then palpated with tenderness found along the lateral retinaculum in those with chronic patella malalignment. The medial retinaculum may be tender in acute lateral dislocations. The medial patella plica can be palpated as a thickened, tender structure and can be rolled over the edge of the femur adjacent to the adductor tubercle in pathological states when the knee is flexed and extended. Finally, the medial and lateral borders and articular surfaces of the patella are palpated. At the end of palpation, it is important to rule out other pathological states that are unrelated to the extensor mechanism: pes anserinus bursitis, meniscal injuries and iliotibial band (ITB) tendinopathy must all be excluded. At this stage, screening tests for ligamentous instability in the knee should be performed [namely, anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL) and posterolateral corner].

Special tests are then performed on the patellofemoral joint. The authors prefer to group these into four main groups of diagnostic categories: instability, arthritis, tendinopathy and muscular tightness.

The patella glide and the apprehension tests are the cornerstone of assessment of instability. The patella glide test is performed to assess the integrity of the medial and lateral restraints. The test should be performed at full extension and then at 20°. At full extension the patella is out of the trochlea groove and easily translated medially and laterally to assess soft tissue constraints. At 20° of flexion, the patella engages in the trochlea groove, and therefore testing at this position evaluates both bony and soft tissue stability. A positive test at 20° necessitates testing at 45° which should increase articular congruity. Residual instability at this position is pathologic and most commonly found with patella alta. The patella glide test is performed by grasping the patella and translating it medially and laterally noting the movement from its normal potion in terms of the width of the patella. The patella is normally divided into quadrants for this purpose. Moving the patella 50% of its width is therefore two quadrants. A positive test for hypermobility or instability is three quadrants or more in either direction. Medial glide of one quadrant or less is indicative of medial tightness. If the patient experiences apprehension and a sense of impending dislocation with lateral translation, then the apprehension test is said to be positive.

A second test for lateral retinaculum tightness is the patella tilt test. Patella tilt is characterised by adaptive shortening of the lateral retinaculum and is associated with increased lateral facet loading. The lateral retinaculum, the ITB and the vastus lateralis all restrict lateral elevation of the patella. Here, the knee is fully extended, and the medial aspect of the patella is compressed, tilting the lateral aspect of the patella anteriorly. A negative value is recorded if the lateral border of the patella cannot be elevated above the medial border. A passive patella tilt of less than zero degrees is indicative of lateral retinacular tightness and is directly correlated with successful outcome of lateral release [6].

Assessment of degeneration in the patellofemoral joint is made with the compression test, which may have been performed earlier with the patient sitting. It can be used to assess both arthritis and chondral injuries from previous dislocation. The patella is directly compressed as the knee is flexed and increased pain indicates a positive test. The degree of flexion at which the pain is greatest can localise which part of the patella or trochlea is affected. Clarke's test, where the patella is compressed against the trochlea manually whilst the patient contracts their quadriceps, is said to be positive when the patient's symptoms are exacerbated. Unfortunately, this test has low sensitivity and specificity particularly in patellofemoral pain syndrome. Clinically, this test creates a lot of false-positive results and is therefore not recommended to be used [9].

The final component of the assessment of the patella femoral joint is to evaluate the tightness of the muscles that cross the knee, as they can increase stresses across the joint and exacerbate patellofemoral abnormalities. Determination of tight muscle groups can help to focus physical therapy. Hamstring tightness is assessed by the popliteal angle—the hip is flexed to 90° and the knee extended as far as possible. The knee angle is measured. Correction of hamstring inflexibility will frequently relieve patellofemoral problems. Quadriceps tightness is assessed with the patient supine, and progressive hyperflexion of the knee is performed. Thomas's test is used to assess specific tightness in the rectus and iliopsoas. For evaluating tightness of the ITB, Ober's test is performed. The patient lies on their unaffected side. The knee is flexed, the hip is extended, and then the leg is adducted with the examiner ensuring that there is no rotation at the hip. An inability to lower the leg past horizontal indicates a tight ITB. Correction of any soft tissue imbalances with the proper stretching regimen is an important component of the nonoperative treatment of patellofemoral disorders.

The examination is completed with an evaluation of the lumbar spine, the hip joint above and the ankle below. An assessment of the neurovascular status of the limb is made.

1.5 Conclusions

An organised, logical approach to the patellofemoral joint examination is essential. The joint must be examined whilst standing, sitting and lying flat. Inspection can be extremely revealing and must not be neglected, not must the fact that the patellofemoral joint behaves differently under static and dynamic conditions. The clinician must use the clinical history to guide the specific special tests that are used when examining the joint.

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Imaging of the Patellofemoral Joint

2

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2.1 Introduction

Imaging is paramount in the evaluation of the patellofemoral (PF) joint, as it provides an objective assessment of several morphological abnormalities, allowing the orthopedic surgeon to determine the most adequate surgical strategy for each patient. This chapter will review the role of imaging tests in the assessment of patients with PF problems.

2.2 Plain Radiographs

Standard plain radiographs include a bilateral standing anteroposterior (AP) view, a true lateral view at 30°, and specific patellofemoral views, either Merchant's view (30° posteroanterior projection with the knee flexed at 45°) or Skyline view (similar, but with the knee at 20° of flexion) [1].

2.2.1 Anteroposterior (AP) View

The AP view is not very helpful to assess the PF joint itself, but is very important to assess the lower limb alignment [2] and for the detection of bipartite patella or fractures. It can also show osteochondral loose bodies in the lateral gutter or the anterior notch that are due to patellar or lateral condyle fractures that occurred during patellar dislocation (Fig. 2.1).

2.2.2 Lateral View

This is probably the most helpful view of the knee for assessment of the patellofemoral joint. It is taken at 30° of flexion; in order to be useful it must be a true lateral with the posterior condyles being superimposed exactly. For interpretation, three lines must be drawn in the anterior portion of the distal femoral epiphysis. The two most anterior lines correspond to the contours of the anterior condyles. The third line corresponds to the Blumensaat line continued by the depression of the trochlear groove (TG).

Lateral X-ray analysis must be systematic and should follow the guidelines provided in the following sections.

2.2.2.1 Patellar Height

Different radiographic indices have been proposed to study the height of the patella on lateral X-rays. According to the method of evaluation,

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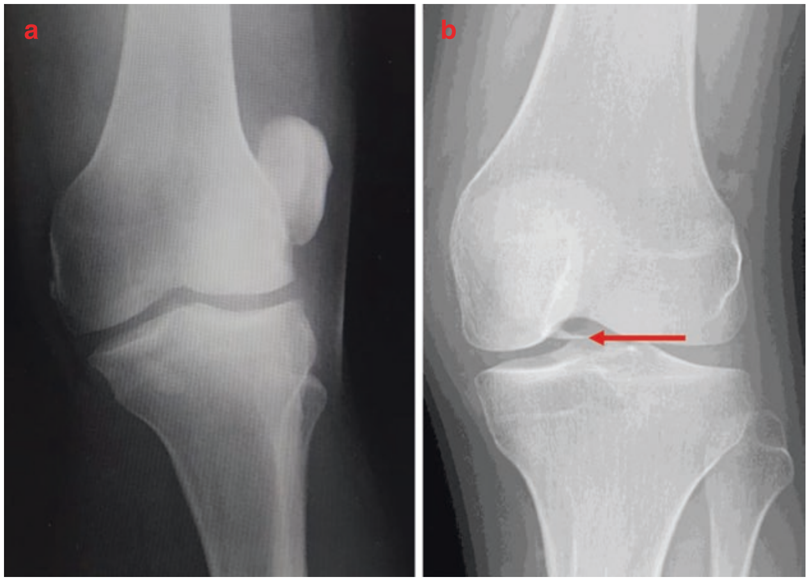

Fig. 2.1 (**a**) AP radiograph demonstrating patellar lateral subluxation. (**b**) AP radiograph showing a loose body (arrow)

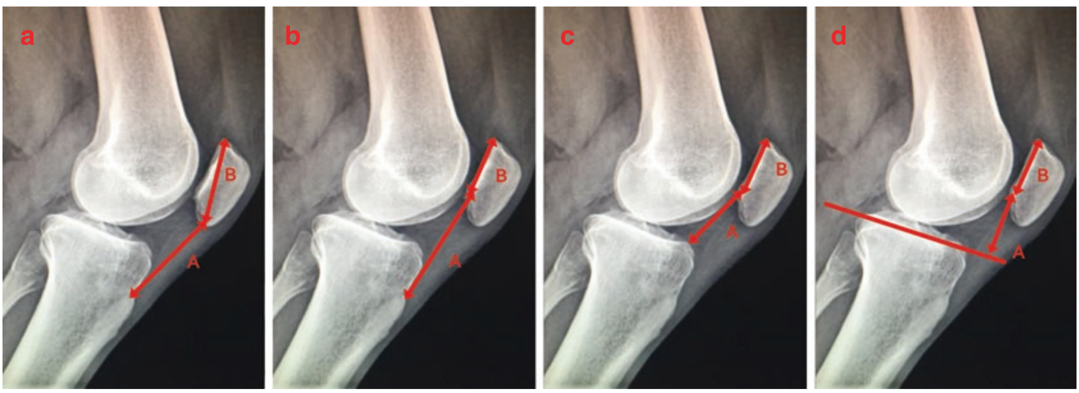

Fig. 2.2 Patella height measurements, patellotibial indices: These are measured on lateral knee X-ray or sagittal MRI with the knee ideally flexed at 30°. (**a**) Insall-Salvati, patellar tendon length (A)/patella length from pole to pole (B); (**b**) modified Insall-Salvati, patellar tendon length (to inferior margin of patella articular surface) (A)/length of articular surface of patella (B); (**c**) Caton-Deschamps, distance between lower patella and upper limit of tibia (A)/length of articular surface or patella (B); (**d**) Blackburne and Peel, perpendicular distance from lower articular margin of patella to tibial plateau (A)/length of the articular surface of patella (B)

these indices can be classified into two groups [3]: patellotibial indices and patellofemoral or trochlear indices.

Patellotibial Indices (Fig. 2.2)

These are measured on lateral radiograph flexed at 30°, which ensures that the patellar tendon is under tension, and so it develops its full length. Patella height is measured using the following ratios.

Insall-Salvati [4]

Patellar tendon length (A)/patellar length from pole to pole (B). Insall determined that this ratio A/B is normally 1. A ratio smaller than 0.8 indicates patella baja. A ratio greater than 1.2 indicates a patella alta. One disadvantage is that variations of morphology of the patella, especially a long-nosed patella, can leave a patella alta undetected.

Modified Insall-Salvati [5]
Patellar tendon length (to inferior margin of patella articular surface) (A)/length of articular surface of patella (B)

Caton-Deschamps [6]
Distance between lower patella and upper limit of tibia (A)/length of articular surface or patella (B); ratio (A/B) of ≥1.2 indicates a patella alta, while a ration of ≤0.6 indicates patella baja. This index can be used for planning the amount of correction needed for a tibial tubercle (TT) transfer (to determine the optimal distalization of the tubercle, the distance will be calculated by subtracting B from A) or to measure the patella height after high tibial osteotomy; however, as it uses the tibial joint surface it cannot be used after total knee arthroplasty (TKA). This index has gained popularity due to its ability to quantify patellar height changes after TT osteotomy and is reliable irrespective of degree of knee flexion, size, patellar morphology, and skeletal maturity and does not need accurately scaled radiographs [1].

Blackburne and Peel [7]
Perpendicular distance from lower articular margin of patella to tibial plateau (A)/length of the articular surface of patella (B). The normal ratio was defined as 0.8. Patella alta is defined as a ratio >1.0, while ratios <0.5 indicate patella baja.

The Caton-Deschamps and Blackburne-Peel indices have been shown to have higher interobserver reliability than the Insall-Salvati ratio [8, 9].

Patellofemoral or Trochlear Indices
(Fig. 2.3)

Bernageau [10]
This is measured on lateral radiograph with the knee in full extension with contraction of the quadriceps muscle. Distance between the superior line of the trochlea (T) and lower articular margin of patella (R). Bernageau determined that T is approximately at the same height as R. Patella alta is present if R is >6 mm above T, and patella baja is present if R is <6 mm beneath T.

Chareancholvanich and Narkbunnam [11]
This is the ratio between two measurements—line A from the midpoint of the patellar articular surface to the superior aspect of the TT and line B from the TT to the posterior angle of the roof of the intercondylar notch on the femur (the most posterior point on Blumensaat's line. The normal value is 1(+/−0.1), which is the same regardless of the scaling of the radiograph.

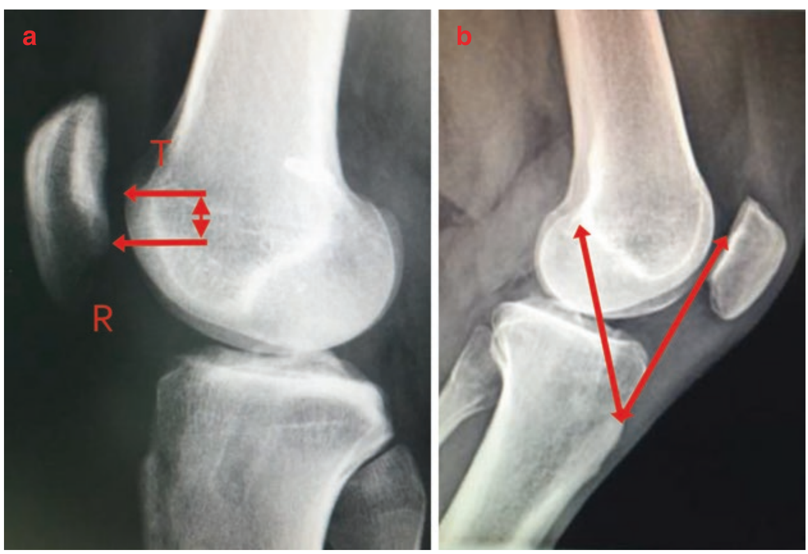

Fig. 2.3 (**a**) Patellar height measurement according to Bernageau. (**b**) Patellar height measurement according to Chareancholvanich

2.2.2.2 Trochlear Dysplasia

Trochlear dysplasia is the most important morphological factor affecting patellofemoral stability (see Chap. 6). Loss of concavity of the femoral trochlear leads to incongruence and abnormal patellar tracking (Fig. 2.4). The three radiographic following signs are important [12] (Fig. 2.5):

Crossing Sign

The crossing sign is pathognomonic for trochlear dysplasia [13]. The crossing sign was described by Henri Dejour on the basis of a true lateral radiograph. Crossing sign is positive when the TG line crosses the anterior border of the two condyles at any point. The crossing sign has been found in 96% of the population with antecedents of true patellar dislocation and in only 3% of healthy controls.

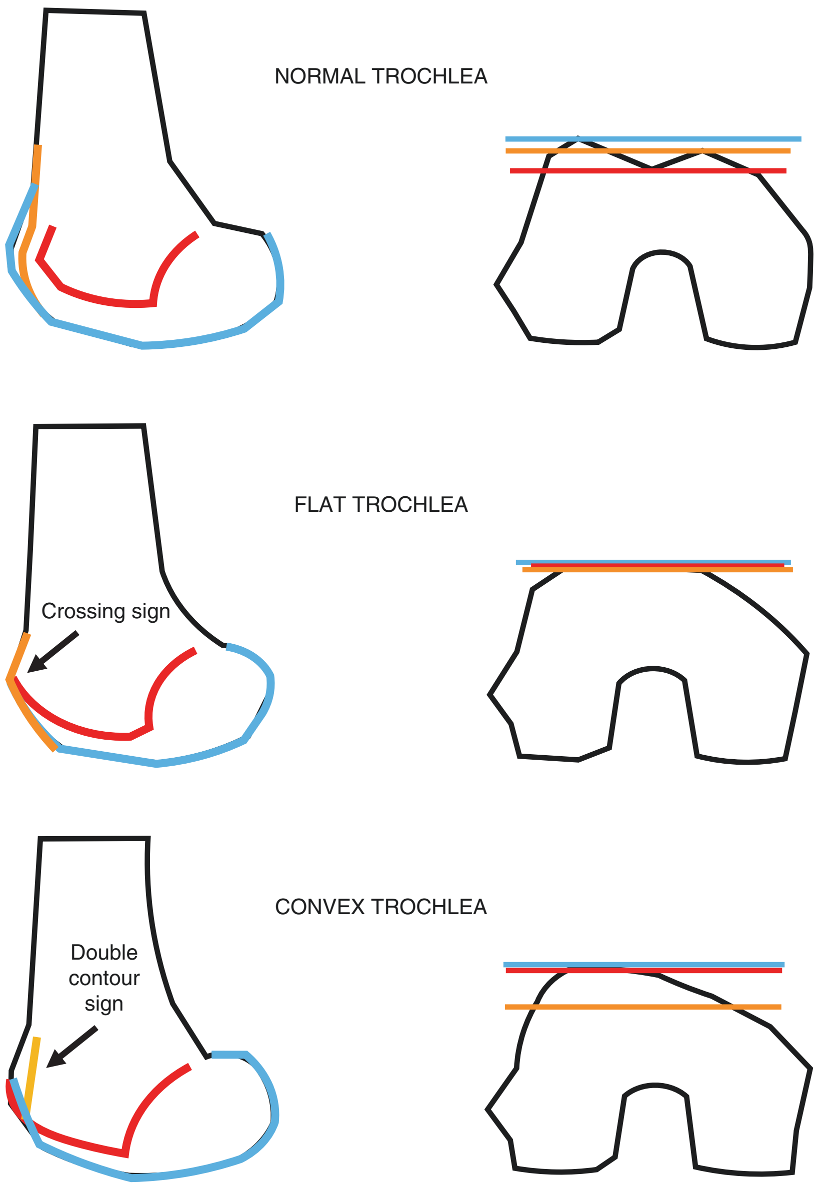

Fig. 2.4 Normal femoral trochlea (upper image), concave trochlea (middle image), and convex trochlea (lower image)

Fig. 2.5 Lateral radiograph showing the three signs of trochlear dysplasia: crossing sign, supratrochlear spur, and double contour

Trochlear Bump and Supratrochlear Spur

A dysplastic trochlea can also present an abnormal prominence on the anterior femoral cortex. This "trochlear bump," again described on the lateral radiograph by Henri Dejour, can cause increased stresses on the PF joint representing an "anti-Maquet" effect. The trochlear bump is defined by drawing a line to continue the plane of the anterior femoral cortex and measuring the distance between this and the most prominent part of the bony floor of the trochlea. The distance is then described as representing either positive (trochlear floor anterior to femoral surface), negative, or neutral. Dejour described normal as being <3 mm of positive trochlear protrusion. When the trochlear bump is steep, it is called trochlear spur, pushing the patella off the lateral facet when the knee flexes. The presence of a supratrochlear spur is characteristic of high-grade trochlear dysplasia.

Double Contour Sign

The line found posteriorly to both the lateral facet and the groove (after the crossing sign) and represents the hypoplastic medial facet.

2.2.2.3 Patella

Patellar tilt and patellar morphology may be assessed on the lateral radiograph. Tilt categorization has been described by Malghem and Maldague [14]. Three positions are described: in a normal position, non-tilted patella, the lateral facet is anterior to the crest; if patellar tilt increases, these references change, and patellar thickness seems increased with the lateral radiograph demonstrating a false profile of the patella, in which the two lines (lateral facet and crest) are on the same level. A severe degree of tilt gives a rugby ball shape to the patella with the lateral facet sitting behind the crest (Figs. 2.6 and 2.7).

2.2.3 Skyline View

Skyline views are very helpful for the assessment of patellofemoral geometry and pathology but are difficult to perform in a standardized way and near impossible in unstable patellae. Their first use is to demonstrate avulsion fractures of the medial patellofemoral ligament (MPFL). This gives a fragment, known as the sliver sign (Fig. 2.8), is pathognomonic for patellar dislocation, and is present in 15% of patients with patellar dislocations. It is also possible to find osteochondral fractures of the lateral trochlear facet or femoral condyle.

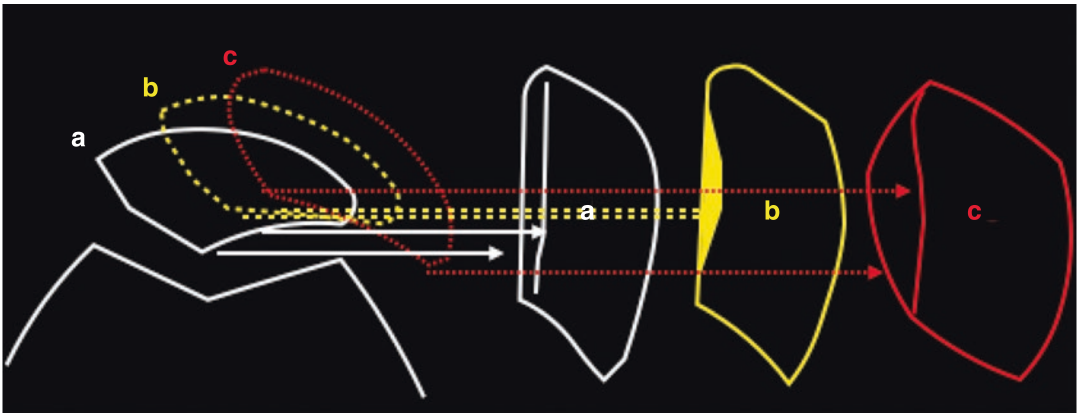

Fig. 2.6 Tilt evaluation in lateral views: (**a**) normal position (white), the lateral facet is anterior to the crest. (**b**) Mild tilt (yellow), the lateral facet and the crest are on the same level. (**c**) Severe tilt (red), the lateral facet is behind the crest

Fig. 2.7 Tilt evaluation in lateral views: (1) normal position, (2) mild tilt, and (3) severe tilt

Fig. 2.8 Avulsion of the medial aspect of the patella. Note the small osseous fragment (circle) that corresponds to the patellar insertion of the MPFL and retinaculum

Patellar morphology is classified according to the Wiberg classification [15] that describes the relative medial and lateral patellar facet sizes, categorizing the patella into four types (Fig. 2.9).

Skyline views can assess the size of osteophytes and permit quantification of the presence and severity of PF osteoarthritis using the Iwano classification [16] based on lateral PF joint space narrowing (Table 2.1).

Computed tomography (CT) scan or magnetic resonance imaging (MRI) should be performed as a second-level exam with a specific protocol.

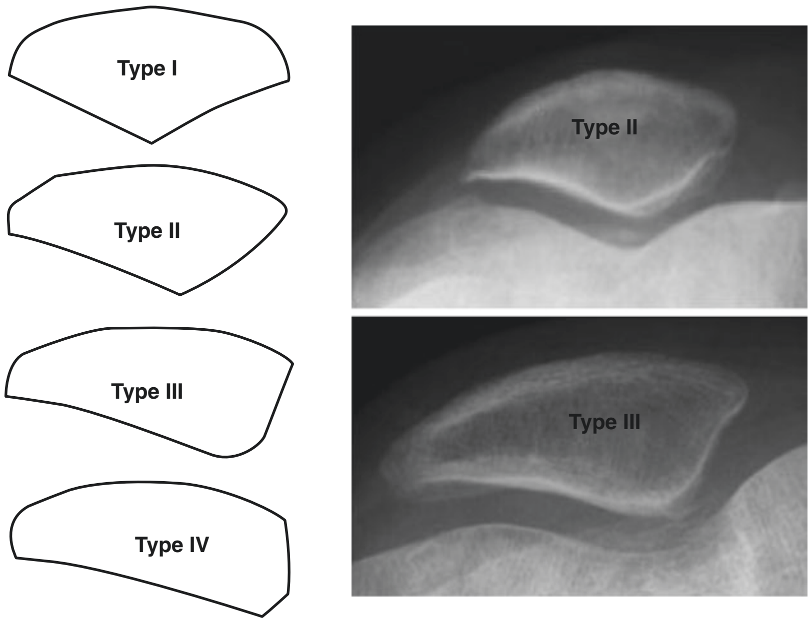

Fig. 2.9 Wiberg classification [15]

Table 2.1 Iwano classification for patellofemoral osteoarthritis [16]

Stage 0	Normal
Stage 1	Mild: joint space at least 3 mm
Stage 2	Moderate: joint space <3 mm but no bony contact
Stage 3	Severe: partial bony contact on less than one-quarter of joint surface
Stage 4	Very severe: joint bony surfaces entirely touch each other

2.3 Computed Tomography (CT)

CT scan is very useful in the analysis of the PF joint; it is probably the best modality for the assessment of bony morphology and the measurement of many of the parameters of dysplasia. The CT scan also has the advantage of showing both knees, allowing a bilateral analysis.

The advantage of CT versus radiography is that it allows the evaluation of patella in the last degrees of extension (0–30°). Axial cuts are useful for identifying osteochondral fractures (although these may be more accurately assessed on MRI) and can also be used to visualize trochlear morphology. By superimposing images, CT allows the accurate measurement of the TT-TG distance and patellar tilt. By using low-dose hip-knee CT protocols, torsional deformities as external tibial torsion and femoral anteversion may be assessed. The major disadvantage of CT is that it is difficult to assess the cartilage except in the state of advanced osteoarthritis (OA). While this can be improved with the use of CT arthrography (Fig. 2.10), this is an invasive procedure, and MRI is more useful for the visualization of cartilage.

One protocol for CT scanning the patellofemoral joint was described by Henri Dejour and is known as the Lyon protocol [13].

Six specific axial cuts are acquired:

- One hip, through both the femoral necks at the top of the trochanteric fossa.
- Four knee: the first through the proximal trochlea (where the intercondylar notch looks like a Roman arch) is called the “reference cut”; the second through the major transverse axis of the patella; the third through the proximal tibial epiphysis, just beneath the articular surface; and the last one through the proximal part of the tibial tuberosity.
- One ankle, near the ankle joint, at the base of the malleoli.

2.3.1 Evaluation of Trochlea

Trochlear angle is defined as the angle between the two trochlear facets in the axial view. An angle ≥150° is indicative of a dysplastic trochlea (Fig. 2.11).

In acute PF instability, avulsion flakes from the MPFL or osteochondral defects may be seen (Fig. 2.12).

The TT-TG distance is the distance between two lines perpendicular to the posterior condyles projected through the deepest portion of the

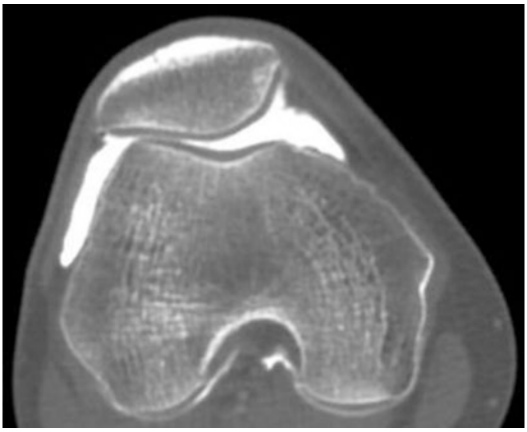

Fig. 2.10 Arthro-CT scan allows excellent evaluation of cartilage

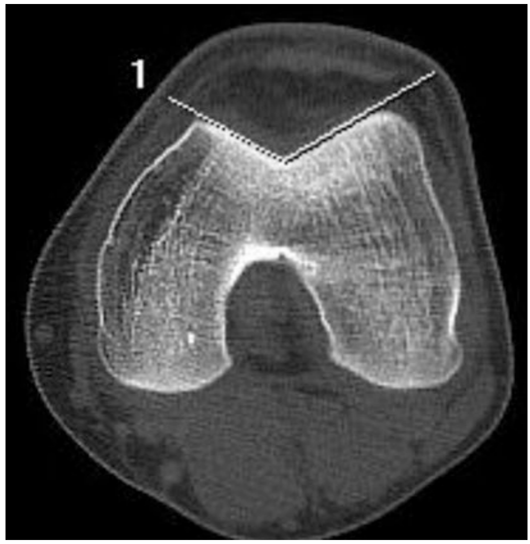

Fig. 2.11 CT scan: Trochlear angle

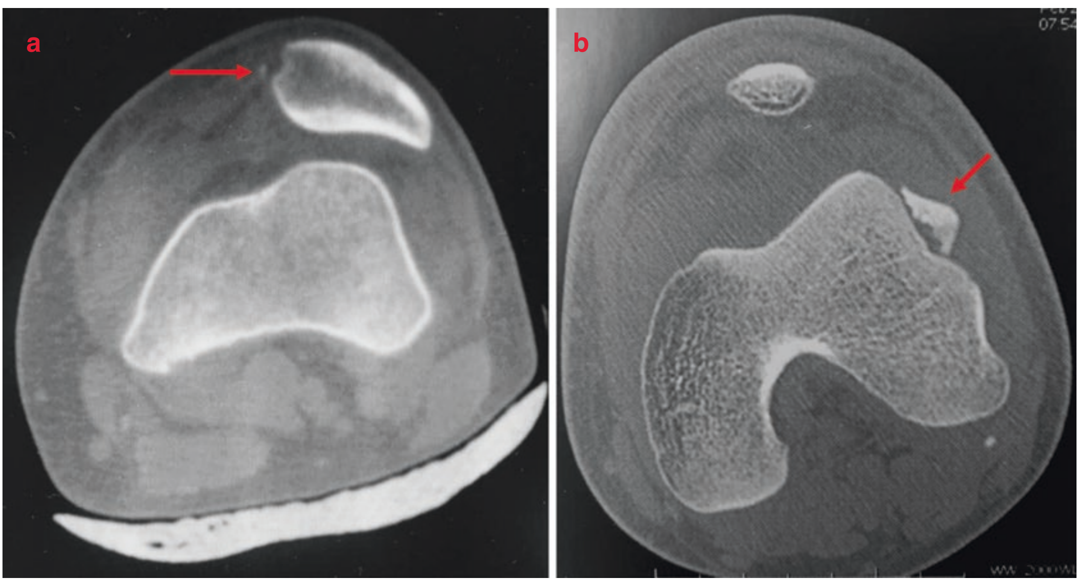

Fig. 2.12 CT scans. Axial views of patellar instability: (**a**) avulsion of the medial patellar edge (arrow); (**b**) osteochondral fragment of the medial facet of the fractured patella in the lateral gutter after patellar dislocation (arrow)

trochlea groove and the anterior prominence of the TT. The normal value in the control population is 12 mm; in the objective patellar dislocation population, this value is greater than 20 mm in 56% of the cases.

2.3.2 Evaluation of Patella

The patellar tilt is the angle between the line tangent to posterior condyles (the same used for TT-TG) and the major transverse axis of the patella. A patellar tilt of ≥20° is considered abnormal. Measurement of lateral patellar tilt is highly reproducible [17].

Patellar tilt can be evaluated on CT scans with and without quadriceps contraction (Fig. 2.13). However, Delgado-Martinez et al. demonstrated that patellar tilt with the quadriceps contracted is proportional to the measurement in a relaxed state [18]. Therefore, only one examination is needed, and it is most straightforward to simply take a single measurement with the quadriceps relaxed.

Dynamic CT scans allow the assessment of the PF joint during knee range of motion and can objectively quantify maltracking patterns [19].

2.3.3 Rotational Measurements

2.3.3.1 Femoral Anteversion

Femoral anteversion is the angle between the line passing through the center of femoral head and the center of the femoral neck and the line parallel to the posterior femoral condyles (Fig. 2.14).

2.3.3.2 External Tibial Torsion

External tibial torsion is the angle formed by the tangent to the posterior aspect of the plateau (beneath the articular surface) and the line passing bimalleolar axis at the center of the ankle (Fig. 2.15).

Three-dimensional reconstructions allow a global assessment of the degree of anatomical abnormality but at present give only a subjective view with quantification being difficult (Fig. 2.16).

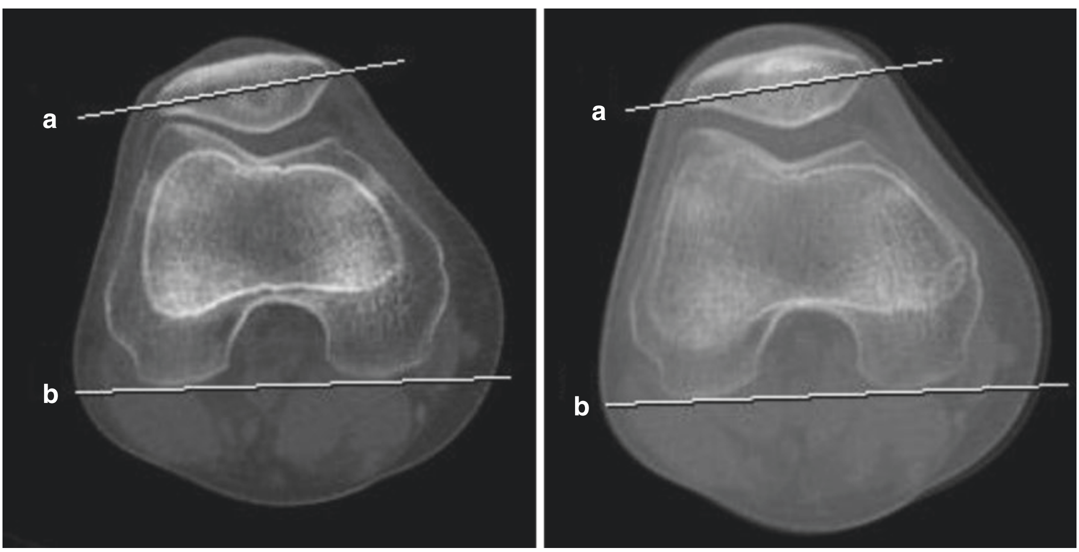

Fig. 2.13 CT scans. Measurements of patellar tilt are performed with quadriceps contracted and relaxed. It is the angle between (**a**) a tangent to the posterior condyles and (**b**) the major transverse axis of the patella

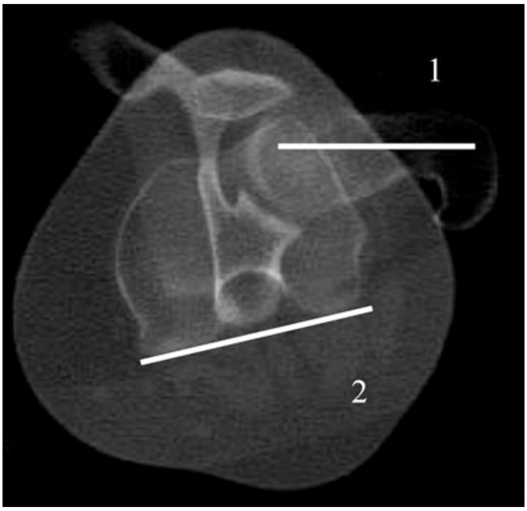

Fig. 2.14 Femoral anteversion. Two CT scan cuts are superimposed: angle between lines 1 and 2. Line 1 goes between the center of the femoral head and the center of the femoral neck. Line 2 is parallel the posterior femoral condyles

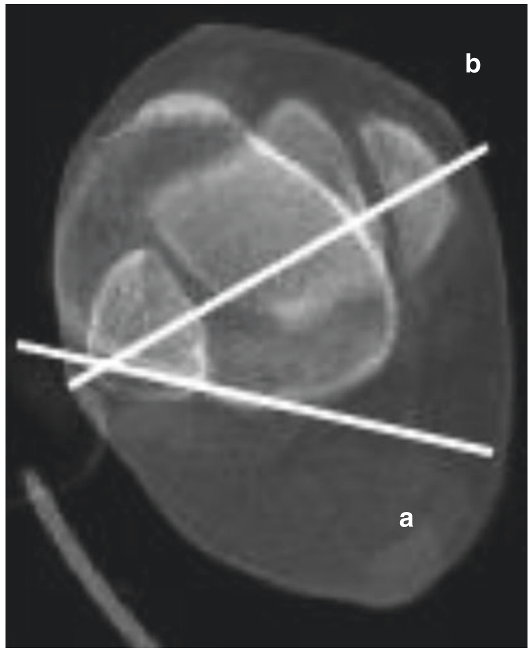

Fig. 2.15 External tibial torsion. Two CT scan cuts are superimposed: angle formed by the tangent to the posterior aspect of the plateau (**a**) and the bimalleolar axis (**b**)

Fig. 2.16 Three-dimensional (3D) computed tomography images: lateral patellar dislocation (**a** and **b**); intraarticular body of the inferomedial part of the patella is seen after acute patellar dislocation (**c**); bony fragment at the patellar medial border (arrow); sequelae from acute patellar dislocation (**d**) (arrow)

2.4 Magnetic Resonance Imaging (MRI)

MRI is now widely used in the assessment of the patellofemoral joint. It has many of the advantages of CT scan (assessment of morphology and measurement of angles) but has thinner slices and does not expose the patient to radiation. MRI has the advantage over CT of allowing accurate assessment of the articular surface and the state of the MPFL. Landmarks are cartilaginous surfaces instead of subchondral bone.

It is essential to have a systematic approach to the assessment of chondral surface and risk factors for patellar instability on MRI. Interpretation of MRI is performed to evaluate morphologic grading of patellar cartilage damage, injury patterns, trochlear dysplasia, PF alignment (patellar tilt, patella height ratio, and TT-TG distance, Table 2.2).

2.4.1 Evaluation of Cartilage and Soft Tissue

MRI is the best imaging method for study of articular cartilage, identification of bone bruising, and assessment of MPFL integrity; it also allows diagnosis of concomitant meniscal or ligamentous pathology.

Cartilage defects of the tibia or femur are best seen on the sagittal and coronal images, whereas the cartilage of the patella and the trochlear portion of the femoral cartilage is best evaluated in the axial and sagittal planes on T2-weighted or proton density images with fat saturation. MRI can detect osteochondral lesions with a high degree of sensitivity, approaching 90% [20].

Abnormalities of cartilage are described using a 4-point grading system according to the International Cartilage Repair Society [21] (Fig. 2.17):

- Grade 1 (low-grade): normal contour of the articular cartilage with swelling and abnormal increased signal
- Grade 2 (intermediate-grade): superficial erosion or ulceration <50%
- Grade 3 (high-grade): partial-thickness cartilage defect of >50% but <100% (no underlying marrow signal change)
- Grade 4 (high-grade): full-thickness cartilage loss with underlying marrow signal abnormalities
- Grade 5: osteochondral injury with separation of an osteochondral fragment

In up to 50% of cases, in particular cases where the patella reduces spontaneously prior to presentation at hospital, patellar dislocation is not suspected prior to obtaining diagnostic imaging (Fig. 2.18). The diagnosis of patellar dislocation can be made in the presence of four major MRI signs [22] (Fig. 2.19):

Table 2.2 Summary of magnetic resonance imaging (MRI) measurements

Parameter	How to measure	Abnormal
Trochlear depth	[(LC + MC)/2] − CC	<3 mm
Sulcus angle		≥145
Trochlea facet asymmetry	(MF/LF) × 100	<40%
Trochlear inclination angle		<11°
Patellar tilt		≥20
Tibial tubercle-trochlear groove (TT-TG) distance		≥15 mm
Caton-Deschamps index		>1.2
Patellotrochlear index		<12.5%, >50%

LC lateral condyle, *MC* medial condyle, *CC* central condyle, *MF* medial facet, *LF* lateral facet

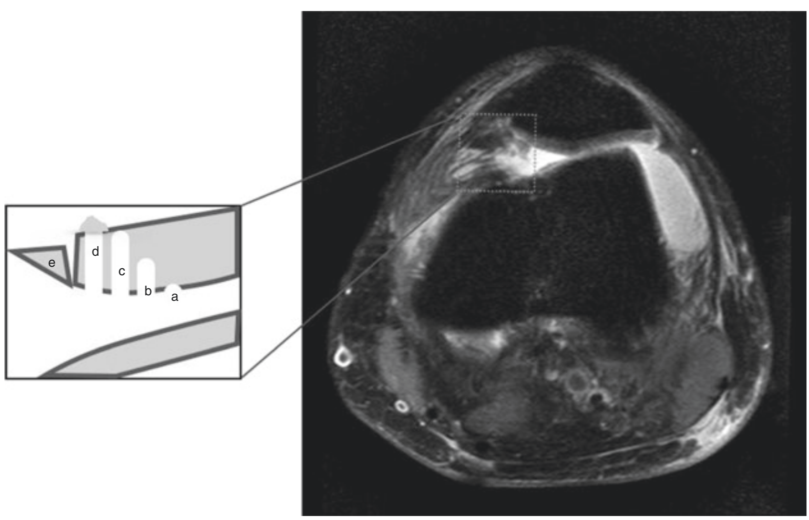

Fig. 2.17 Osteochondral injury classification: (**a**) swelling and abnormal increased signal; (**b**) superficial erosion <50%; (**c**) partial-thickness cartilage defect of >50% but <100% (no underlying marrow signal change); (**d**) exposed/bruised subchondral bone; (**e**) osteochondral injury with separation of an osteochondral fragment

- Hemarthrosis.
- Edema and/or osteochondral lesion in the anterolateral aspect of the lateral femoral condyle (isolated osteochondral injuries of the TG are referred to as “lunge” lesions, secondary to a shearing action of the patella impacting the TG).
- Edema and/or osteochondral lesion o the inferomedial facet of the patella. This is the most common site of articular cartilage injury after patellar dislocation [23].
- Injury to the MPFL.

Fig. 2.18 MRI demonstrating lateral patella dislocation

The MRI classification of MPFL injury places injuries into three groups depending on the location of the injury and resulting pattern of edema. Most (76%) are injuries of the patellar attachment of the MPFL with edema at the patellar insertion; 49% have an injury to the femoral attachment site with edema at the medial femur; 30% have a midsubtance injury. Up to 48% have a multifocal injury (edema was at two locations: patellar and femoral, patellar and central, or diffuse edema along the ligament) [24]. Severity of MPFL injury is defined from 0 to 3 [25] (0, normal; 1, periligamentous edema; 2, partial tear; and 3, complete tear) and if there is an associated avulsion fracture fragment. Chronic MPFL tears are more difficult to detect because they lack edema-like signal, but these can show focal or diffusely attenuated or abnormally thickened fibers. The ligament fibers may be elongated, wavy, or irregular [26, 27].

2.4.2 Trochlear Dysplasia

Trochlear morphologic characteristics are assessed on axial images and may be defined by the following MRI measurements (Fig. 2.20):

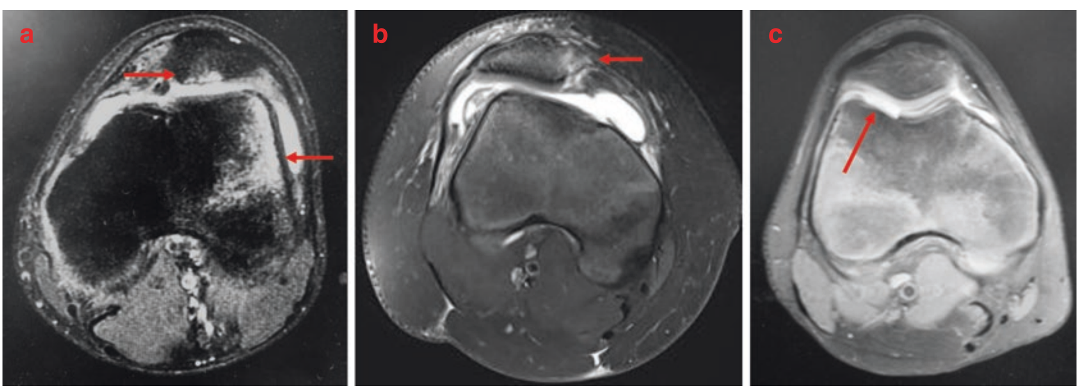

Fig. 2.19 Skyline MRI images following acute lateral patellar dislocation. (**a**) The classic bone bruise pattern can be seen, showing edema in the lateral femoral condyle and medial facet of the patella (arrow); (**b**) note discontinuity of signal in the area of the medial patellofemoral ligament (MPFL) (arrow), medial patellar osteochondral lesion and joint effusion; (**c**) lateral femoral condyle osteochondral lesion (arrow) (“lunge” lesion)

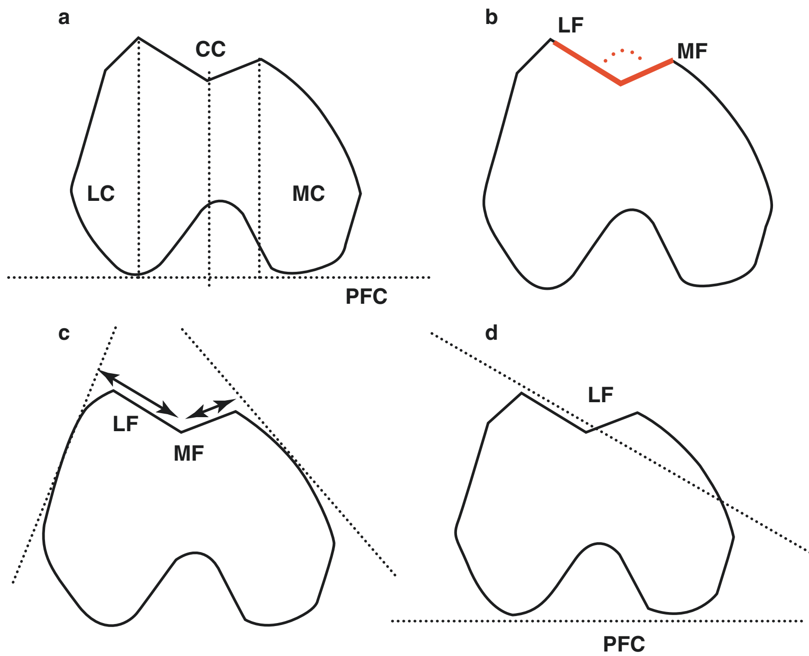

Fig. 2.20 Axial MRI measurements: (**a**) trochlear depth, (**b**) sulcus angle, (**c**) trochlear facet asymmetry, (**d**) lateral trochlear inclination. *PFC* posterior femoral condyle, *LT* lateral condyle, *MC* medial condyle, *CC* central condyle, *LF* lateral facet, *MF* medial facet

2.4.2.1 Trochlear Depth (mm)

To define the trochlear depth, the average is taken of the maximal AP lengths of the lateral condyle (LC) and medial condyle (MC), before subtracting the central condylar (CC) height, [(LC + MC)/2] − CC. Trochlear dysplasia is defined as <3 mm, which identifies individuals with a diagnosis of dysplasia with a specificity of 100% and sensitivity of 96% [27].

2.4.2.2 Sulcus Angle (°)

The angle between the lateral facets (LF) and medial facet (MF) of trochlear. Trochlear dysplasia is defined as ≥145° [28].

2.4.2.3 Trochlear Facet Asymmetry (%)

The ratio of the medial facet (MF) length to the lateral facet length, (MF/LF) × 100. Trochlear dysplasia is defined as <40% [27].

2.4.2.4 Lateral Trochlear Inclination (°)

The lateral trochlear inclination (LTI) angle is between the posterior femoral condyle (PFC) and a line across the lateral facet. The mean value of lateral trochlear inclination is reported to be 16.9° in knees without trochlear dysplasia and 6.17° in patients with patellar instability. The threshold for trochlear dysplasia is <11; the measure has shown a sensitivity of 93% and a specificity of 87% for trochlear dysplasia [29]. The lateral trochlea inclination measurement is used for the diagnosis, the planning of treatment, and the prediction of future risk of patellar dislocation. In a recent literature review, it was rated as the most useful measurement of trochlear dysplasia [30].

2.4.2.5 Ventral Trochlear Prominence

In the same review article, measurement of ventral trochlea prominence was highly rated for the diagnosis of trochlear dysplasia but has the disadvantage of not having an international consensus on a normal value. The ventral trochlear prominence is described as the distance between the line paralleling the ventral cortical surface of the distal femur and the most ventral cortical point of the femoral trochlear floor (Fig. 2.21).

Fig. 2.21 Sagittal MRI showing prominent bony protrusion of the femoral condyle (arrow), indicating trochlear dysplasia

Axial and sagittal MRIs can be used to classify the trochlear morphology according to the Dejour classification [31] (Fig. 2.22):

- Type A, trochlear morphology is preserved with a fairly shallow trochlea and is characterized by a sulcus angle >145°.
- Type B, flat or convex trochlea, is characterized by supratrochlear spur.
- Type C, asymmetrical trochlear facets with dominant and convex lateral facet and a hypoplastic medial facet.
- Type D, complete lack of medial trochlear facet with a cliff pattern.

In practice Lippacher et al. [32] found this classification system to be most reliable for separation of low-grade (type A) and high-grade (types B–D) dysplasia.

2.4.3 Patellar Tilt (°)

Patellar tilt is evaluated on axial slices in the same way as it is on the CT scan. The angle between the posterior condyle and a line at the greatest patellar width (patellar midpoint). Abnormal is defined as ≥20 [33] (Fig. 2.23).

2.4.4 TT-TG Distance

The TT-TG is measured on axial MRI to determine the lateralization of the TT relative to the center of the TG.

TT-TG is the distance between a line at the most inferior level of the TG perpendicular to the posterior condyle line and a line parallel at the midline of the patellar tendon (PT) insertion into the tibia (Fig. 2.24). The TT-TG distance uses two slices, but there is some debate as to which is most accurate. The midpoint of the trochlea can be defined on the most distal axial image with an intact intercondylar notch [34], the axial image with the largest anterior-to-posterior femoral condylar dimension [35], or the axial image with the most proximal view of the complete trochlear cartilage [36]. The TT can be defined on the most distal MRI with a visible patellar tendon inserting at the TT (which is analogous to the center of the TT on CT scan). The measurement is widely used in the literature and has a high intra- and inter-reliability for both orthopedic surgeons and musculoskeletal radiologists [37]. Generally, MRI values are less than CT values [38]; the normal range of values for TT-TG has been reported to be 8.9–11.1 mm on MRI [36]. Abnormal is defined as ≥15 mm [39].

Brady et al. [34] demonstrated TT-TG distance to be superior to TT-posterior cruciate ligament (PCL) distance as a measurement of coronal malalignment and that the proximal and distal techniques for measuring the TG are similar; however, TT-PCL may be useful in conjunction with TT-TG for better understanding the tracking of the extensor mechanism in the knee joint [40].

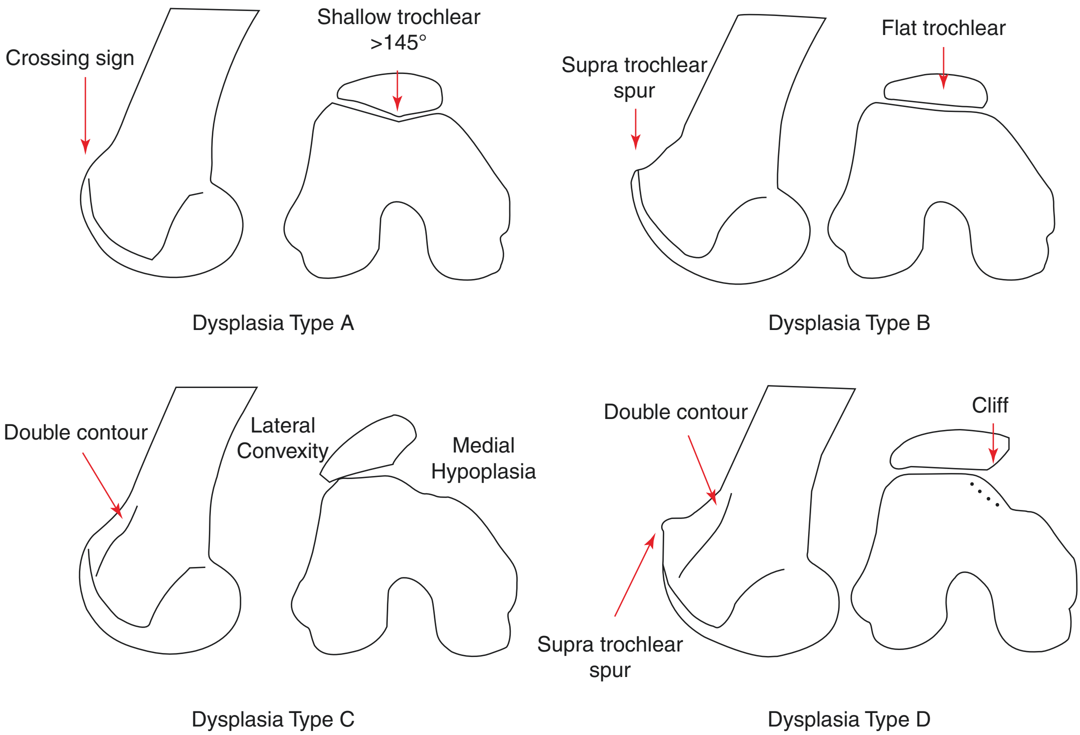

Fig. 2.22 Dejour classification of trochlear dysplasia

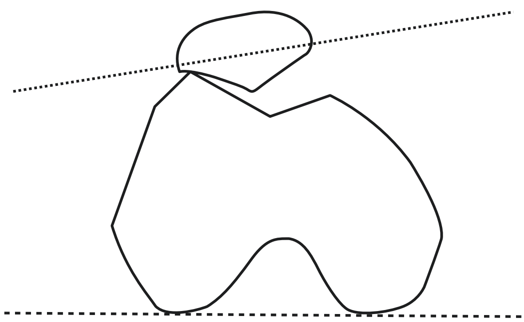

Fig. 2.23 Patellar tilt measurement

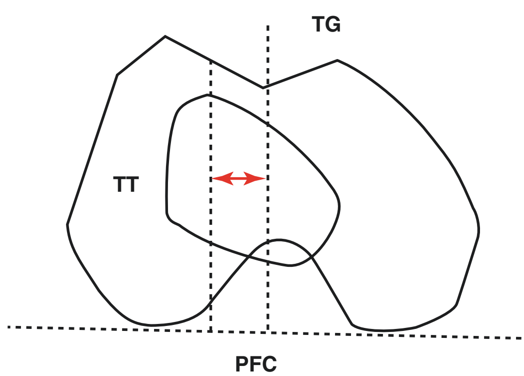

Fig. 2.24 TT-TG distance. Superimposed axial MRI image. *TT* tibial tubercle, *TG* trochlear groove

TT-TG measurements decrease significantly with increasing knee flexion because the tibia externally rotates about 15° on the femur during the last 20° of knee extension. With an externally rotated tibia at knee extension, the TT is positioned more laterally relative to the femur, explaining why TT-TG measurements are higher in extension. If the patient cannot maintain the position of the leg, the distance TT-TG may be variable [41].

2.4.5 Patellar Height

There is no significant difference between the values obtained for the major measures of patellar height (Caton-Deschamps, Blackburne-Peel, and Insall-Salvati indices) measured on lateral radiographs and on sagittal CT scan slices. The sagittal slice showing the greatest length of the patella

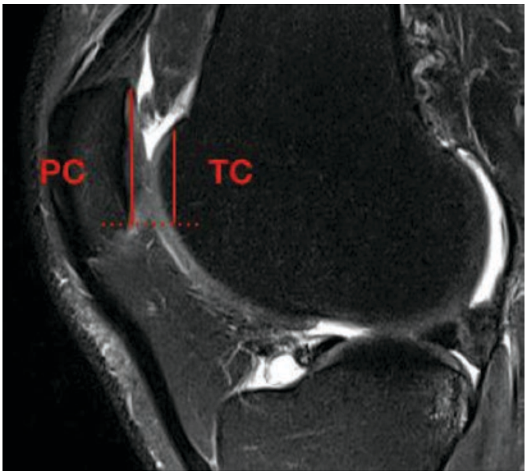

Fig. 2.25 Patellotrochlear index. Patellar articular cartilage (PC) and trochlear articular cartilage (TC) were measured from the caudal extent of patellar cartilage to the cranial end of trochlear cartilage overlapping with patellar cartilage

(through the central part of the patellar facet) is used for sagittal measurements of patellar height.

Albrecht and Biedert [42] described a new measure, the patellotrochlear index, on sagittal MRI with knee in 0° extension, the foot in 15° external rotation, and the quadriceps muscle relaxed. The patellotrochlear index is the ratio between the trochlear articular cartilage (TC) and patellar articular cartilage (PC) calculated in percentages. Biedert and Albrecht determined a patella alta I values less than 12.5% and patella baja if values more than 50% (Fig. 2.25). This index is not always measurable because it uses a single MRI slice; thus it cannot be measured in cases of a dislocated patella.

2.5 Conclusions

A number of measurements exist for the assessment of patellofemoral morphology on radiographic studies. When measured with care, most are highly reproducible. Plain radiographs are the mainstay of initial assessment and can be used accurately for the assessment of patellar height and trochlear dysplasia, although measurement of TT-TG distance is not possible and detailed assessment of the trochlear morphology is limited by the difficulties in standardizing the skyline view.

Both CT scan and MRI are useful for determining patellofemoral morphology. CT scan has the advantage of allowing the assessment of torsional abnormalities as well as the accurate assessment of all morphological indices. MRI can assess many of the same measurements but can also be used to determine the degree of soft tissue injury, the presence of osteochondral injuries and the presence of other intraarticular pathology.

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3 Acute Patellar Instability in Children

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3.1 Introduction

Patella instability is a common cause of knee pain in children and adolescents with a reported incidence of 30–50 per 100,00 each year in 10–18-year-olds [1, 2]. The term patella instability describes a range of conditions including patella dislocation, patella subluxation and persistent symptomatic maltracking.

Acute patella dislocation occurs in two main groups: those with an anatomical or physiological predisposition to instability (patella alta, ligamentous laxity, trochlear dysplasia, etc.) where less significant trauma may cause dislocation and where dislocation may then become habitual; it also occurs as a distinct traumatic episode in children with no predisposing anatomical or physiological abnormality, where significant trauma is required to produce a dislocation.

Acute first-time patella dislocation occurs with an incidence of 29 per 100,000 in adolescents [3] and accounts for 3% of all knee injuries (children and adults) [4]. In females, the incidence has been quoted in the literature as being up to 104 per 100,000 [5]. These commonly occur during sporting activities or secondary to other activities such as dancing. The patella dislocates laterally. Medial patella dislocations are usually iatrogenic due to excessive lateral release [6] and will not be considered further here. Overall, patella instability is a complex problem which can be difficult to manage. Even without recurrent dislocation, patients may continue to suffer from pain and instability after an acute dislocation. Management involves establishing the correct diagnosis, the cause of the instability and treating it appropriately.

3.2 Anatomy and Predisposing Factors

The patella has a convex inferior surface which articulates with the concave trochlear groove of the femur. Proximally, this groove has a higher lateral facet which provides a deeper portion and stability in knee extension. As the knee flexes, the forces within the patellofemoral joint increase and are highest in mid-flexion. If there is variation in bony anatomy, this engagement between the patella and trochlear groove is altered and may manifest as patellar instability. This is highlighted in patients with patella alta who have abnormal engagement during knee flexion and are therefore at risk of recurrent dislocation [7]. Trochlear dysplasia is a major predisposing factor to patella instability and said to be present to some degree in 85% of patients with patellofemoral instability [8]. It is defined as an abnormality of the morphology or depth of the trochlear

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groove, mainly the proximal portion where the patella engages the trochlea. The flattening of the trochlea and altered morphology was further classified by Dejour who described four types (A–D) [9]. The presence of both patella alta and trochlea dysplasia decreases the ability of the patella to articulate within the trochlea groove at all degrees of flexion thereby increasing the risk of patella dislocation.

Patella dysplasia is another major factor contributing to instability. Three quarters of the inferior surface of the patella represent the articular surface. There is a large lateral facet which articulates with the lateral femoral condyle and a smaller medial facet which contacts with the medial femoral condyle. The larger lateral facet prevents lateral subluxation by acting as a buttress as the knee flexes. Abnormalities of the lateral facet can therefore contribute to patellofemoral instability; and patella shape has been classified by Wiberg (A–C) [10]. When trochlear and patellar dysplasia are combined, the capacity for the patella to sit within the groove is greatly reduced at all degrees of knee flexion. Although the presence of one of these dysplasias can lead to dislocation, having both present increases the risk exponentially [11].

Axial deformity, e.g. genu valgum or rotational abnormality such as increased femoral anteversion or external tibial torsion, has also been shown to contribute to patella maltracking [12] and should be considered during patient assessment. This is due to an increase in the lateral vector pulling on the patella in flexion which has been shown to be up to 4600 N at 120° of knee flexion [13]. The patellar tendon and quadriceps tendon act as two different force vectors on the patella, and this is represented by the Q (quadriceps) angle which increases with knee extension. The Q angle is calculated using two lines. The first line is drawn from the anterior superior iliac spine (ASIS) to the centre of the patella and the second from the tibial tuberosity to the centre of the patella. The normal angle is often measured with the knee in extension and is slightly higher in girls than boys due to a wider pelvis. With an increasing Q angle, a patellar-lateralising vector arises and increases the risk of lateral patella dislocation. Factors increasing the Q angle include genu valgum and increased femoral anteversion.

In conjunction with bony stabilisers, soft tissue stabilisers play a vital role in patellar stability. The quadriceps, more specifically the vastus medialis obliquus (VMO) and lateralis, are normally balanced preventing patella tilt. However, with a weakened VMO, the patella tilts and becomes aligned with the vastus lateralis, leading to an increased lateral force vector, maltracking and risk of dislocation. There are several static soft tissue stabilisers. Medially, the medial patellofemoral ligament (MPFL) is a major contributor and represents a fascial band connecting the medial border of the patella to the medial femoral condyle. It provides 60% of the medial stabilising force [14] and should have a mean tensile strength of 208 N [15]. The medial patellomeniscal ligament also plays a minor role in preventing lateral movement. Laterally, there are several structures which paradoxically provide restraint to lateral dislocation. These include the fascial portions of the iliotibial band, lateral retinaculum and lateral portion of the knee capsule [16]. Table 3.1 summarises predisposing factors for patellar dislocation.

Table 3.1 Risk factors for patellar dislocation

Trochlear dysplasia
Patella alta
Increased TT-TG (tibial tuberosity-trochlear groove) distance (lateralised tibial tubercle)
Patella dysplasia
VMO (vastus medialis obliquus) deficiency or weakness
Increased Q angle
Generalised ligamentous hyperlaxity
Genu valgum
Increased femoral anteversion
External tibial torsion

3.3 Mechanism of Injury

Sporting injuries are the commonest cause of acute patellar dislocations. Knee flexion and valgus +/− external rotation are reported to be the leading mechanism of injury associated with patellar dislocation, accounting for as many as 93% of all cases [5, 16]. One report suggests that in 10% of cases, a direct blow to the medial aspect of the patella may be the causative force [17].

3.4 Assessment

A complete history and thorough clinical examination are vital in identifying and correctly managing an episode of acute dislocation. The mechanism of injury is important. The causative factors of patellar instability should be enquired about, particularly if there is a history of recurrent dislocations, in which case other relevant aspects of the history include the presence or absence of pain, and history of previous dislocations and treatment received.

Acute traumatic patellar dislocation causes disruption of the medial soft tissues such as the medial patellar retinaculum and the MPFL, resulting in tenderness over the medial patellar retinaculum and a haemarthrosis. Osteochondral fractures have been noted in nearly 25% of acute patellar dislocations [5].

Detailed examination is difficult in the acute situation, particularly in the presence of a haemarthrosis, and therefore joint aspiration can be useful, both to improve patient comfort and facilitate clinical examination and radiographic assessment. The presence of fatty globules in the aspirate is suggestive of an osteochondral fracture. Further detailed examination may only be able to be performed once the acute symptoms have settled, and therefore imaging plays a key role in assessing the injury further. Within the limits of examination in the acute setting, some assessment of risk factors for patellar dislocation can be made (Table 3.1); for example, malalignment of lower extremities and hypermobility of the contralateral knee can give useful additional information.

3.4.1 Radiological Assessment

The main aim of imaging in the acute setting is to assess for the presence of other bony injuries and to confirm or exclude an osteochondral fracture, as this may influence immediate management. The skyline view is particularly useful in this respect (Fig. 3.1) but may be difficult to obtain immediately after the acute episode. Plain weight-bearing radiographs in the form of AP and lateral views are useful and help to evaluate patella position and height, as well as the presence or absence of trochlear and patellar dysplasia. A standing long leg film may be useful to assess lower leg alignment for genu valgum, but may not be possible or beneficial in the acute situation. MRI is used in order to further assess the MPFL and soft tissues as well as to search for osteochondral fractures (Fig. 3.2). After the acute episode has settled, MRI and CT have a role in assessing bony anatomy and alignment, as well as calculating rotational profile.

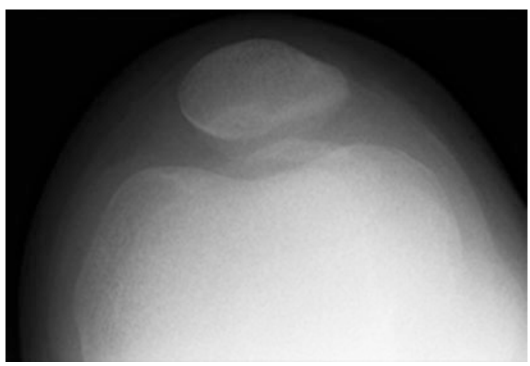

Fig. 3.1 The main aim of imaging in the acute setting is to assess for the presence of other bony injuries and to confirm or exclude an osteochondral fracture, as this may influence immediate management. The skyline view is particularly useful in this respect but may be difficult to obtain immediately after the acute episode

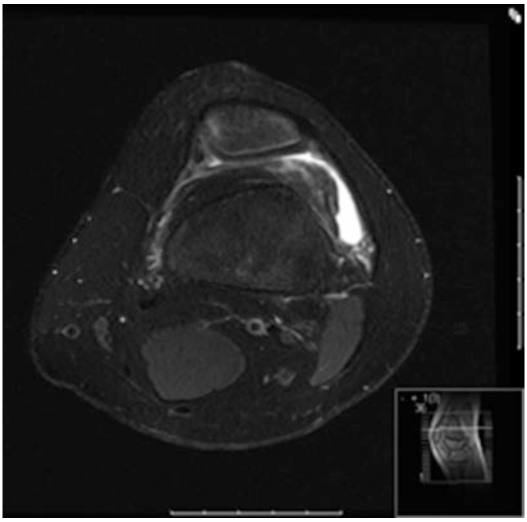

Fig. 3.2 MRI is used in order to further assess the MPFL and soft tissues as well as to search for osteochondral fractures

3.5 Treatment

In the setting of an acute patella dislocation, the majority reduce spontaneously but those that fail to do so may require closed reduction in the emergency department.

3.5.1 Operative Treatment

In the immature skeleton, operative treatment is indicated in the presence of large displaced osteochondral fractures (>5 mm) or loose bodies. The majority originate from the patella but may also arise from the lateral femoral condyle or both [18]. These fragments can be fixed using a variety of fixation devices such as headless compression screws.

The role of surgery for acute instability and following first-time dislocation in skeletally immature patients, in the absence of osteochondral fractures, remains controversial. A Cochrane review found the evidence was not of sufficient quality to demonstrate a significant difference in outcome between surgical and nonoperative management in first-time patella dislocation [19]. However, a recent systematic review found a higher recurrence rate of dislocation with non-operative management (31%) compared to those treated with surgery (22%) [20], confirmed in another systematic review of meta-analyses [21] although the two studies differed in their conclusion concerning long-term functional outcome. The surgical technique was variable in the studies included with the majority of studies focussing on MPFL repair and only one study on MPFL reconstruction.

In general, if there is no osteochondral fracture, treatment consists of a 6-week period of immobilisation followed by rehabilitation, and generally this has been considered the gold standard of care [22].

Bracing has been shown to reduce patellofemoral joint pressure by modifying and limiting knee kinematics during the period of rehabilitation and has been shown to reduce the risk of re-dislocation and residual pain [23]. Progressive increase in permitted flexion over a 6–8-week period using a hinged knee brace may also be beneficial in avoiding stiffness secondary to immobilisation and retain some muscle strength [24].

Physiotherapy and rehabilitation should then address any dynamic dysfunction of the patellofemoral joint. A systematic review demonstrated delayed VMO activation relative to vastus lateralis in patients complaining of anterior knee pain secondary to instability [25]. Exercises therefore concentrate on strengthening of the quadriceps, with particular attention to the VMO and muscle re-education.

3.6 Outcome

Following a first-time patella dislocation, there is a risk of recurrent instability or dislocation, pain, reduced activity level and later development of patellofemoral osteoarthritis [26]. Recurrent instability has been quoted as occurring in up to 50% of cases [27, 28], with the highest risk being found in children with trochlear dysplasia, patella alta and sports-related injuries [11].

After the acute episode has settled, it is advisable to perform a detailed examination for signs of instability, including a general examination of gait and overall alignment of the lower limbs including Q angle, as described above. The knee should be examined for overall stability (cruciate and collateral ligaments). A patellofemoral joint examination will assess patella tracking, patellar quadrant movement and patella apprehension. Examination for overall ligament laxity should be included, for example, using the Beighton score [29]. A thorough radiological examination can be undertaken to assess osseous and ligamentous anatomy for dysplasia or deficiency.

In the context of recurrent instability and patellar dislocation, a variety of surgical techniques may be used, and this will be discussed in a later chapter.

3.7 Conclusion

Acute patellar instability can be challenging to manage in children. Nonoperative treatment remains the preferred option with surgical intervention reserved for osteochondral fractures and those considered at a high risk of developing recurrent instability or dislocation. A thorough clinical assessment of mechanism of injury and risk factors will help identify those at risk of developing recurrent instability.

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4 Acute Lateral Patellar Dislocation in Adults

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4.1 Introduction

Patellar instability is one of the most common problems of the knee affecting young people. It has a reported incidence of 5.38 cases per 100,000 patients, most of them in the young active population [1, 2]. Of those with a first dislocation, up to 15% of patients go on to recurrence (with 50% of those recurrent dislocators experiencing subsequent episodes) and up to 33% have residual symptoms after the first episode [3].

Patellofemoral stability is determined by a combination of limb alignment, osseous anatomy of the patellofemoral joint, and static and dynamic soft tissue constraints. Dislocation, as in other joints, can lead to recurrent instability and pain, as well as cartilage injuries, osteochondral fractures, and, finally, patellofemoral osteoarthritis.

Patellofemoral instability is a challenging problem. This chapter will review current management of acute lateral patellar dislocation in adults, focusing on the acute symptomatic management of dislocation and the prevention of further recurrence.

4.2 Patellar Stabilizers and Physiology

4.2.1 Osseous Constraints

Patellar movement and surfaces of contact vary during flexion-extension. In full extension, the patella is located out of the trochlear groove. This is the position with the higher risk for dislocation. In the early stages of flexion (about 20–30°), it engages the groove, contacting lateral facet of the femoral trochlea with lateral facet of the patella and stability increases. As the knee flexes, contact migrates from lateral facet of the patella and trochlea through medial and proximal part of the patella and lateral aspect of the medial facet of the trochlear groove.

Osseous anatomy of the trochlear groove and the patella are essential for patellar stability. The trochlear groove is deeper (while the lateral facet shape is higher) at the anterior part of the distal femur. As it becomes more distal and posterior, the lateral facet loses height. Trochlear groove structure is mainly involved in patellar instability in knee extension and the first degrees of flexion, while the quadriceps action (with a posterior vector of action) is more important for patellar stability in deep flexion [4]. As a result, knees with *patella alta* are prone to instability. In those cases, the osseous constraints are reduced as well as the

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area of contact, determining more instability and increased contact pressure on cartilage [5, 6].

Limb alignment (specially coronal and axial planes) plays an important role on patellar instability. Excessive valgus (femorotibial angle), femoral anteversion, and external tibial rotation contribute to increase patellar instability as they increase the Q angle (the angle between the lines of action of the patella and the quadriceps tendon), and those knees are more prone to patellar dislocation.

4.2.2 Soft Tissue Constraints

In addition to the bony constraints, the soft tissues around the patellar have an important stabilizing action. These include ligaments, tendons, and muscles.

Retinacula are formed by several layers on both sides of the patella. The lateral retinaculum is formed by three layers. The most superficial is formed by the superficial expansions of the iliotibial band. The middle layer is formed by the lateral patellofemoral ligament, reinforced by expansions of the iliotibial band. Finally, the deepest layer is formed by the synovial capsule of the knee [7–9].

Expansions from iliotibial band to the patella are important in providing stability to the patella. The iliotibial band passes on the lateral side of the knee, varying its position over the lateral femoral tubercle with knee flexion-extension, and plays an important role in patellar tracking and anterolateral stability of the knee.

The medial patellofemoral ligament (MPFL) is the main component of the medial retinaculum. It acts as the most important constraint to lateral patellar displacement, especially within the first 30° of flexion [10]. It is the most strongest of the medial retinacular ligaments, exceeding the resistance of the medial patellotibial ligament and medial patellomeniscal ligament [11, 12]. When there is a deficient MPFL, the force required to displace the patella is reduced by 50% [13].

The muscles around the knee, principally vastus medialis obliquus (VMO) and vastus lateralis obliquus, are considered to be active constraints to patellar dislocation; these deviate the patella medially or laterally, respectively. Imbalance of strength in these muscles may lead to patellar instability, and they are important in recovery after dislocation. The VMO is usually the first component of the quadriceps to weaken and the last to strengthen after the injury [7]. Its contribution to patellar instability is especially important in the first 90° of flexion. It has been reported that complete inhibition of the VMO may decrease the force to displace the patella laterally up to 30% [14].

4.3 Mechanism of Injury and Presentation

The patella is in its most unstable position within the first few degrees of flexion. In this position, the MPLF is virtually the only structure that provides medial constraint to the patella. As a result, acute dislocations usually occur in the context of torsion with the knee completely or almost extended. When the patella dislocates in knee flexion, other factors such as severe trochlear dysplasia should be considered.

The patella usually dislocates laterally. Medial dislocation is significantly rarer and usually the result of structural abnormalities. When the patella is displaced laterally, several structures are damaged. In almost every case, there is disruption of the MPFL, most of which are avulsions of the femoral insertion [15, 16]; other patterns of injury include avulsion from the medial patella or a midsubstance tear. Cartilage injuries affecting medial facet of the patella (which generally occur during reduction of the dislocated patella) or, less frequently, lateral facet of the trochlea (which happen at the time of dislocation) can also appear in acute cases.

Clinically, acute dislocation is well recognized. The patella is localized on the lateral side of the knee. Severe hemarthrosis and medial tenderness are also frequent. Pain is diminished after reduction and is localized on the medial side.

4.4 Radiographic Evaluation

In the acute setting, standard anteroposterior and lateral views are used for diagnosis. Several risk factors of instability can be assessed, as patella alta or trochlear dysplasia. However, they are more important in the evaluation of chronic instability than in acute dislocation.

An axial (skyline) view can also provide accurate information about patellofemoral surfaces and can be useful for diagnosing of fractures or obstacles to reduction and, in case of chronic instability, to assess patellar tilt, patellar subluxation, and trochlear dysplasia.

If osteochondral loose bodies are noted, a computed tomography (CT) scan can be used to assess the size of the fragment and location of the fracture. Trochlear and patellar dysplasia can also be assessed with this technique, and reconstructions are useful to have a general idea of the anatomy of the knee. The distance between tibial tuberosity and trochlear groove (TT-TG distance) is a factor of risk of instability if it exceeds 20 mm [17]. If some sections are taken at the hip and ankle, rotational profile of the lower limb can also be assessed.

Magnetic Resonance Imaging (MRI) can also assess osteochondral fragments and is the best modality for defining the size of the resultant defect. MRI is also useful to assess the medial patellofemoral ligament [18] and other concomitant injuries [15]. Figure 4.1 shows medial patellofemoral ligament avulsion after primary dislocation. Trochlear dysplasia and patellar tilt have been identified as the main risk factors for patellar dislocation in skeletally immature patients [19]. Table 4.1 summarizes the main risk factors for patellar dislocation.

Fig. 4.1 Medial patellofemoral ligament avulsion after primary dislocation

Table 4.1 Risk factors for dislocation

Patella alta
Genu valgus
Femoral anteversion
Tibial extratorsion
Patellar tilt >20°
Tibial tuberosity (TT)—trochlear groove (TG) distance >20 mm
Trochlear dysplasia (depth <3 mm)

Fig. 4.2 Osteochondral fracture after dislocation

Bone bruising and osteochondral fractures usually appear in the medial facet of the patella and the lateral facet of the trochlea [20, 21]. Figure 4.2 shows an osteochondral fracture after dislocation.

4.5 Treatment

4.5.1 Nonoperative Treatment

Most cases of patellar dislocation can be reduced with gentle medial force on the patellar and extension of the knee. The aim of the treatment after reduction is to facilitate gluteus and VMO activity while diminishing swelling of the knee and recovering full range of motion. Early control and treatment of the effusion is important to facilitate recovery of quadriceps activity [7].

Several regimes of treatment have been reported in the literature [22, 23]. Protocols vary from immobilization in a full leg length cast to elastic bandage, splints, and orthoses. Complete immobilization leads to faster resolution of swelling, but stiffness is more frequent and usually a hard problem to resolve. Gluteal and quadriceps weakness should also be fought to avoid recurrence, because adduction and internal rotation of the femur while walking increase the risk of instability. In a recent systematic review, no form of nonoperative treatment was demonstrated to show any superiority over any other in terms of redislocation. All treatments evaluated showed good patient-reported outcomes, despite the type of treatment used [22].

There is no consensus about the time of treatment and the rehabilitation protocol. In recent years, there is some evidence that supports close-chain exercises of quadriceps and gluteus and early weight bearing over open-chain exercises. In our practice, we use a protocol of 3 weeks of immobilization and full weight bearing with a knee extension orthosis and, after that, physiotherapy to increase range of motion and closed-chain exercises to strength gluteus and VMO.

4.5.2 Operative Treatment

In recent years, there has been a trend toward operative treatment in first-time dislocations over conservative treatment [24, 25]. There is not a gold standard technique for addressing patellar dislocation, and more than 100 different procedures have been reported [7]. Many of these techniques are reported in other chapters of this book. In this chapter, we will focus only in the operative treatment of acute patellar dislocation.

We consider MPFL avulsion from the patella and osteochondral fracture as absolute indications for primary surgery in the context of first-time dislocation. These injuries are usually repaired with transosseous sutures, anchors, or screws (depending of the size of the fragment) in case of MPFL avulsion and with fixation of osteochondral fracture with absorbable or nonabsorbable screws.

However, controversy exists about the preferred technique to avoid redislocation in absence of fracture or avulsion. One of the classical techniques to approach treatment of first patellar dislocation is medial repair. Medial repair is advocated for some authors due to its ability to reconstruct vastus medialis obliquus action on the patella [7]. They also argue that medial patellofemoral ligament reconstruction may overload the patella, because the load to failure of the MPFL is about 208N [26] and hamstring graft can be up to 1600N [27]. Authors favoring MPFL reconstruction argue that medial repair is not an anatomic technique and that overplication can lead to medial displacement of the patella and maltracking. Furthermore, injuries affecting the MPFL at the femoral attachment are not well addressed with medial repair.

In Nikku et al. [28, 29] and Palmu et al. [30] series, no differences in subjective results and rate of redislocation were observed after medial repair in the treatment of first-time dislocations. In contrast, some complications occur in the operative group. Thus, medial repair is no longer recommended for the treatment of first-time patellar dislocation.

MPFL reconstruction has gained popularity in the last years. It has the advantage of addressing injuries affecting femoral attachment of the ligament while providing a strong, anatomic, and reliable reconstruction [7]. However, it is not used routinely for the treatment of an acute dislocation [31].

4.6 Conclusions

Most cases of patellar dislocation can be reduced with gentle medial force on the patellar and extension of the knee. Controversy exists about the preferred technique to avoid redislocation in absence of fracture or avulsion. One of the classical techniques to approach treatment of first patellar dislocation is medial repair. Authors favoring MPFL reconstruction argue that medial repair is not an anatomic technique and that overplication can lead to medial displacement of the patella and maltracking. That is why medial repair is no longer recommended for the treatment of first-time patellar dislocation. We consider MPFL avulsion from the patella and osteochondral fracture as absolute indication for primary surgery in the context of firs-time dislocation. These injuries are usually repaired with transosseous sutures, anchors, or screws (depending on the size of the fragment) in case of MPFL avulsion and with fixation of osteochondral fracture with absorbable or nonabsorbable screws.

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5 Recurrent Lateral Dislocation of the Patella in Children

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5.1 Introduction

Patellofemoral dislocation is the most common acute knee disorder in children and adolescents, with an estimated incidence of 43/100,000 children [1]. Dislocation of the patella usually occurs for the first time in the preadolescent or adolescent, with a peak incidence between the ages of 10 and 17 years [2–4]. Age at onset is older in those patients without generalized laxity and/or patella alta [3]. Girls are more commonly affected [4]. Bilateral dislocation occurs in 30–40% of the patients, with the second knee dislocating an average of 2 years after the first [3].

Other than acute, first-time patellar dislocation, instability can be divided into [5]:

- Recurrent: repeated dislocation after initial dislocation due to trauma. Most cases of patellar instability can be considered as recurrent.
- Obligatory: dislocated with every episode of knee flexion, self-reduced in extension.
- Fixed dislocation: patella remains dislocated laterally during knee flexion and extension (Fig. 5.1).
- Syndromic: Down syndrome, nail-patella syndrome, and Ehlers-Danlos syndrome.

5.2 Etiology

Patellofemoral instability (PFI) is a multifactorial disorder with a combination of hyperlaxity, anatomic alterations, and trauma [3, 6, 7]. Although there is always some kind of trauma associated with the acute event, patellar dislocation is almost never observed in the absence of predisposing factors [3]. These predisposing factors include genu valgum, genu recurvatum, patella alta, trochlear dysplasia, femoral anteversion, external tibial torsion, ligamentous laxity, hypoplasia of the lateral femoral condyle, abnormal attachment of the iliotibial band, and syndromes such as nail-patella and Down syndrome [8] (Table 5.1). Disorders of the static stabilizers are the most common causes of instability [9].

Anatomic alterations of the patellofemoral joint such as trochlear dysplasia or patella alta decrease patellofemoral stability. Some other predisposing factors increase the lateral vector forces acting over the patella (genu valgum, femoral anteversion, or external tibial torsion), while some others decrease the medial restraining forces (vastus medialis weakness or MPFL insufficiency).

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Fig. 5.1 Radiograph showing a bilateral fixed lateral dislocation of the patella

Table 5.1 Predisposing factors

Anatomical abnormalities of the patellofemoral joint
Trochlear dysplasia
Hypoplasia of the lateral femoral condyle
Patella alta
Factors increasing the lateral vector forces acting over the patella
Genu valgum
Increased tibial tuberosity-trochlear groove (TT-TG) distance (femoral anteversion, external tibial torsion)
Abnormal attachment of the iliotibial band
Factors decreasing the medial restraining forces
Medial patellofemoral ligament (MPFL) insufficiency (generalized joint laxity or MPFL traumatic tear)
Vastus medialis weakness

5.2.1 Anatomic Abnormalities of the Patellofemoral Joint

5.2.1.1 Trochlear Dysplasia

The prominence of the lateral facet of the trochlea tries to resist the lateral vector forces acting over the patella. An association between dislocation and the shape of the condylar groove has been proved. Dejour et al. [6] demonstrated that trochlear dysplasia is a constant abnormality in patellar instability and that, due to its presence bilaterally in almost every case (92.5%), it should be considered a constitutional abnormality. The abnormality has been found in the proximal trochlea [10]. Trochlear dysplasia has been described as a major predisposing factor for recurrent instability and, also, for failure of stabilizing surgery in childhood and adolescence [11].

According to Glard et al. [12], the morphology of the trochlea appears to be the same in the fetus as in adults, which could point out a genetic origin of trochlear dysplasia. In fact, some authors consider trochlear dysplasia as a congenital, hereditary disease with an X-linked heritance [9]. Furthermore, the hereditary disposition for patellar dislocation is well known, with around 10–28% of relatives affected [3, 13].

The cartilaginous trochlear morphology differs markedly from that of the underlying bony trochlea in patients with a normal knee and in those with trochlear dysplasia, being the cartilage morphology worse than the bony morphology [10, 14]. The thickness of the articular cartilage was greatest in the center of the trochlea and decreased over the condyles [10]. Trochlear dysplasia was classified according to the criteria of Dejour [6]:

- *Type A*: a preserved, but shallow trochlear morphology
- *Type B*: flat trochlea
- *Type C*: lateral convexity and medial hypoplasia
- *Type D*: lateral convexity and medial hypoplasia with additional vertical link

5.2.1.2 Patella Alta

In the young embryo, the anlage of the patella is being detached very quickly from the anlage of the lower part of the femur. Separation takes place proximal to the region of the future joint. Therefore, in the embryo, the anlage of the patella is formed higher up than the definitive position of the patella. Further in intrauterine life, the patella descends [15]. It remains unclear if patella alta is consequence of an arrested development.

Patella alta has been suggested as an important risk factor in the development of patellar dislocation [6, 16, 17]. In knee extension, the patella ascends away from the femoral groove if the patellar tendon is too long. This fact could cause problems in centering patella in the femoral groove during early knee flexion. Since the degree of knee flexion required for the patella to reach the trochlea depends solely on patellar tendon length, a patella alta would increase the range of motion of the knee in which the patella is restrained mostly by soft tissues [18, 19]. A relation between patella and trochlear dysplasia has also been pointed out, since normal development of the trochlea would be more difficult when the patella is not normally positionated [20]. In fact, Rünow described a flatter trochlea as the Insall index increased [3]. It remains unclear if a prompt correction of patella alta would improve trochlear dysplasia [20]. However, most people with patella alta are asymptomatic [21]. It seems that other factors must be present in order to patellofemoral instability occurs.

5.2.2 Factors that Increase the Lateral Vector Forces Acting over the Patella

The valgus vector, lateral vector of the forces acting on the patella, increases with the Q-angle, i.e., the lateral angle between the quadriceps muscle and tendon. Because of the Q-angle, tension on the quadriceps will tend to produce a lateral movement of the patella. The Q-angle is increased in genu valgum, femoral anteversion, and external tibial torsion. As knee valgus increases, the stresses at the lateral patellofemoral joint increase [18].

The amount of lateralization of the tibial tubercle relative to the trochlear groove has been termed the tibial tubercle-trochlear groove (TT-TG) distance. The TT-TG distance has been shown to be abnormal in 56% of cases with patellofemoral instability and only 3.5% in control knees [6]. Dickens et al. [22] found that TT-TG distance increases from birth to adulthood; and a percentile-based growth chart has been developed to more appropriately represent these normal values for a given age. The overall median TT-TG distance described in normal children is 8.5 mm, with no significant difference between sexes [22]. While the threshold for pathological instability in adults has been stablished between 15 and 20 mm [22, 23], the median TT-TG distance described in children with instability is 12.1 mm [22]. Therefore, we should consider age-related normal values, as opposed to a fixed value, in skeletally immature patients.

5.2.3 Factors that Decrease the Medial Restraining Forces

5.2.3.1 Medial Patellofemoral Ligament (MPFL) Insufficiency

In full extension of the knee, the patella is located superior and slightly lateral of the trochlea groove. Between 10° and 30° of knee flexion, the patella starts to make contact with the trochlea and slides into the sulcus [24]. The MPFL is the primary passive restraint resisting lateral translation of the patella since it accounts for more than 90% of medial stabilization of the patella between full extension and 30° of flexion [9, 25]. In the course of increasing knee flexion (more than 30° of flexion), the depth of the trochlea increases, and the bony factor becomes the main stabilizer of the patellofemoral joint [26], whereas it is located in the notch in 90° of flexion and more.

It has been shown that the MPFL provides the main restraining force to lateral displacement of the patella [25]. The MPFL can be insufficient because of several reasons. First of all, the MPFL is damaged when the patella dislocates laterally. In fact, 90% of primary patellar dislocations result in injury to the MPFL [27]. In children, MPFL rupture occurs more frequently at the patellar insertion [25, 28]. On the other hand, the MPFL may also be chronically insufficient in children when the patella is pushed into a wrong position because of trochlear dysplasia or bony malalignment (genu valgum or rotational deformity of the lower limb) [9].

Generalized joint laxity is also associated with MPFL insufficiency and patellar dislocation [3]. The incidence of generalized joint laxity was six times higher than normal in both males and females with patellar dislocation [3]. Patellar instability, expressed as the incidence of frequent and bilateral dislocations, was lowest in people without generalized joint laxity and with a normal Insall index [3].

5.2.3.2 Vastus Medialis Weakness

Some authors consider that the fibers of the vastus medialis obliquus exert an active medial displacement force on the patella during the first few degrees of flexion and that its weakness causes patellar instability [29, 30]. Other authors believe that the vastus medialis obliquus (VMO), as the most important dynamic stabilizer of the patellofemoral joint (PFJ), affects the stability only in flexion of more than 60° [31]. In cadaveric studies, the absence of vastus medialis obliquus tension causes the lateral displacement of patella (4.2 mm) [32]. In our opinion, vastus medialis weakness is more related to anterior knee pain than to patellofemoral instability.

5.3 Natural History

Recurrent instability is considered to be highly associated with chondral and osteochondral lesions of the patellofemoral joint [33], leading to patellofemoral pain and degenerative arthritis [8].

There are three main types of associated fractures:

(a) Avulsion-fracture of the medial border of the patella that does not affect the articular surface. It is thought to be caused by traction of the capsule when the patella dislocates [3, 34]. The avulsion fractures are more common in knees without evidence of joint laxity and may be an expression of relative inelasticity of the medial capsule [3].
(b) Osteochondral fracture of the medial patella facet that occurs when the patella reduced from a dislocated position. This osteochondral fracture is observed more often when the Insall index is within normal limits [3]. A normal quadriceps tendon seems to predispose to osteochondral fractures.
(c) Osteochondral fracture of the lateral femoral condyle (lateral border of its joint surface).

The incidence of fractures, both avulsion and osteochondral, is highest in the absence of both joint laxity and abnormally high Insall index [3]. The incidence of osteochondral fractures is inversely proportional to frequency of dislocation. The occurrence of fracture was an expression of relative stability, and trauma was then often a contributing etiologic factor [3]. However, trauma need not be severe for dislocation of the patella to be associated with avulsion or osteochondral fractures. In fact, an insignificant trauma has been described in the majority of the cases with osteochondral fracture [3].

5.4 Physical Examination

Acute instability is covered in more detail in chapter 3. The presence of a frank dislocation that requires reduction manually is rare. The majority of the situations in children and adolescents are dislocations or subluxations that reduce spontaneously. Usually a mid-trauma is involved. It is not unfrequent for the episode not even being recognized as a patellar dislocation [9]. Sometimes, the only sign of a patellar dislocation is a hemarthrosis with an osteochondral fracture at the patella or trochlea. The presence in the MRI of bone marrow edema in the lateral femoral condyle and medial patellar facet confirm the diagnosis.

In the youngest (approximately 6–10 years), parents usually describe their children falling down because their knee gave way during normal walking or running. Parents also consult because limping or asymmetrical walk of their child. Children usually described that felt something going out of joint or that the knee gave way [3].

Physical examination should be oriented to confirm a patellofemoral instability situation, to rule out associated osteochondral lesions, and to identify predisposing factors. Acutely, the clinician should confirm concentric reduction (Fig. 5.2), assess for patellar tracking and apprehension [35], and assess the degree of lateral patellar displacement (Fig. 5.3). Acute treatment is indicated in cases of osteochondral fracture (Fig. 5.4), but in most cases of acute dislocation, conservative treatment is indicated (see chapter 3).

Fig. 5.2 Physical examination of a child with a congenital dislocation of the patella. The patella can be palpated in the outer part of the knee with an empty trochlea in the front

During follow-up after an acute dislocation, the physician should assess for predisposing factors in a systematic way:

- Assess the overall alignment of the lower limb with the patient in a standing position with the main focus on potential valgus deformity (Fig. 5.5) or malalignment syndrome (Fig. 5.6).
- Investigate the "J-sign" to detect a lateral shift of the patella during terminal active extension.
- Evaluate the Q-angle, the angle between the quadriceps muscle and the patellar tendon. The abnormal Q-angle was defined following Insall's criteria [36], considering a Q-angle of 14° as normal and above 20° as abnormal. You should keep in mind that the Q-angle is falsely normal in patients with a laterally subluxated patella.
- Rule out the presence of patella alta.
- Explore the torsional profile in prone position: hip internal and external rotation to rule out excessive femoral anteversion, as well as the foot-thigh angle to rule out external tibial torsion.
- Assess the laxity of the soft tissue.

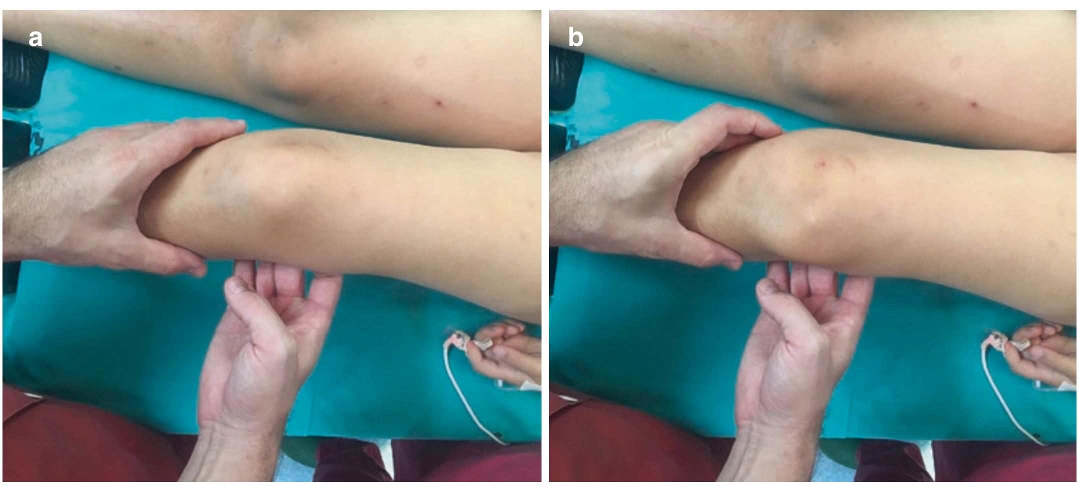

Fig. 5.3 During physical examination, the amount of lateral displacement of the patella should be evaluated. Figure shows how a reduced patella (**a**) completely dislocates when a lateral vector force is applied (**b**)

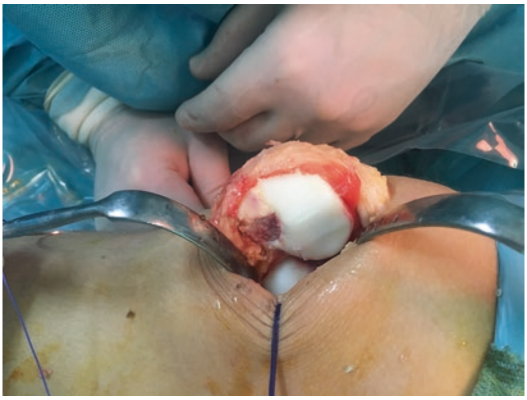

Fig. 5.4 Osteochondral lesion of the patella after sustaining a patellar subluxation that reduced spontaneously

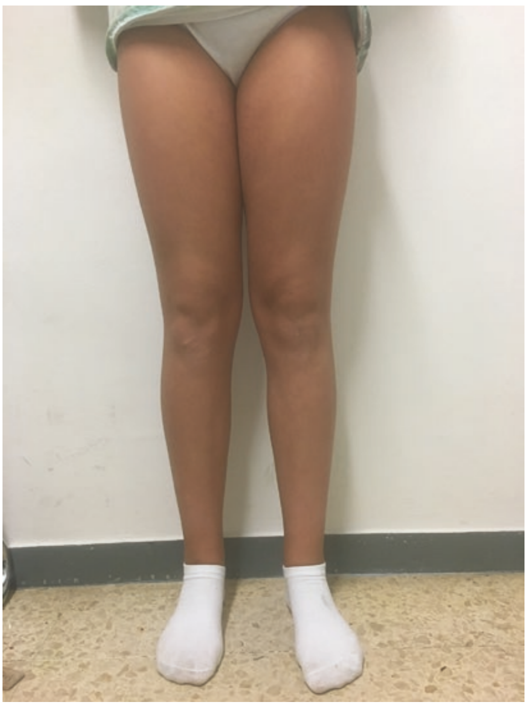

Fig. 5.5 Genu valgum in a preadolescent that suffered from recurrent patellar subluxation episodes

5.5 Imaging

Imaging of the patellofemoral joint is covered in detail in Chap. 2. In children with instability, anteroposterior, lateral, and Merchant radiographs of the knee should be obtained. An anteroposterior long-leg radiograph of the lower extremities should also be obtained if assessment of the lower limb alignment is needed.

The lateral radiograph is useful to assess patella alta. Various indices have been described (see chapter 2) including the Insall-Salvati ratio and its modification [37, 38], the Caton-Deschamps index [39] and the Blackburne-Peel index [40]. In children, it should be kept in mind that bone fragments from the tuberosity in cases of Osgood-Schlatter disease are included in the length of the tendon for all measures [3].

While all cases should have a Merchant view, this may not provide sufficient indication of the morphology [41]. MRI and CT give more accurate information and can allow assessment of chondral lesions, trochlear morphology, and TT-TG distance [22, 42].

5.6 Treatment

The optimal treatment immediately after the first episode of a traumatic patellar dislocation is nonoperative. The recurrence rate described in patients younger than 14 years after an initial patellar dislocation is 60% [43]. When recurrent lateral dislocation occurs, physical therapy and/or bracing usually fail [44, 45], and surgical treatment is indicated. There are over 100 operations described in the literature for the treatment of patellar instability [46]. In general, treatment options are focused on releasing an abnormal tethering vector, providing a balance to the medial vector, and aligning the quadriceps patellar-tibial mechanism [47–49]. Treatment in the skeletally immature patient differs from treatment in adults since physis of the distal femur and proximal tibia is present. Our treatment algorithm is represented in Fig. 5.7.

5.6.1 MPFL Reconstruction

Advancement of the vastus medial muscle (Insall's method) has been abandoned because of the high recurrence rate of patellar dislocation [50]. The aim of surgical treatment should be to repair or reconstruct the passive retinacular

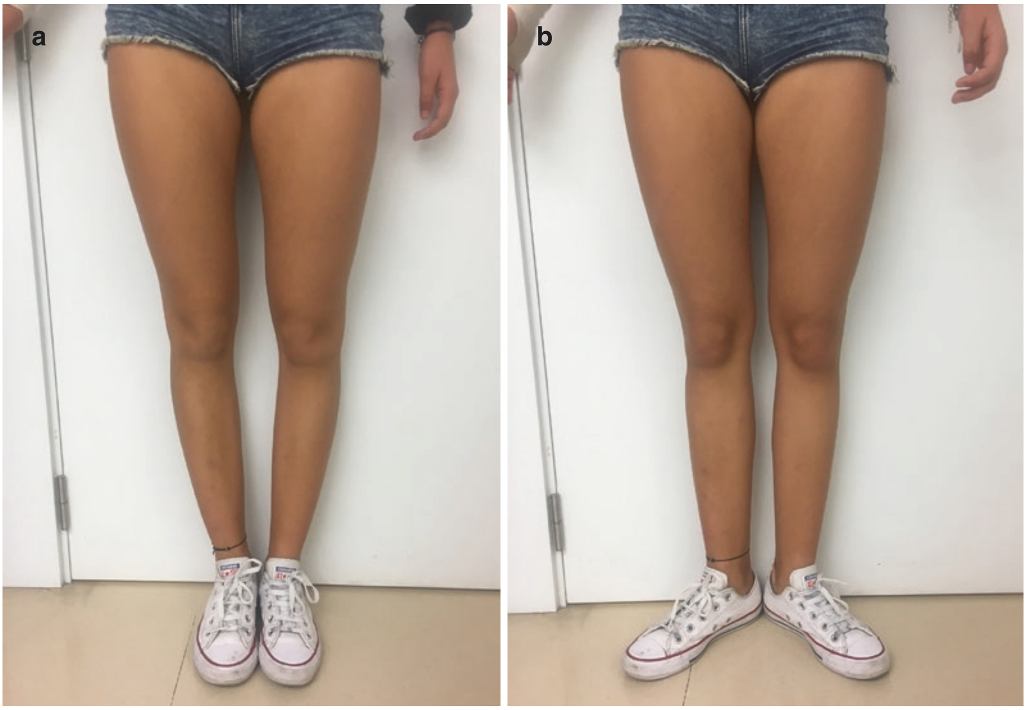

Fig. 5.6 Malalignment syndrome (femoral anteversion and external tibial torsion) increases the TT-TG distance (**a**). Figure (**b**) shows normal alignment when patellas are facing forward

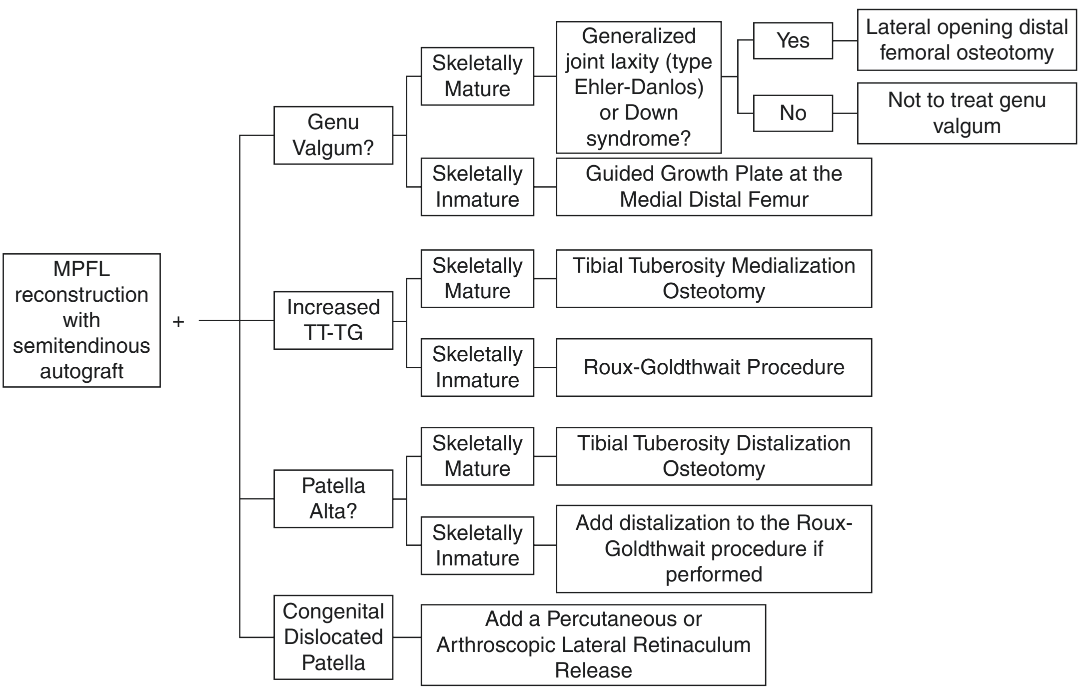

Fig. 5.7 Treatment algorithm used in our center

restraints [51]. Since it has been demonstrated that medial reefing does not restore the tensile strength of the MPFL [25], reconstruction of the MPFL has been advocated as the treatment of choice in skeletally immature patients [52, 53].

Studies have found MPFL mean length to be 53–55 mm and its width from 3 to 30 mm, widening at the patellar attachment [54]. Different soft tissues have been used to form the graft: the adductor magnus, the quadriceps tendon, and the semitendinosus tendon [8, 53].

The most demanding part in the adolescent MPFL reconstruction with a free graft is the femoral fixation because, first of all, physis must be avoided and, on the other hand, the length change pattern of a reconstruction of the MPFL depends critically on the site of femoral attachment. A femoral insertion too proximal would lead to increasing distance to the patellar attachment as the knee flexes, and vice versa for a femoral insertion too distal [25]. Failure to restore the anatomic femoral insertion is a main risk factor for the failure of MPFL reconstruction [55]. Some authors, in order to avoid femoral tunnel, transfer the semitendinosus tendon or the adductor magnus tendon to the patella leaving the tendon attached distally [8]. Whenever using the adductor magnus tendon, the graft is rotated 90° and attached to the patella [54]. In case of using the semitendinosus tendon attached distally to the pes anserinus, the tendon is transferred to the patella directly through a drill hole made obliquely inferomedial to superolateral through the patella (Galeazzi's procedure) [56, 57], or via the pulley of the posterior one-third of the proximal MCL [8]. In Galeazzi's procedure, the direction of force applied to stabilize the patella is not medially directed [8], and, in fact, the patella is translated medially and distally before fixation of the semitendinosus tendon that can lead to a restriction of ROM especially during the flexion [58]. Galeazzi's procedure increases patellar pressures and as a result is associated with chondromalacia [56, 57]. Whenever transferring the semitendinosus tendon via the pulley of the proximal MCL, the surgeon should take into account that, although the pulley point is close to the normal MPFL attachment of the femur, the patellar attachment is narrower than normal [8]. Furthermore, the adductor sling technique has shown elevated redislocation rates [59].

We prefer to use a free semitendinosus tendon graft. In order to facilitate femoral tunnel placement, radiographic landmarks have been described so the anatomic femoral insertion of the MPFL could be identified intraoperatively with the aid of fluoroscopy [60] (Fig. 5.8). In the young patient with open growth plate, the femoral insertion is located on average between 5 and 6.5 mm distal to the femoral physis [9, 28, 60]. If femoral tunnel is made proximal to the physis, proximalization of the femoral insertion while growing will occur [53]. The surgeon should also control that tunnel placement or screw fixation at or tangential to the distal femoral physis is avoided. We recommend, after verification of the entry point in the lateral view on the fluoroscope, to drill the guide pin while observing an AP view on the fluoroscope. Doing so, one can confirm that the pin is located distal to the physis (Fig. 5.9). Once the

Fig. 5.8 Intraoperative fluoroscopy with a guide pin at the anatomic femoral insertion of the MPFL. The mean location of the femoral MPFL insertion is 1.3 ± 1.7 mm anterior to the posterior cortex extension line; and between the lines perpendicular to the posterior cortex extension line at the level of the point where the medial condyle intersect the posterior cortex; and at the level of the most posterior point of the Blumensaat line [60]. In children, the femoral insertion is located averaged between 5 and 6.5 mm distal to the femoral physis [9, 28, 60]

Fig. 5.9 The guide pin should be drilled while observing an AP view on the fluoroscope to ensure that distal femoral physis is not violated

pin is located, we recommend checking isometry of the reconstruction before the femoral tunnel is made (Fig. 5.10). If the graft has too much tension with knee flexion, the pin should be distalized and vice versa. The tunnel should also have an adequate depth so optimal graft tensioning is allowed.

For the patellar attachment, some authors preferred to suture the transferred tendon onto the surface of the patella when the patient is skeletally immature instead of making a bone tunnel in the patella [8]. We prefer to perform a "V"-shaped tunnel in the medial border of the patella and pass the graft through it (Fig. 5.11). The two ends of the graft are pulled between the deep fascia and the joint capsule, along with the superficial band of the medial collateral ligament [25], to the femoral insertion point. Then the graft is passed through the femoral tunnel and secured with an interference screw with the knee flexed to 30° (Fig. 5.12). It is easier to overtighten the graft and risk iatrogenic medial subluxation if the graft is tensioned in extension. Overconstraining of the graft must be avoided.

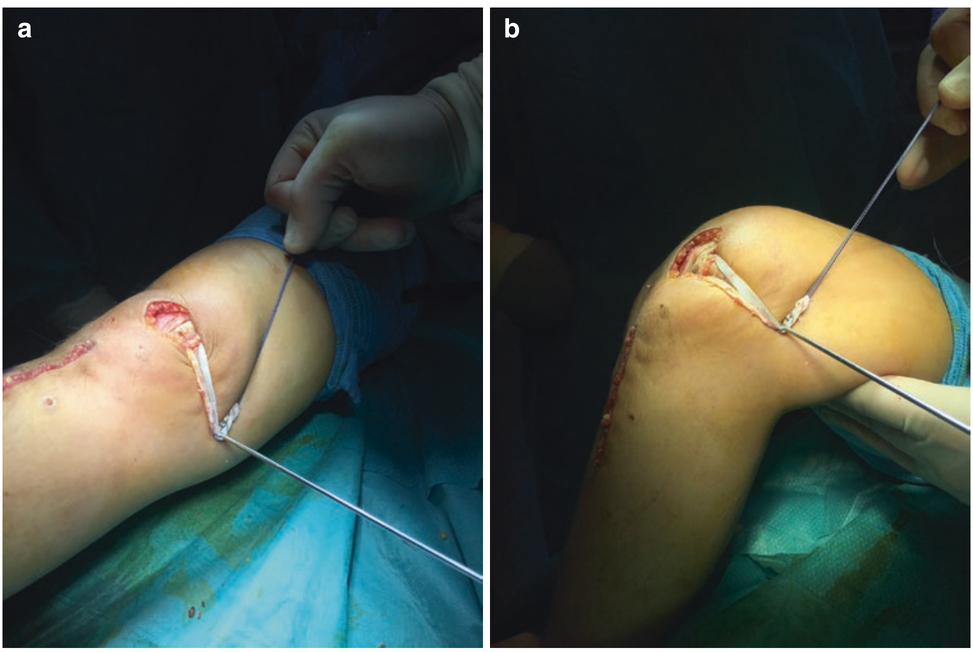

Fig. 5.10 Surgeon should replicate the anatomic femoral insertion of the MPFL in order to obtain isometry of the reconstruction. We recommend, after locating the anatomic femoral insertion point of the MPFL under fluoroscope, to corroborate the symmetry of the reconstruction with extension (**a**) and flexion (**b**) before fixating the graft. If surgeon feels that reconstruction needs more length while flexing the knee, then insertion point should be distalized a little and vice versa

Fig. 5.11 For patellar fixation of the reconstruction, we perform a "V"-shaped tunnel in the medial border of the patella and pass the graft through it. Both ends of the graft will be fixated in the femoral tunnel. Figure shows an osteochondral lesion of the medial facet fixated at the same time MPFL was reconstructed

Fig. 5.12 The graft is passed through the femoral tunnel and secure with an interference screw with the knee flexed to 30° avoiding overconstraining of the graft. Appropriate tension of the graft should allow the surgeon to manually displace laterally the patella approximately 1 centimeter. We recommend not trying several times in order to avoid fracture of the patellar tunnel

Surgeon should keep in mind that, when the patella is manually displaced laterally with the knee fully extended, there should be laxity in the system with a firm end point [9].

MPFL reconstruction in children and adolescents with open growth plates has been proven to be a safe and effective procedure for the treatment of recurrent patellar dislocation [8, 53]. The procedure permits patients to return to organized sports without redislocation of the patella. However, although recurrent dislocations after MPFL reconstruction are rare, positive apprehension sign is common [8].

Some authors have found no association between the presence preoperatively of an increased patella alta or an increased TT-TG distance and unfavorable results of an MPFL reconstruction [53]. It has also been demonstrated that radiographic patellar height indices improve to within normal ranges after MPFL reconstruction with hamstring autograft in children [19].

5.6.2 Distal Realignment: Roux-Goldthwait Procedure

The aim of distal realignment is to correct the malalignment of the extensor mechanism, manifested by an increased Q-angle and TT-TG distance [58]. Tibial tuberosity transfer, commonly used in adults, cannot be done in the skeletally immature due to the risk of premature physeal closure and subsequent development of genu recurvatum [49].

In the Roux-Goldthwait procedure [61, 62], the patellar tendon is split longitudinally and its lateral half detached from the tibial tuberosity, transferred distally beneath its intact medial half, and sutured to soft tissues on the medial side of the tibia (Fig. 5.13). The surgeon must avoid an excessive medial transposition that could lead to an increased medial facet patellofemoral contact pressures in flexion [6].

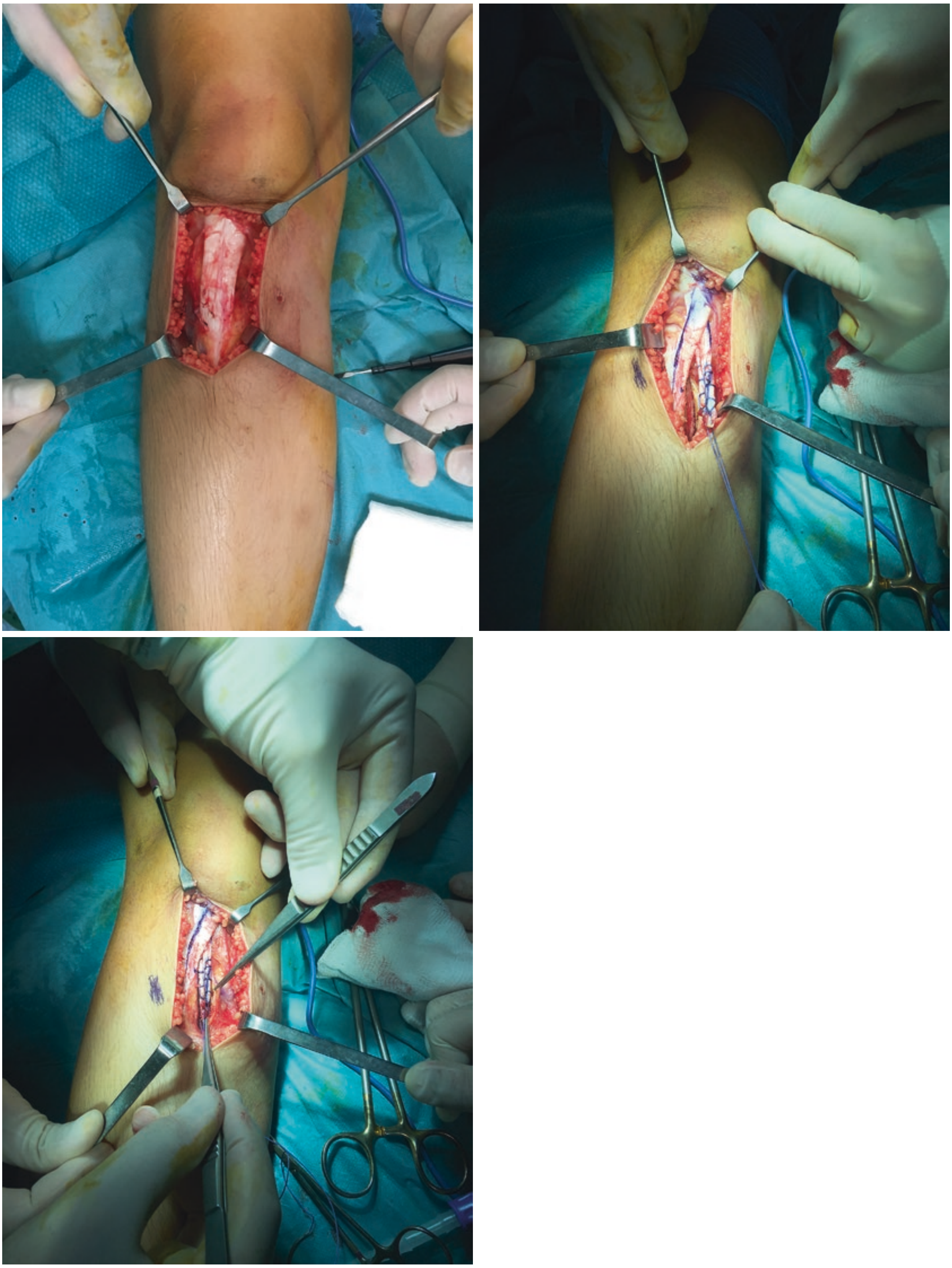

Fig. 5.13 In the Roux-Goldthwait procedure, the patellar tendon is split longitudinally and its lateral half detached from the tibial tuberosity, transferred medially beneath its intact medial half, and sutured to soft tissues on the medial side of the tibia. Excessive medialization should be avoided

The Roux-Goldthwait technique performed alone or in combination with proximal procedures provides good clinical results with a low rate of recurrence in the long-term follow-up [58, 63]. Furthermore, no physeal bar has been described after this procedure [63]. However, a persistent apprehension symptom is commonly present [46], and, in patients with unilateral surgery, a mild loss of strength has been described (80–90% of contralateral side) [49].

The Roux-Goldthwait procedure, as well as the MPFL reconstruction, improves patella alta [46]. However, the RG procedure can cause late knee osteoarthritis because of an increase in patellofemoral pressures from posterior patella positioning and patellar tendon shortening [46]. In fact, an increase rate of patellofemoral osteoarthritis has been described after both the Roux-Goldthwait technique and, even more so, the Elmslie-Trillat technique [46]. For this reason, distal realignment is only recommended in patients with an increased TT-TG distance.

5.6.3 Guided Growth for Correcting Genu Valgum

Selective hemiepiphysiodesis of the medial distal femur is a well-described and common procedure for correcting genu valgum in children [64]. In patellofemoral instability, correcting genu valgum will result in decreasing the Q-angle and, therefore, improving knee extensor mechanism. Controversy remains if it should be performed alone or if it should be added to other procedures such as MPFL reconstruction or distal realignment. Kearny et al. [65] described complete resolution of patellofemoral instability in 69% of patients treated with selective medial hemiepiphysiodesis alone for correcting genu valgum (Fig. 5.14). When correcting genu valgum with guided growth at the same time than reconstructing the MPFL, care should be taken so the guided growth plate is put first and the MPFL reconstructed afterward. Furthermore, when guided growth plates are removed because limb alignment is obtained, care should be taken so MPFL reconstruction is not violated since the graft is just above the plate (Fig. 5.15).

5.6.4 Trochleoplasty

It has been found that 96% of patients with a history of a true patellar dislocation had evidence of trochlear dysplasia [6]. Both osteotomy and trochleoplasty have been proposed to correct bony dysplasia: an opening wedge osteotomy of the lateral condyle is technically difficult, risks damage to the articular cartilage, and creates an incongruent patellofemoral articulation; trochleoplasty creates as well an incongruent patellofemoral joint and risks damage to the articular cartilage.

In children, trochleoplasty can only be performed after closure of the growth plate of the distal femoral physis. If satisfactory biomechanics of the patellofemoral joint is achieved in early childhood, remodeling of the shallow trochlea may occur, and trochleoplasty might be avoided [66]. For these reasons, trochleoplasty is not indicated in children. However, surgeon should keep in mind that trochlear dysplasia is a major predisposing factor for failure of stabilizing surgery [11].

5.6.5 Lateral Retinaculum Release

Isolated lateral release for the treatment of recurrent dislocations is controversial. The release facilitates the other procedures to recenter the patella but is never sufficient by itself [6]. Some authors even stated that lateral release might induce serious complications such as medial or even lateral patellar instability [11]. More details are given in chapter 9.

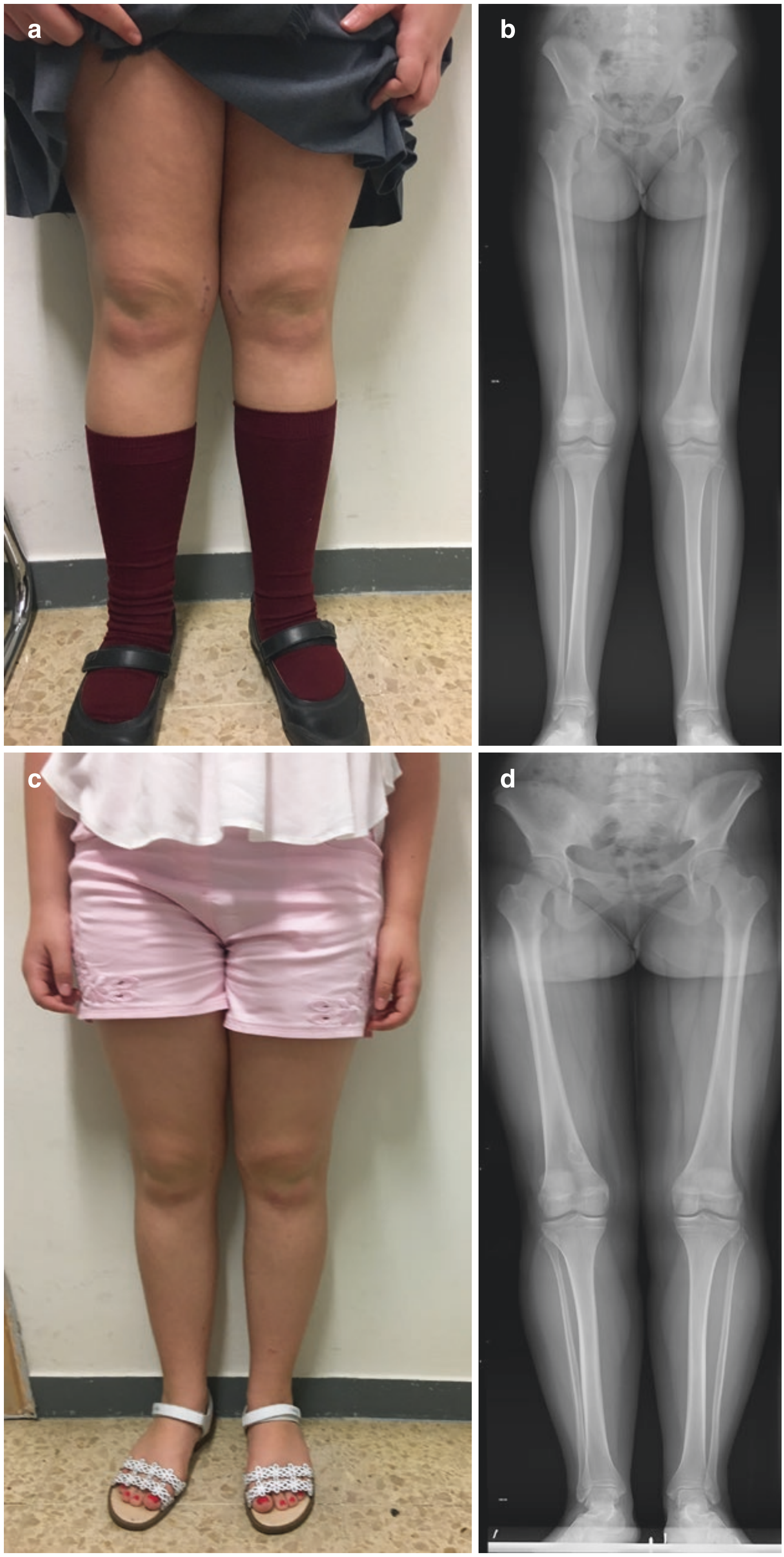

Fig. 5.14 A pre-adolescent girl with genu valgum and recurrent episodes of patellar subluxation (**a**) and (**b**). Patellofemoral instability disappeared after correcting genu valgum with guided growth at the level of medial distal femoral physis (**c**) and (**d**)

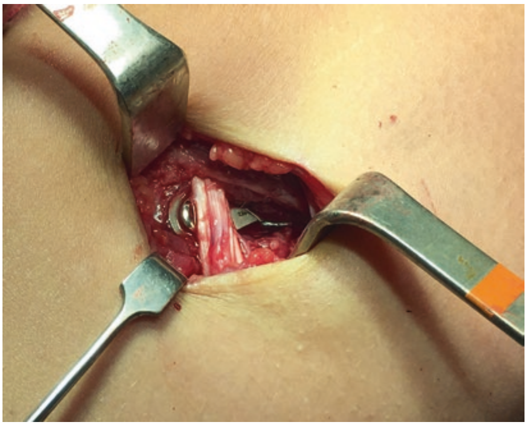

Fig. 5.15 Intraoperative picture showing a free semitendinosus graft lying over the guided growth plate

5.7 Special Situations

5.7.1 Congenital Dislocation of the Patella

A complete irreducible congenital lateral dislocation of the patella is rare [67] (Fig. 5.1). There is some confusion about terminology. While some authors believe that the term congenital dislocation of the patella (CDP) should refer only to a permanently fixed patella on the lateral aspect of the lateral condyle, irreducible by closed means and associated with a fixed flexion contracture of the knee [68], other authors name CDP any lateral patellar dislocation or subluxation diagnosed during the first decade of life. Controversy remains also regarding if patellar dislocations found in Down and nail-patella syndromes should be included in the group of CDP.

CDP is thought to be caused by a failure of internal rotation of the myotome, which contains the quadriceps and patella [69]. When the patella is laterally dislocated, the quadriceps tendon exerts a lateral and posterior pull on the tibia, which results in knee flexion contracture, genu valgum, and external rotation of the leg (even subluxation of the tibia) [70, 71]. Genu valgum has been reported to recur after supracondylar osteotomies when patellar dislocation has not been addressed [70]. The laterally dislocated patella also causes a lack of power in the knee extensor mechanism that could reduce walking ability and lead to some degree of disability [67, 72]. Parents consult because their children limp or fall over frequently without provocation. Radiographically, the ossification center of the patella does not appear until age 3 or later, and, in this condition, it ossifies later than normal [70].

In order to avoid secondary deformities, some authors believe that correction should be done early in childhood, when the patient is 2–3 years old, so open reduction may be easier and trochlear remodeling with growth could occur when the patella is reduced in its position [67, 73]. Trochlear remodeling may avoid recurrence of instability or arthritis in the future. The problem is that this deformity is often not recognized early in life.

Closed reduction of the patella is not possible, even under general anesthesia (Fig. 5.16). Lateral release and distal realignment are necessary to obtain reduction. The surgeon should keep in mind that extensive lateral release has caused peroneal palsies in the past [74]. In the skeletally immature patient, some authors prefer to transfer the complete patellar tendon [74], while others prefer to transfer just the lateral half of the tendon (the Roux-Goldthwait technique) [69]. We prefer the Roux-Goldthwait technique so weakness of the extensor mechanism is avoided. In our opinion, once the patella has been reduced and the extensor mechanism is aligned, MPFL reconstruction should be performed in order to avoid recurrence of patellar instability. Vastus medialis oblique advancement has obtained fair results in the literature [70, 74]. Genu valgum should also be corrected in conjunction with treatment of the dislocated patella. Our treatment algorithm in CDP is percutaneous or arthroscopic lateral release, plus the Roux-Goldthwait technique, plus MPFL reconstruction with a free semitendinosus autograft, plus guided growth of the medial distal femur if genu valgum is present (Fig. 5.17).

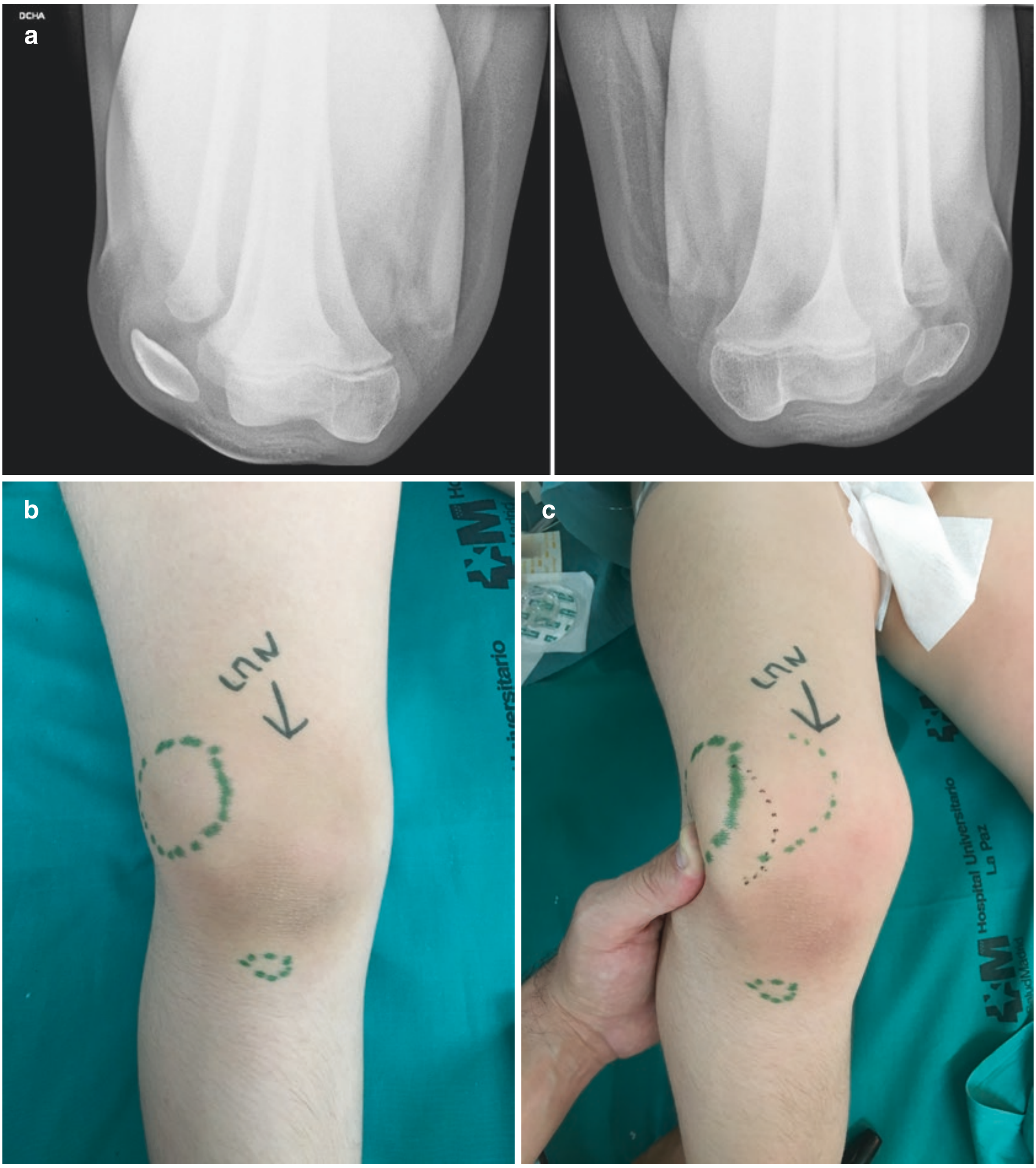

Fig. 5.16 Closed reduction of a congenitally dislocated patella is not possible, even under general anesthesia. (**a**) Axial view of both knees showing a bilateral congenitally dislocated patella. Green line in Figure (**b**) shows the resting position of the patella. Black dotted line in Figure (**c**) shows the subluxated position of the patella when reduction by closed means under general anesthesia is attempted

5.7.2 Down Syndrome

Most of the orthopedic manifestations in Down syndrome are related to ligamentous laxity, muscular hypotonia, and joint hypermobility. Since life expectancy of patients with Down syndrome has improved, the consequences of these orthopedic problems in terms of pain or reduction of autonomy in the adult age are getting increasing attention [75]. The described

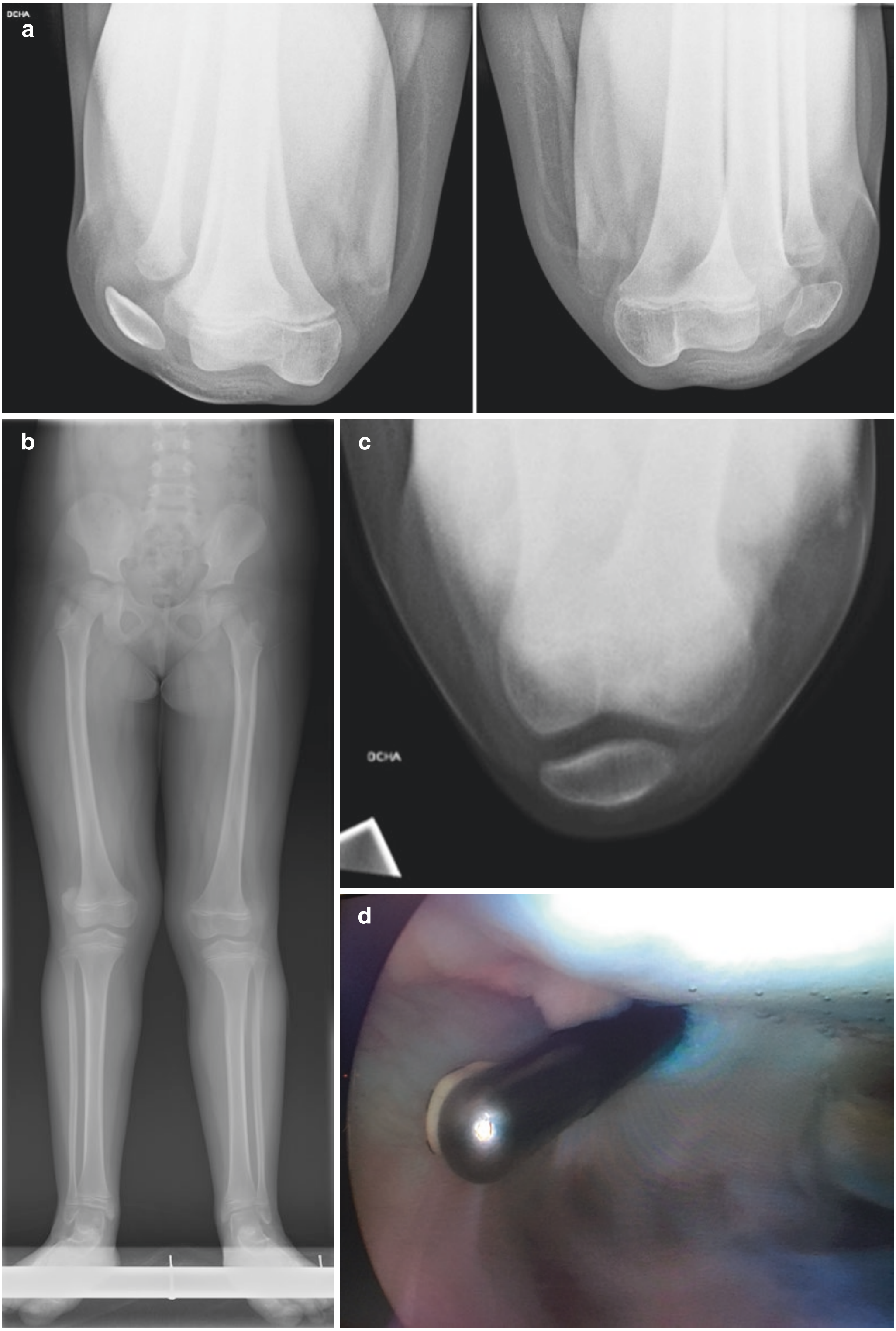

Fig. 5.17 Congenital dislocation of the patella (**a**) and (**b**) treated successfully (**c**) with arthroscopic lateral release (**d**), distal realignment with the Roux-Goldthwait technique (**e**), MPFL reconstruction with a free semitendinous autograft; and guided growth at the distal medial femoral physis (**f**)

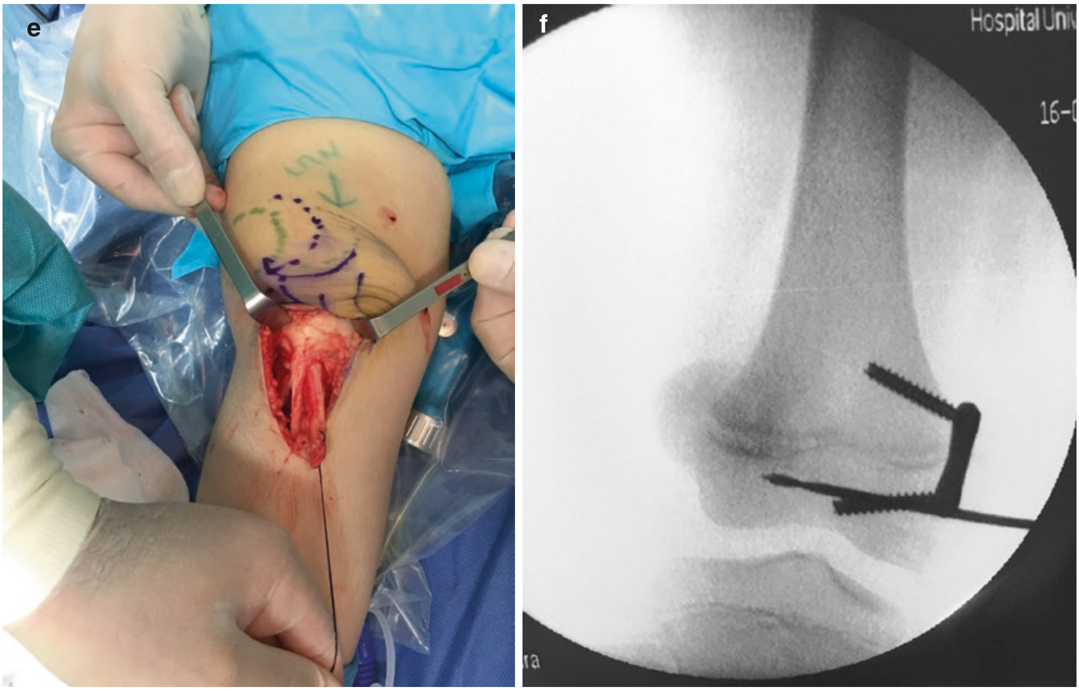

Fig. 5.17 (continued)

incidence of dislocatable or dislocated patella in patients with Down syndrome is between 6.3% and 8.3% [76, 77]. Dugdale et al. [76] described a classification of patellofemoral instability in patients with Down syndrome: (1) normal laxity, (2) subluxates more than 50% of patellar width, (3) dislocatable, (4) dislocated but reducible, and (5) dislocated but not reducible. Grade 2 instability is rarely problematic [77], and studies have focused on grades 3–5.

Symptoms described in the literature are limping, pain, or falling alone [75, 77]. Controversy remains if we should treat patellofemoral instability in Down syndrome patients who are asymptomatic and with good function. We should keep in mind that there is no relation between the degree of patellofemoral instability and functional disability [75, 77]. Mendez et al. [77] described that more than half of their patients with grade 5 patellar instability (dislocated and not reducible) were asymptomatic. However, as stated before, the permanently dislocated patella provokes the quadriceps to act as a knee flexor and cause knee flexion contracture, genu valgum, and external tibial torsion [77, 78]. Those who advocate surgical treatment in asymptomatic patients believe that surgery would avoid progression toward higher grades of instability and functional worsening [78].

Nonoperative treatment has been shown to be ineffective when treating patellofemoral instability in patients with Down syndrome [77]. Surgical treatment of patellar instability in patients with Down syndrome with lateral release and imbrication of the medial capsule (plus vastus medialis advancement in some cases) did not result in preventing degenerative changes in grades 4–5 knees. However, the Roux-Goldthwait technique plus proximal realignment (creating a suprapatellar checkrein with a capsular strip according to the Cambell technique) has proved to decrease pain and improve function in Down syndrome patients with grades 3–5 patellar instability. No cases of recurrence of the dislocation have been described with this technique [75]. We prefer to reconstruct the MPFL with a free tendon graft instead of performing the Campbell technique. Since Down syndrome is associated with ligamentous laxity, we prefer to use a semitendinosus allograft in these patients. Surgical treatment of a dislocated patella in Down syndrome has proven to improve gait ability [78].

Whenever operating a patellar instability in a Down syndrome patient, efforts must be made to correct also the associated deformities and not simply the instability [77]. Therefore, guided growth for correcting genu valgum must be contemplated [75].

5.7.3 Nail-Patella Syndrome

Nail-patella syndrome (NPS) is an autosomal-dominant disorder characterized by the presence of nail dysplasia and hypoplastic or absence of patella*e*. *Patella*r hypoplasia is far more common (86%) than patella aplasia (4%) [79]. Complaints of the knee are reported in up to 74% of patients with NPS, being patellar dislocation the main orthopedic problem (48%) [80, 81]. Radial head dislocation and iliac prominences (iliac horns) may also be present. These patients consult the orthopedic surgeon when they are preadolescents, mainly because of patellar instability or knee pain [80]. When patients seek surgical treatment, the main reasons for surgery were pain and lack of function (including instability) [81]. Arthroscopic reports have described the presence of a midline thick soft tissue band dividing the trochlea in medial and lateral compartments [82, 83]. Recurrence of this midline synovial septum after being resected has also been described [84].

There is no consensus regarding the appropriate treatment, conservative or surgical, and, if surgical treatment is performed, regarding the recommended surgical technique. Patients with nail-patella syndrome and asymptomatic patella dislocation have been described [85]. Some series have found that patients that underwent surgery had lower scores than patients that had not on both the KOOS and Kujala scores [81]. However, other series have found conservative treatment leading to pain, lack of knee extension, patellofemoral arthritis, or anterior knee instability [71, 80, 86].

Regarding appropriate surgical technique, Guidera et al. [87] report poor results after proximal realignment and favorable outcome after combined proximal and distal realignment. Surgical treatment when infant (3–5 years of age) with lateral retinaculum release, advancement of the medial vastus over the patella, and medial capsular plication with or without lengthening of the rectus femoris have obtained excellent results in the long term (average 26 years) [80]. Those patients were asymptomatic with a well-centered patellar and no radiological degenerative changes. MPFL reconstruction with or without distal realignment has also obtained excellent results in patients with patella hypoplasia [83, 88, 89]. Our recommendation is to treat symptomatic patients with MPFL reconstruction, distal realignment (Roux-Goldthwait technique vs. osteotomy of the tibial tuberosity), and lateral release [83].

5.8 Conclusions

Patellofemoral dislocation is the most frequent acute disorder in children and adolescents. The main predisposing factors are genu valgum, patella alta, trochlear dysplasia, femoral anteversion, external tibial torsion, or ligamentous laxity. Conservative treatment of recurrent patellofemoral instability commonly fails. MPFL reconstruction is the indicated surgical procedure, accompanied by distal realignment or guided growth of the distal femur when required. Since osteotomies of the tibial tuberosity cannot be carried out during childhood, the Roux-Goldthwait procedure is the surgical technique performed for distal realignment.

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6 Risk Factors and Demographics for Recurrent Lateral Dislocation of the Patella in Adults

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6.1 Introduction

Acute dislocation of the patella is a common injury amongst young adults. Whilst most patients who dislocate for the first time may be managed nonoperatively, around one third of patients treated nonoperatively will go on to develop recurrent patellar instability. The development of recurrent patellar instability depends upon a number of factors and the successful identification of patients at high risk of recurrent instability will guide management of acute cases. The aim of this chapter is to determine the demographic and morphological risk factors for the development of recurrent patellar instability in adults.

6.2 Incidence of Primary and Recurrent Patellar Instability

Acute patellar dislocation is a common injury, with an incidence estimated between 2 and 78 per 100,000 people per year depending on setting and cohort [1]. Sanders et al. identified 609 patients over a 20-year period using a cross-sectional cohort of patients from a single county in the USA [1]. They calculated an overall incidence of 23.2 per 100,000 person-years, rising to 147.7 per 100,000 person-years amongst adolescents, with a mean age of first dislocation being 21.4 years. Two studies exist where the incidence of patellar dislocation was examined in large military cohorts, in Finland and the USA [2, 3]. Unsurprisingly, in these studies of active patients, the incidence was higher than in the general population, being 69 and 77.4 per 100,000 person-years, respectively.

In the long term, around 30% of patients who suffer a first patellar dislocation will go on to develop recurrent instability when treated nonoperatively, although this varies by patient population. Using the same cohort as the Sanders study, a 2017 study of Christensen et al. estimated that 30.4% of patients will go on to have at least one recurrence following ipsilateral patellar dislocation within 20 years [4]. The majority of these (23.3% of patients) develop their recurrence within 5 years of the initial dislocation. Contralateral dislocation was less common, affecting only 5.4% of patients, but again, most of these occurred within 5 years of the first dislocation.

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6.3 Patient Risk Factors for Recurrence

Recurrent dislocation is more common if the original dislocation occurred during adolescence. Chritensen reported an odds ratio of 2.4 for the development of recurrent instability in patients who had their first dislocation before the age of 18 [4]. Lewallen reported the results of a retrospective study of 326 knees in 312 patients presenting to a single institution with first patellar dislocation over a 12-year period [5]. The overall rate of recurrent instability was 29.8%, similar to the 30.4% reported in the Christensen study. They reported that the rate of recurrence decreased by around 9% for every year increase in age; the presence of open physes more than doubled the risk of recurrence (hazard ratio- HR 2.22; 95% confidence interval- CI 1.45–3.41). Similarly, Fithian et al., who report a 5-year rate of recurrence of 17% following first dislocation in a sample of 153 patients, give an odds ratio of 0.93 for every year of increasing age [6]. It is not clear whether age and skeletal immaturity are risk factors in themselves or whether patients who present younger have a higher chance of having morphological risk factors. Askenberger et al. published a randomised trial of operative versus nonoperative treatment of first patellar dislocation in children and found that 60 of the 74 patients (81%) had two or more risk factors for dislocation [7]. This rate is substantially higher than seen in studies of older patients—for example, in Steensen et al.'s study of 60 recurrent dislocators and 120 healthy controls, only 2 patients in the control group had more than one risk factor, and only 58% of those in the recurrent dislocation group did [8].

Whilst the rate of primary patellar dislocation is higher amongst females than males, it is not clear whether gender affects the risk of recurrence. Again, there is the difficulty that, given the higher rate of structural risk factors in women, it is difficult to isolate the risk associated with being female in itself [6]. If an effect exists, it appears to be marginal—in Christensen's study, females had an increased risk of recurrence (odds ratio- OR 1.5, 95% CI 1.1–2.4) [4]. However, there is a growing body of work which suggests that gender is not a statistically significant risk factor for recurrent dislocation [5, 9]. Likewise, body mass index (BMI) does not seem in itself to be a risk factor [5].

Other demographic risk factors include the patient's occupation (with those in more physical jobs being more likely to have recurrence) and the mechanism of injury (with sporting injuries and those involving significant trauma being more likely to result in recurrent dislocation) [9]. Soft tissue abnormalities, such as hyperlaxity, appear to be important in predicting subsequent instability, but this has only rarely been studied [10]. Mechanism is important both due to the likelihood of the patient returning to high-risk sporting activities and to the likely structural injury which results. It makes intuitive sense that patients with a 'normal' knee who sustain a traumatic dislocation may benefit more from reconstruction of the medial patellofemoral ligament (see Chap. 12) than patients with an anatomically abnormal knee who sustain a nontraumatic dislocation. This latter group may be at higher risk of progressing to recurrent dislocation without effective treatment of the risk factors displayed [10].

6.4 Morphological Risk Factors for Recurrence

Multiple morphological factors have been identified as affecting the rate of recurrence following primary patellar dislocation. Dejour defined four important risk factors for recurrent dislocation in 1994 [11]. The first was trochlear dysplasia. Dejour classified this into four types (Fig. 6.1) and suggested that types B and D were particularly susceptible to dislocation. Other studies have used sulcus angle (Fig. 6.2) as a continuous measure of trochlear dysplasia [12]. The second factor was patella alta. This can be quantified by a number of indices including those of Blackburne and Peel [13], Caton and Deschamps [14] and Insall and Salvati [15] (Fig. 6.3), but most studies follow Dejour's lead in using the Caton-Deschamps index with a cut-off of ≥1.2. The third factor was an increase in the tibial

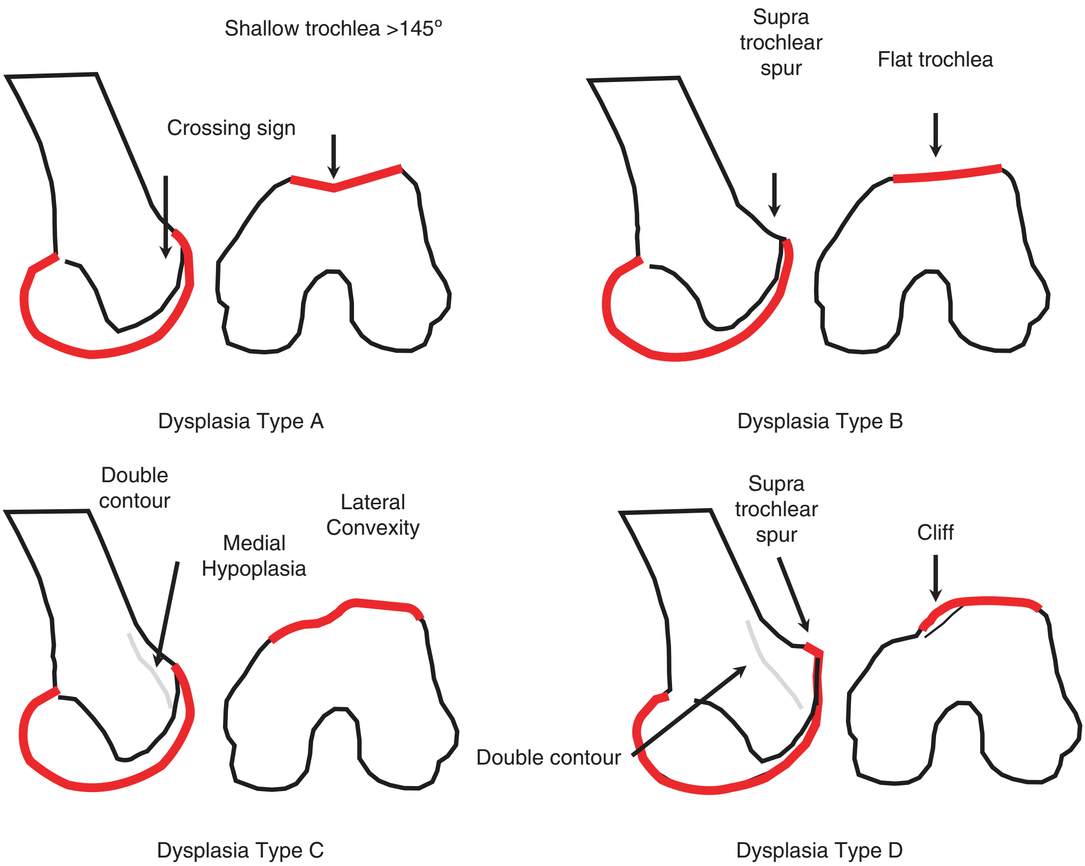

Fig. 6.1 Dejour classification of trochlear dysplasia

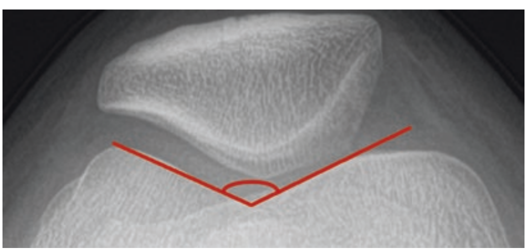

Fig. 6.2 Trochlear sulcus angle. This is measured from the lowest point in the trochlear sulcus to the highest points of the medial and lateral condyles. The mean value in healthy individuals is around 128

tuberosity-trochlear groove distance (generally defined as greater than 20 mm, Fig. 6.4), and the fourth is patellar tilt of ≥20° (Fig. 6.5).

Other factors that have been identified include dysplasia of the patella itself, a high Q-angle, genu valgum and external tibial torsion [8]. In addition, the presence of a diagnosed soft tissue injury (such as avulsion of the medial patellofemoral ligament, Fig. 6.6), muscle weakness (particularly of the vastus medialis obliquus) and the presence of a soft tissue abnormality such as Ehlers-Danlos syndrome may be important factors. Each of these morphological factors must be borne in mind when determining risk of recurrence and also when offering surgical treatment to patients with patellar instability as failure to address them may lead to failure following reconstructive surgery.

The presence of morphological risk factors strongly predicts progression to recurrent instability. In the case-control study of Steensen et al. [8], over half of patients with recurrent dislocation had two or more anatomical risk factors, which was the case in less than 2% of controls. They reported significant differences between the groups in terms of patellar height, TT-TG

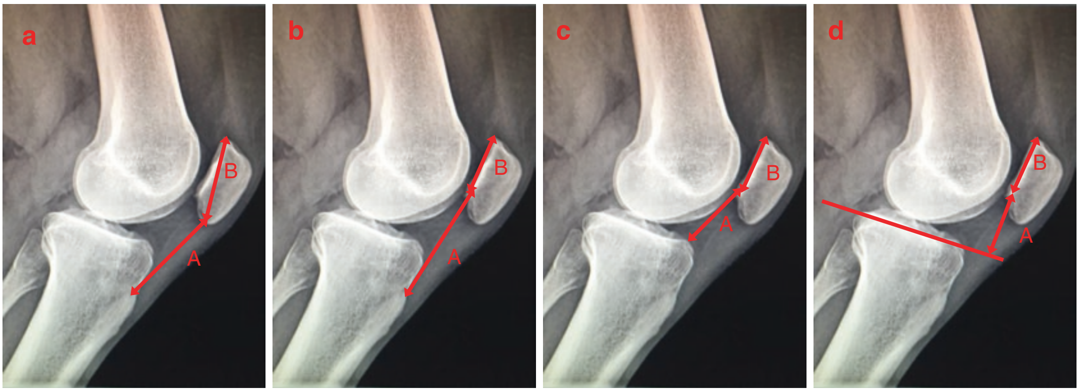

Fig. 6.3 Patella height measurements: These are measured on lateral knee X-ray or sagittal magnetic resonance imaging (MRI) with the knee ideally flexed at 30 degrees. (**a**) Insall-Salvati: patellar tendon length (A)/patella length from pole to pole (B). (**b**) Modified Insall-Salvati: patellar tendon length (to inferior margin of patella's articular surface) (A)/length of articular surface of patella (B). (**c**) Caton-Deschamps: Distance between lower patella and upper limit of tibia (A)/length of articular surface or patella (B). (**d**) Blackburne and Peel: perpendicular distance from lower articular margin of patella to tibial plateau (A)/length of the articular surface of patella (B)

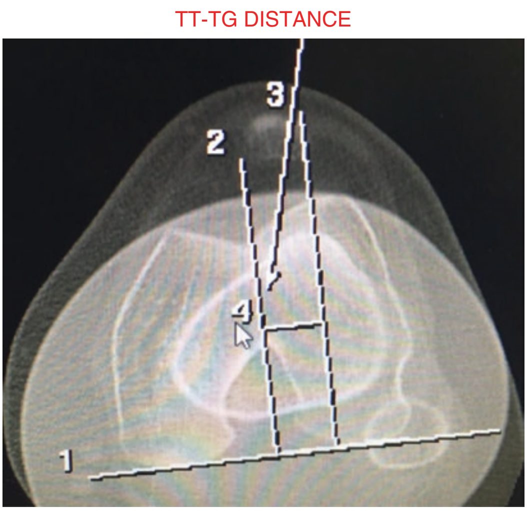

Fig. 6.4 Trochlear groove (TG) to tibial tubercle (TT) distance (TG-TT distance). Axial superimposed computed tomography (CT) scan of TG (1) and TT (2), perpendicular to the deepest portion of TG (3), perpendicular to the prominence of TT and (4) measurement of the TT-TG distance

(tibial tubercle-trochlear groove) distance and femoral rotation. Lewallen [5] examined the effect of patella alta and trochlear dysplasia on risk of recurrence, finding a hazard ratio of 1.61 (95% CI 1.07–2.43) for the former and 3.27 (95% CI 2.14–4.99) for the latter. Christensen [4] reported an even greater effect of morphological risk factors with trochlear dysplasia (OR 18.1, 95% CI 9.9–34.5), patella alta (OR 10.4, 95% CI 5.8–19.1) and TT-TG distance (OR 2.1, 95% CI 1.1–3.9) being significantly associated with recurrence. In their review article, Parikh et al. reinforce the importance of these factors along with patellar tilt in predicting recurrence [9].

A number of attempts have been made to determine the composite effect of multiple anatomical and demographic risk factors in order to determine a score to predict recurrence. Jaquith and Parikh [16] devised a score based on four risk factors (trochlear dysplasia, patella alta as determined by a Carlton-Deschamps index >1.45, history of contralateral dislocation and skeletal immaturity) and stratified the risk of recurrence from 13.8% with no risk factors to 88.4% with all four. The helpfulness of this scoring system would appear to be compromised by the failure to provide any weighting (for instance, giving equal weighting to trochlear dysplasia, which is a major risk factor, and history of contralateral dislocation, which is a minor one) and by the failure to include other important factors such as the TT-TG index and patellar tilt. The Patellar Instability Stability Score, devised by Balcarek, includes age, the presence of bilateral instability, trochlear dysplasia, patellar height, TT-TG distance and patellar tilt, giving a mark of up to seven points [17]. Those with a score above four

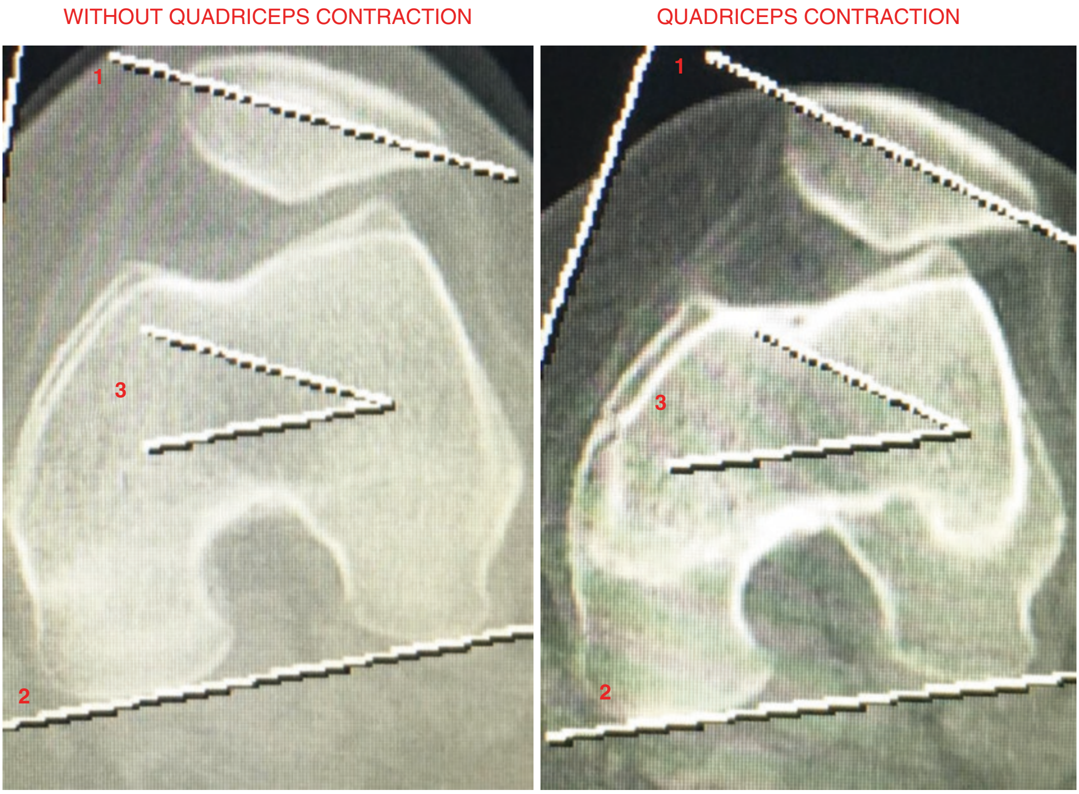

Fig. 6.5 Computed tomography (CT) scan showing patellar tilt without quadriceps contraction (left) and with quadriceps contraction (right). Patellar tilt is the angle between the line along lateral facet of the patella (A) and a parallel line along the posterior femoral condyles (B). (C) CT scan showing patellar tilt without quadriceps contraction (left) and with quadriceps contraction (right)

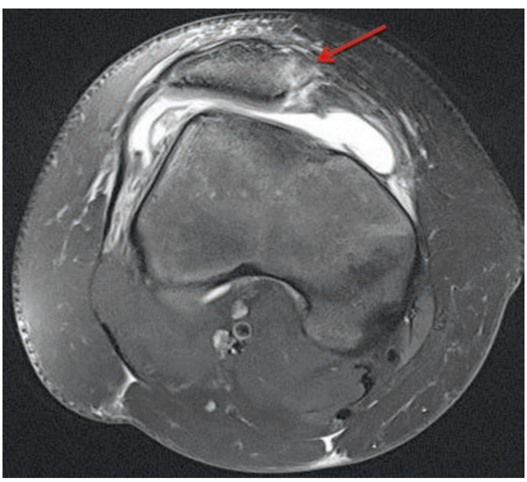

Fig. 6.6 Axial magnetic resonance imaging (MRI) view following patellar dislocation in a case of recurrent lateral patellar dislocation. Note discontinuity of signal in the area of the medial patellofemoral ligament (MPFL) at the medial border of the patella (arrow)

points are said to have an OR for recurrence of 5. To our knowledge, neither scoring system has been validated against an independent data set, and their usefulness in predicting those who will require surgery is doubtful.

Fitzpatrick et al. took a different approach to quantifying the effect of different morphological risk factors, creating a finite element model of the patellofemoral joint and modifying it to modify one or more of four anatomical factors (trochlear dysplasia, patellar height, TT-TG distance and femoral anteversion) [12]. They found that trochlear dysplasia (quantified by reduction in the sulcus angle) was the most powerful factor leading to a reduction in lateral constraint of the patella, followed by patellar height and TT-TG distance. However, in agreement with the clinical studies, they found that multiple factors were necessary in order to lead to significant instability. They produced a simple algorithm to determine the risk of dislocation based on the relative importance of each factor tested and tested it against data from 60 recurrent dislocators and 120 controls. This was a qualified success, with 90% of the recurrent dislocators classified as such on the basis of the model and 87.5% of the controls being classified as stable using the model.

Whilst most study of risk factors for recurrence focus on the bony morphology, soft tissue factors are important in determining stability. Senavongse and Amis [18] examined the effect of trochlear dysplasia, vastus medialis obliquus (VMO) tension and rupture of the medial retinaculum. Whilst (in common with other studies) trochlear morphology was the most important factor affecting stability, there was significant loss of constraint to lateral patellar displacement with rupture of the retinaculum (which decreased the force needed to displace the patella by 49%) and relaxation of VMO (30%) both had a substantial effect. Whether this translates to a higher rate of redislocation is not clear.

6.5 Conclusions

Primary traumatic patellar dislocation is common, occurring in around 77 per 100,000 people per year, with younger people being more likely to be affected. Around a third of these go on to develop recurrent instability.

There are a number of demographic and morphological factors which predict subsequent instability. It appears the morphological factors are the most important, but a combination of factors is normally present. Most patients who go on to develop recurrent instability have two or more morphological abnormalities. Whilst several attempts have been made to quantify the risk of recurrent instability after first patellar dislocation, work is still ongoing. Development and validation of a predictive model for risk of subsequent patellar dislocation would allow surgeons to better decide which patients are likely to need surgery and which may be managed nonoperatively.

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7 Nonoperative Treatment of Patellofemoral Problems: The Role of Physical Medicine and Rehabilitation

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7.1 Introduction

Patellofemoral pain syndrome (PFPS) is the most common cause of overuse pain in physically active patients [1], affecting one in four adults. Its treatment is difficult, and around 50% of patients have persistent pain, which may be present in the long term. Its clinical manifestation is pain, located in the retropatellar or peripatellar area, during activities which load the patellofemoral joint such as squatting, running, or climbing stairs [2]. It is caused by a mechanical dysfunction between patella and femur, although its exact etiopathogenic mechanism is not completely known. The development of PFPS is related to a collection of biomechanical factors [3]:

1. Maltracking of the patella
2. Weakness in the muscles of the lower limbs (especially the quadriceps, abductors, and external rotators of the hip)
3. Delayed contraction of the vastus medialis
4. Limitation in the flexibility of the lower limbs
5. Hyperpronation of the foot

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The optimal treatment of PFPS is a topic of intense debate. Around 100 reviews have been published on the subject, 70 systematic reviews and 20 meta-analyses [3]. The mainstay of treatment is nonoperative, incorporating a number of modalities. This chapter will provide an overview of the role of different nonoperative treatments in the management of PFPS, focusing on physical medicine and rehabilitation. These include therapeutic exercise, therapeutic modalities, manual medicine, and orthopedic therapy (Table 7.1).

The aim of nonoperative treatment in a patient with PFPS aims to control pain and improve the range of movement of joints and to improve strength, proprioception, and gait. The objectives

Table 7.1 Description of physical therapies used in physical medicine and rehabilitation

Therapeutic exercise	Use on the body for physical exercise or movement
Thermotherapy	Use the change of temperature in a body area
Electrotherapy	Employs different types of non-ionizing radiation
Therapeutic ultrasound	Therapeutic use of different types of mechanical waves
Laser	Use a beam of light in which all the rays have the same wavelength
Manual medicine	Use movement-based techniques to treat benign alterations of the musculoskeletal system
Orthoses	Device that is applied externally to the human body to modify the structural or functional characteristics of the neuro-musculoskeletal system

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are to achieve functionality, participate in sports without limitations, and improve quality of life.

It is very important to empower the patient. Empowerment is defined as one's knowledge of his own health and the ability to influence the health of others [4]. The patient must be informed about his or her pathology, and procedures must be facilitated so that the patients themselves are involved in the therapeutic process. A well-informed patient is an important ally in therapy.

Conservative treatment of PFPS should be carried out in a multidisciplinary way. The rehabilitation physician works in coordination with other medical specialists, physical therapists, orthopedic technicians, trainers, occupational therapists, and other members of the multidisciplinary team to provide comprehensive patient care and achieve maximum clinical benefit.

7.2 Clinical Evaluation

Before treating PFPS, a comprehensive clinical and functional evaluation must be performed. The patient's symptoms such as pain, swelling, crepitus, and functional limitation should be noted as well as the degree of injury, previous treatments, and physical activity status together with the expectations of the patient.

A full, systematic physical examination should be performed, including the patellofemoral joint but also the general condition of the patient including comorbidities, old age, physical deconditioning, and so on.

7.3 Conservative Treatment Techniques

There are numerous physical therapies that are employed in the conservative treatment of PFP. The characteristics and peculiarities of each of them are described in more detail below.

7.3.1 Therapeutic Exercise

Therapeutic exercise is the treatment modality most commonly used in the conservative management of PFPS. It is also the one that gives the best clinical results [2, 3]. When a therapeutic exercise program is prescribed, it must be done individually [5]. The main groups of exercises used in the treatment of PFPS are the following: force training exercises, exercises of flexibility, exercises of proprioception, and gait retraining [6, 7]. These different groups of exercises will be discussed in more detail below.

7.3.1.1 Force Training Exercises

Force training involves the improvement of different parameters of the skeletal muscle such as strength, power, and endurance. Strength is the ability of a muscle to overcome resistance; power is the production of strength in a short period of time; and endurance is the capacity of endure repeated muscle contractions. There are different types of contractions and work modes, which can be combined according to the specific objectives established for achieving functional recovery [8, 9].

There are several types of muscular contractions. In PFPS, the isometric and isotonic types are usually performed. In an isometric contraction, muscle tension is generated without changes in muscle length. Although it does not produce joint mobilization, it can produce great tension in the muscle, so it should be used with caution. In isotonic contraction, the muscular tension produces change (shortening or lengthening) in the length of the muscle. There are two types of isotonic contractions, concentric and eccentric. In the concentric mode, the muscle is contracting as its length is shortening (as the point of muscular origin and insertion approaches). They are usually recommended in PFPS because of their ease of use. In eccentric contraction, the muscle is producing tension while trying to overcome a superior resistance, generating a lengthening of the muscular length [10]. It is a typical contraction of sport activities, where it is usually performed as a braking and control system. For example, in the forefoot strike phase of the gait, there are both a concentric contraction of plantar flexors and an eccentric contraction of ankle dorsiflexors, facilitating a more balanced movement.

Plyometric contraction arises from the combination of a concentric and an eccentric muscular contraction. In plyometric mode, an eccentric contraction of a muscle is associated with a concentric contraction of the same muscle, which is performed immediately afterward. This initial eccentric contraction increases and facilitates the posterior concentric contraction. The greater the muscle length at the eccentric contraction, the greater the amount of force generated by the concentric contraction. These types of contractions are usually performed in jumps.

From the different possibilities of performing isotonic exercises, two types of work modes can be considered: closed kinetic chain (CKC) and open kinetic chain (OKC) (Fig. 7.1). The concept of kinetic chain involves the transmission of force vectors through the different body segments involved in a movement (so in lower limb the chain would be the foot, ankle, leg, knee, and hip). What differentiates one modality from another is whether the distal segment is anchored to a fixed surface or not (resting the foot on a wall, e.g., if it is a CKC exercise). There are differences between these two ways of working that are shown in Table 7.2. In PFPS, a combined treatment is recommended, mixing CKC and OKC exercises [11].

There is a third type of muscle contraction, called isokinetic contraction [12]. It is a dynamic contraction in which an angular velocity is constantly maintained throughout the joint range. It requires an expensive system, such as isokinetic dynamometry equipment [13] (Fig. 7.2). An isokinetic dynamometry allows to accurately evaluate the maximum moment of force as well as the relationship between the agonist-antagonistic torque. In fact, data obtained can be showed not only as numerical values but also by means of graphic representation (a curve), whose morphological analysis is also interesting.

Isokinetic dynamometry allows not only measurement but also muscular training in concentric and eccentric mode. It allows great control in the therapeutic prescription and is a very safe way of exercising, as it allows constant speed contraction. Also, it provides an objective way to define

Table 7.2 Characteristics of open and closed chain kinetic exercises

	OKC	CKC
Distal segment	Free	No free
Weight-bearing	No	Partial at least
Work mode	Analytical of a body segment	Global of the chain
Proprioceptive input	Low	High
Load	Artificial	Physiological
Example	Kee extension with weight	Squat

OKC open kinetic chain, *CKC* closed kinetic chain

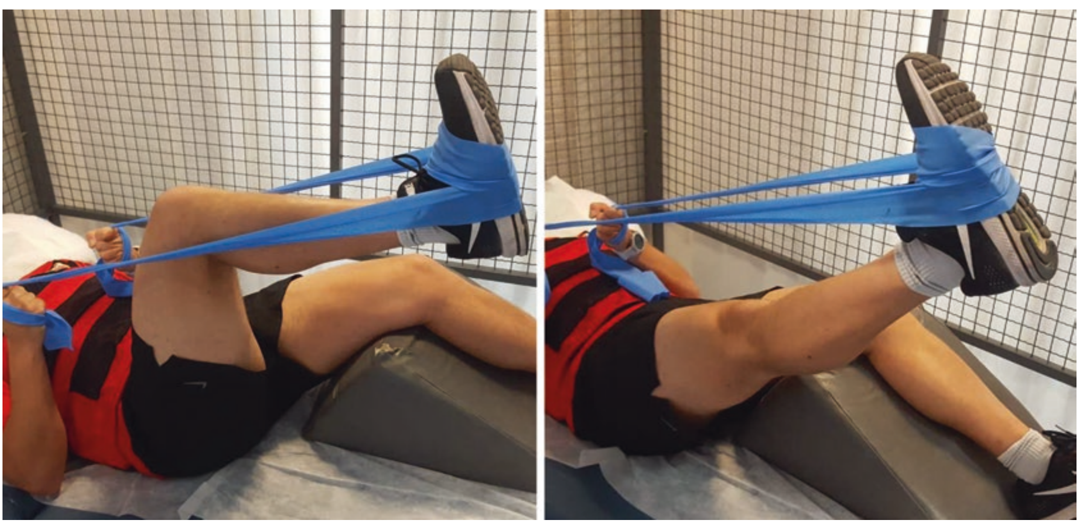

Fig. 7.1 Strengthening exercises with elastic band in open kinetic chain. The distal end is not anchored to any surface

Fig. 7.2 Isokinetic dynamometry machine. The maximum moment of force as well as the agonist-antagonist torque ratio can be accurately evaluated. It also allows treatment at constant speed, both in concentric and eccentric mode

the degree to which a patient can progress in a physical treatment plan (specific muscle load, the time the patient can start running, or return to sports) [14].

When prescribing exercise, the patient should be given the most accurate and complete information possible. The load or weight that patient must use in each contraction should be customized, as well as the number of repetitions and series of which the exercise is consisted. To do this, the strength of the patient must be evaluated [15]. It is possible to determine the maximum resistance (MR) a patient can achieve in one contraction (1MR) or in ten contractions (10MR) and prescribe the load accordingly. An assessment with static or dynamic dynamometry can also be performed, although these are more expensive options. There does not seem to be any difference in results when prescribing the exercise according to the value obtained in 1MR or 10MR [14]. The exercise should always be progressive.

One of the goals of force exercises in PFPS is to improve the strength of hip and knee extension, as it is usually decreased in patients with PFPS [16]. It is also recommended to selectively strengthen the abductor and external rotator musculature of the hip, to correct the excessive adduction and internal rotation observed in patients with PFPS [17].

Through strengthening, physical exercise may improve load tolerance of the patellofemoral joint, reducing pain [18]. In addition, physical exercise may also produce desensitization at central nervous system level. This would be an aspect that would contribute to clinical improvement in patients with PFPS, in addition to the purely mechanical benefits of exercise [19].

In PFPS the traditional treatment strategy is a quadriceps strengthening exercise program [20]. However, recent studies have highlighted the role of hip and trunk musculature in PFPS [21]. Incorporating hip strengthening exercises may result in earlier clinical improvement and greater gains in muscle strength at the hip and knee [22]. Regarding specific muscular work, it is recommended to perform coordinated strengthening of vastus medialis obliquus (VMO) and vastus lateralis, the hip abductors and adductors, as well as the gluteal musculature.

Exercises can be performed under with or without weight-bearing. Weight-bearing exercises are considered more functional as they involve the action of various joints, facilitate muscle synergies, and provide a significant proprioceptive stimulus [23]. In addition, during weight-bearing the alteration in the alignment of the patellofemoral joint may be due to internal rotation of the femur rather than lateral displacement of the patella [24]. Among the benefits of weight-bearing exercise may be reduction of pain and improvement in quadriceps muscle coordination between vastus medialis and vastus lateralis [25].

There is weak but consistent evidence that exercise in PFPS produces a clinically relevant improvement in pain and function. It also facilitates long-term improvement. What is not so clear is to know which specific exercises may be indicated to treat PFPS depending on each patient. An exercise program that includes the hip and knee seems more effective than an isolated knee exercise program [26]. Thus, the type of exercise that offers the best results in pain and function in the short-, medium-, and long term is a combined program to strengthen the lumbopelvic, hip, and knee muscles, involving both CKC and OKC work [11].

Within the therapeutic exercise framework of PFPS, strengthening exercises with blood flow restriction (BFR) have been recently incorporated. These are low-load exercises performed, while a tight tourniquet is placed over the upper thigh area. The compression effect is usually produced by a pneumatic cuff with an elastic wrap. The advantage of this technique is that it provides the benefits of high-load strengthening but with a better tolerance, thanks to using a lower weight. Exercise with BFR allows strength gains with resistances as low as 30% of 1MR. It also produces hypertrophy similar to that obtained using high resistances. The mechanism by which BFR produces the effect is due to the increase in metabolic and mechanical stress caused by ischemia on the muscle performing the exercises. Its effectiveness has been published in studies in patients suffering osteoarthritis of the knee or undergoing ligament reconstruction [27]. In a study of patient with PFPS, a low-load BFR knee exercise program was compared to a high-load conventional knee strengthening program. Low-load knee BFR exercise further reduced pain at 8 weeks, although the results for both groups were equal at 6 months [28].

Fig. 7.3 Passively placing quadriceps in a maximum extension position and holding it for static muscular stretching

7.3.1.2 Flexibility Exercises

These exercises aim to achieve a full range of motion of the joint without pain. They are indicated in patients with PFPS as they have been noted to usually have decreased flexibility of the lower limb musculature [29].

Two stretches are usually used in PFPS:

- Static stretching: It is the conventional stretching mode. Static stretching involves passively placing a muscle in a maximum extension position and holding it for about 30 s (Fig. 7.3). They are the safest and simplest, and, as a result, they are the more frequently used.
- Proprioceptive neuromuscular facilitation stretching (FNP): These consist of a contraction of an antagonist muscle followed by a static stretch of the agonist muscle. They aim to achieve greater relaxation by Sherrington's principle of reciprocal innervation, by which the contraction of an antagonist produces a reflex relaxation of its agonist.

A conventional static stretching program and an FNP stretching program have been compared in the treatment of PFP. Both reduce pain, improve function, and increase joint range, but FNP stretch program produces greater improvements in pain, function, and range of movement [30].

7.3.1.3 Proprioceptive Exercises

Proprioception involves a complex neuromuscular and articular process integrating sensory and motor afferents [31, 32]. Proprioception tries to enhance static and dynamic stability to a joint complex, optimizing energy consumption in movement [33]. It can be trained at different levels [34]:

- Conscious higher centers: through conscious and repetitive positioning activities
- Unconscious higher centers: incorporating distraction exercises
- Brain stem: avoiding visual aid and moving from stable to unstable surfaces and from unilateral to bilateral stances
- Spinal cord: producing sudden changes in the position of joints

Instrumental techniques are used to assess proprioception, which attempt to measure the patient's ability to detect passive movement or joint position in space.

Neuromuscular control of the musculature of the trunk and pelvis can affect the movement of the lower limbs and affect the patellofemoral joint [35]. Thus, incorporating postural stabilization exercises can reduce pain and increase function in patients with PFPS [36].

In the case of PFPS, proprioceptive techniques are usually used in a broader therapeutic context (Fig. 7.4), as part of physical exercise programs that also involve strengthening and stretching. CKC exercises, weight-bearing exercises, and orthoses have an important proprioceptive component within the clinical benefits they produce in patients with patellofemoral pain [36, 37].

Fig. 7.4 Balance exercises in an unstable plane to enhance proprioceptive ability

7.3.1.4 Gait Retraining

Another conservative treatment option in runners suffering PFPS is gait retraining. Gait retraining is a retraining program in which the patient receives individualized physical therapy focused on increasing step rate, softer footfall, and adoption of a non-hindfoot strike pattern for reducing the impact on the heel. Gait retraining has not been shown to reduce pain at 5 months compared to physical exercise (both interventions incorporated a load management program) [38]. However, in hindfoot striker runners with PFPS, a change from hindfoot to forefoot strike pattern does appear to improve pain in the short term (up to 1 month after intervention) [39].

7.3.2 Therapeutic Modalities

Therapeutic modalities can be classified according to the physical principle on which they are based, as shown in Table 7.1. The most commonly used therapeutic modalities in the treatment of PFPS are described below.

7.3.2.1 Thermotherapy and Cryotherapy

The application of heat and cold can be helpful in PFPS. To administer cold, an ice pack can be used; there are cold packs containing a silica gel or cellulose to keep the cold for a longer time; also, a cooling spray, usually ethyl chloride, can be employed to produce very rapid skin cooling. Although deep thermotherapy (diathermy) can be used, most heat therapy for PFPS is applied superficially. The ways for applying heat are also multiple: fomentos (a wet and hot piece of cloth that is drained), paraffin (a mixture of solid paraffin and hot paraffin oil), or infrared (light emitted in a certain frequency that produces heat by molecular agitation), among others.

Heat and cold have very different effects, but they also have some common. That is why they both can be used in the same patient depending on the different clinical circumstances. Both heat and cold are analgesics (being cold the more analgesic of the pair), but heat also improves the distensibility of collagen tissues, improving range of movement. The effect of cold lasts for a longer time and has a remarkable anti-inflammatory component. No heat (superficial or deep) should be applied if there is edema present.

There is not enough evidence to assess the clinical effect of thermotherapy and cryotherapy as isolated treatments in PFP. Therefore, it is recommended to use these techniques as an adjunctive treatment to other, more complete, physical therapies [40].

7.3.2.2 Electrotherapy

Electrotherapy is based on the physiological effects of the passing of an electric current through the body. Based on an electromagnetic principle, the different types of electrotherapy can be divided by the number of cycles per second (measured in hertz) they reach during their emission.

Electrotherapy also allows the permeation of medicinal substances through the skin using a continuous electric current; this is called iontophoresis. The most commonly used substances are lidocaine, dexamethasone, nonsteroidal anti-inflammatory gels, and acetic acid [41]. Iontophoresis has not been shown to be effective in the treatment of patients with PFPS, so it is not recommended [42].

TENS (transcutaneous electrical nerve stimulation) currents are also frequently used in PFPS patients. TENS are low-frequency electrical currents, with a mainly analgesic effect. They usually involve symmetrical compensated pulses of different forms. TENS can be administered in the form of single pulses or pulsed train (or burst), which are usually better tolerated.

TENS allows its use in several modes depending on the parameters of the current used, of which two should be highlighted:

- Conventional (high frequency and low intensity) provides fast but short-lasting analgesia.
- Acupuncture-like type (low frequency and high intensity), which provides a more durable analgesia, but of later onset. This mode is usually less well tolerated.

The pathophysiological mechanisms by which TENS produce their effects are various. Its clinical indications are derived from its analgesic properties and are usually used for treating painful pathology at joint, muscle, or tendon locations.

Studies using TENS in PFPS do so as an adjunctive treatment to other therapies. Therefore, the therapeutic effect of isolated TENS on PFPS cannot be determined [42].

An electric impulse applied to a muscle with sufficient intensity can have an excitomotor effect; this is called neuromuscular electrostimulation (NMES). Electrically induced muscle contraction has not the same characteristics as voluntary muscular contraction. When an electric pulse is applied, the phasic muscular fibers contract first, and neither spatial nor temporal summation effects are achieved. The administration of impulses in succession increases the contraction time. It is more effective to combine electrostimulation with voluntary muscle contraction [43] (Fig. 7.5).

The use of NMES for the treatment of patients with PFPS is common. The NMES can be used to stimulate the contraction of the entire quadriceps or on the VMO selectively (especially when it is hypotrophic and its contraction is delayed in respect of the vastus lateralis) [44]. It is important to use electrodes of the correct size and place them in the right location [45]. The electrical current used in the NMES of patients with PFP must be programed with some parameters [45, 46]:

- Frequency: usually between 50 and 70 H.
- Type of pulse: monophonic or biphasic, usually rectangular in shape
- Pulse duration: typically between 100 and 400 microseconds
- Duration of the contraction cycle: usually 10 s of working time and 50 s of rest
- Intensity: according to individual tolerance

Usually NMES is used in combination with voluntary muscle contraction. Exercise programs

Fig. 7.5 NMES (neuromuscular electrostimulation) combined with voluntary muscle contraction to stimulate the contraction of the entire quadriceps

that combine NMES have been shown to decrease pain and improve function in PFPS patients. However, the therapeutic effect of adding NMES to physical exercise is unclear, and the benefits reported may be related to the effects of physical exercise alone [42, 47]. Patients who receive NMES as adjunct to physical exercise report no discomfort or increased fatigue compared to those who do not [48].

Biofeedback via EMG can also be used in the physical treatment of PFPS. Biofeedback is a technique in which the muscular contraction is represented by means of a visual or auditory output, facilitating and enhancing this contraction. Biofeedback by EMG facilitates selective contraction of the VMO, which can improve the coordination between contraction of the VMO and the vastus lateralis. However, associating exercise with biofeedback via EMG has not shown to improve pain or function in patients with PFPS [49].

One form of electrotherapy is magnetotherapy, which is based on the use of low-frequency magnetic fields (10–100 Hz) for therapeutic purposes. Magnetotherapy has analgesic and anti-inflammatory properties, reducing the release of pro-inflammatory cytokines such as IL-1b, IL-6, IL-8, and PGE2 [50]. Magnetotherapy can be used to promote the formation of bone [51]. It also has a role in PFPS because of its chondroprotective effect, increasing the anabolic activity of chondrocytes by increasing the synthesis of proteoglycans [52]. In patients with PFPS, adding magnetotherapy to an exercise program reduces pain and improves function compared to an exercise program alone, with benefits that last for a year after the intervention [53].

7.3.2.3 Therapeutic Ultrasound

Therapeutic ultrasound is based on a sequence of waves produced by non-audible acoustic vibrations. It can be used in continuous mode with thermal effect or pulsed mode (with emission periods and pause periods) with no thermal effect. It can be used to assist the delivery of topical drugs (corticosteroids, NSAIDs, or local anaesthetics) through the skin, a process known as sonophoresis [54]. Although ultrasound has traditionally been used in the treatment of PFPS as an adjuvant, there is no evidence that it produces a clinically relevant effect in either of its uses [42].

7.3.2.4 Laser

Laser (light amplification by stimulated emission of radiation) is a beam of light in which all the rays have the same wavelength. This makes it monochromatic and coherent. There are different types of laser, being the most widely used in the field of musculoskeletal disorders those of medium power (less than 100 mW).

Among the effects of the laser, it is noteworthy its minimal thermal action, since the heat it produces is low and very superficial. Its therapeutic action is due to a photochemical effect, accelerating physiological processes of the body by stimulating metabolic reactions at a cellular level. Its therapeutic utility is mainly analgesic and anti-inflammatory, also improving tissue repair mechanisms [55]. In the case of PFPS, it does not appear to provide a clinical benefit over placebo [56].

7.3.3 Manual Medicine

Manipulation can be defined as a forced movement (thrust) applied, directly or indirectly, to a joint or set of joints. That thrust places the joint elements beyond their normal physiological range of movement, but without exceeding the limit that anatomy imposes on that range. It is a short, brisk, unique impulse that must be applied when the limit of the normal passive arc of the joint is reached and is usually accompanied by a noise or cracking sound [57]. In this way it differs from mobilization, in which the movement does not exceed the limit of the normal articular range.

In order to apply a manipulative technique, it is necessary to carry out an adequate prior assessment which includes the performance of specific pre-manipulative maneuvers.

The therapeutic efficacy of manipulations may be related to a mechanical, neurophysiological, and/or placebo effect. The evidence about the effectiveness of manipulative techniques is controversial [58]. Due to the potential risks of the manipulative technique, its careful application is recommended. In the treatment of PFPS, manipulative techniques can involve locations as the proximal femoropatellar, tibiofemoral, tibioperoneal, and more proximal areas such as the lumbar spine or sacroiliac joint.

Therapeutic massage is a mechanical technique of manual application that aims to mobilize the soft tissues to achieve a sedative or stimulation effect. It must be performed by trained personnel.

Both manipulations and therapeutic massage are employed in PFPS, sometimes simultaneously. This makes it hard to assess their isolated clinical effect. Moreover, the mechanism by which manual techniques would work in PFPS is not well known. They may improve the mobility of the patella or reduce the stiffness of the surrounding soft tissues. Proximal application of manual techniques (at the lumbar and sacroiliac joints) may decrease quadriceps inhibition [59, 60].

Manual techniques may improve pain in the short term (6 weeks or less), but do not appear to affect function. They could therefore play a role only as part of a more complete treatment of the patient with PFPS [61].

7.3.4 Orthoses

Another element that has been widely used in the conservative management of PFPS is orthosis. Orthosis is defined as any device that is applied externally to the human body to modify the structural or functional characteristics of the neuromusculoskeletal system. Knee orthoses and foot insoles are the most commonly used in PFPS.

Knee orthoses for PFPS are usually made of neoprene, with different sizes to suit the volume of the area they cover [62]. The function of a knee orthoses in PFPS would be to centralize the patella within the femoral trochlea, correcting patellar maltracking [63]. Knee ortheses usually have a hole in the patella area for this purpose (Fig. 7.6). Some orthoses include strips or reinforcements to facilitate the task of centralizing the patella [64]. In addition to correcting maltracking, other therapeutic effects of orthoses are:

- Thermal, increasing circulation over the area [65]
- Proprioceptive [37]

Fig. 7.6 Knee orthosis with a hole in the middle to centralize the patella and lateral reinforcements. This is commonly used, but there is low evidence that it does not improve pain or function in the short term

- Offloading the patellofemoral joint, decreasing the contact pressure between the patella and the femoral trochlea [66]
- Improving tolerance to training and optimizing the clinical effects of therapeutic exercise [67]

In the treatment of PFPS, different types of orthoses, such as knee sleeve, knee brace, and knee strap, are usually prescribed. These orthoses are usually recommended as adjuncts to a wider therapeutic exercise program. There is little evidence that use of a knee orthoses improves pain or function in the short term (less than 3 months) [68].

Shoe insoles are also often used in the PFPS. Insoles are contoured removable devices that are molded from a footprint or through computer software. They are placed inside the shoe. They are made of different materials and improve load distribution providing support for different areas of the foot. The objective of insoles is to change the reaction force from the ground to the heel, modifying the vectors of force that act on the lower limb. This effect improves the distribution of pressure on the foot, ankle and knee during walking and running. Insoles are useful for modifying muscle work, absorbing impacts, improving pain, and limiting progressive deformity [69].

Insoles can be prefabricated or custom-made using a three-dimensional mold of the patient's foot. Since there is no evidence that employing a custom-made shoe insole in PFPS improves clinical outcomes, prefabricated templates are recommended, as they are cheaper. The prefabricated insoles used in PFPS usually have a structure for the internal plantar arch support and a medial wedge in the rearfoot. Shoe insoles appear to be an effective treatment option in PFPS, improving pain in the short term [2]. It is not known for sure which subgroup of patients might benefit most from using shoe insoles or which specific type of insoles they should use. It has been suggested that patients whose midfoot width increases by 11 mm or more with loading could especially benefit from the use of insoles [70].

7.3.5 Taping

Patellar taping is a technique in which an adhesive band is applied to the patella or the anterior area of the knee. The adhesive tape is glued directly onto the skin. Taping can be done by a physician, a therapist, or even the patient himself [71]. There are different types of tapes (elastic or rigid) as well as various techniques for the application depending on the direction of the pull (upper, lower, medial, lateral, rotational, or no directional pull).

In PFPS, patellar taping attempts to correct patellar maltracking by improving the contraction of the VMO. The application of patellar taping specifically addressing the inclination, sliding, and rotation of the patella can be effective in reducing pain in the short term [72]. However, given the heterogenicity of taping technique in its application and effects obtained, there is controversy about its effectiveness in PFPS [71]. For this reason, its application is not recommended as isolated therapy, but as an adjunct to wider treatment options such as therapeutic physical exercise [2].

7.4 Conclusions

PFPS is a very prevalent pathology that usually persists over time, causing pain and limiting activities of daily living. There exist many frequently used conservative treatment options that have been studied in a wide variety of studies. This heterogenicity makes prescribing conservative treatment for patients with PFPS very complex.

Among the conservative treatment options, the one that obtains the best results in terms of improving pain and function is therapeutic exercise. Exercise prescribed should include both the knee and the hip. The training programs offering the best clinical results are those that combine CKC and OKC exercises. Incorporating weight-bearing exercises may have a clinically relevant effect.

There are other treatment options that can be used as adjuncts to therapeutic exercise and that may improve patellofemoral pain symptoms.

Among them, magnetotherapy, manual medicine, shoe insoles, and patellar taping are recommended. The use of thermotherapy, electrotherapy, ultrasound, laser, and knee orthoses has not been shown to be clinically effective.

More studies with adequate methodological quality are needed to better define the role of each treatment technique in the conservative management of patients with PFPS.

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8 Cartilage Defects of the Patellofemoral Joint

Yaser Ghani and James Donaldson

8.1 Introduction

Chondral lesions of the knee are a common problem. Effective management can be difficult due to the inherently poor potential for spontaneous healing [1, 2]. Despite an improvement in our understanding of the structure, biochemistry and biomechanics of articular cartilage in the patellofemoral joint, chondral lesions remain a challenge for both the patient and surgeon.

The aetiology of cartilage defects is usually multifactorial and includes trauma, focal degeneration, instability and secondary injuries arising as a result of abnormal biomechanics. If the chondral defects of either the patella or trochlea are left untreated, they will alter the normal distribution of weight-bearing forces and predispose patients to the development of osteoarthritis [1].

The prevalence of patellofemoral cartilage defects is controversial. It is unknown what proportion of lesions has become symptomatic enough to prompt evaluation. To successfully treat patellofemoral pain, each contributing factor requires individual management and often an 'a la carte' solution. Some of these factors include patella alta, trochlea dysplasia, increased lateral position of the tibial tubercle relative to the femoral sulcus (previously assessed as a 'Q' angle), malrotation, excessive femoro-tibial valgus and secondary soft tissue problems, such as a weakened or hypoplastic vastus medialis muscle with a contracted lateral retinaculum. These pathomechanics lead to abnormal forces of the patellofemoral joint (PFJ), which can cause injury to the articular cartilage in itself through repetitive microtrauma or exacerbate the effects of a traumatic event.

8.2 Anatomy and Biomechanics

The articular surface of the patella has a midline ridge that is congruous with the trochlear groove. The distal 25% of the under surface is non-articulating.

The articular surface of the patella is divided into two large facets, medial and lateral. These are then divided into several subfacets that vary from person to person. The lateral facet is generally concave, with two transverse ridges that separate upper, middle and lower thirds of the articular surface [3]. The lateral facet is larger and extends more proximally and anteriorly than the medial facet. The facet morphology can be classified into one of three groups on the basis of the Wiberg classification scheme (Table 8.1).

The femoral trochlea is a groove, 0.5 cm deep in the distal aspect of the femur that closely articulates with the patella. The trochlear groove is

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Table 8.1 Wiberg classification

Type 1 (10%)	The facets are concave, symmetrical and of equal size
Type 2 (65%)	The medial facet is smaller than the lateral facet and flat or only slightly convex. The lateral facet is concave
Type 3 (25%)	The convex medial facet is markedly smaller than the concave lateral facet, and the angle between the medial and lateral facets is nearly 90°

covered by a 2–3 mm thick cartilage cap, which tends to be thinner medially.

The trochlea functions to provide a lateral buttress to lateral subluxation of the patella, starting at approximately 15°–20° of knee flexion [3–5]. The patellar contact area changes with increasing knee flexion. In general, the contact area reaches a maximum at 90° of knee flexion and moves proximally on the patella from extension to 90° flexion. At 90° flexion, the proximal aspect of the patella is in contact with the femoral trochlea. As the knee flexes beyond 90°, the patellofemoral contact area decreases, and the tendo-femoral contact area increases. Contact pressure is the ratio of the contact area and the patellofemoral joint reaction force. Force increases from extension to 90° of flexion at a greater rate than contact area increases. The maximum compressive pressures occur at 60°–90° of flexion [6].

8.3 Clinical Presentation and Examination

The commonest presentation in patients with patellofemoral cartilage injuries is activity-related anterior knee pain. It is usually felt in either the retropatellar or peripatellar areas with patella cartilage defects and in the popliteal area in cases of trochlea defects. It can be associated with intermittent swelling and mechanical symptoms in some cases. Patients often describe a dull aching pain in the anterior knee, especially after prolonged flexed knee position and stair climbing. Participation in sports activities is historically the most common cause of chondral lesions and may present as sharp pain. Occasionally, the presentation is with patellar instability and a history of traumatic subluxation or dislocation [7].

A thorough physical examination should be undertaken with specific focus on assessment of conditions that could predispose the patient to patellar instability or excessive patellofemoral contact pressures. The examination should begin with the patient standing to assess the overall varus or valgus alignment. One should assess the patellar position to gauge the femoral version and tibial rotation. Evidence of any previous surgical procedures should also be noted. This should be followed by examination of the patient in a sitting position, and observation of the patella position, tibial torsion, vastus medialis obliquus atrophy and knee range of motion should be carried out. Crepitus and patellar tracking can be evaluated by putting a patient's knee through a range of motion. Typically, crepitus and pain in early flexion represent distal patellar pathology. Supine exam is then performed focusing on the presence of an effusion, decreased quadriceps or gastrocnemius flexibility, and the presence of patellar apprehension with applied laterally directed stress at 30° of knee flexion.

8.4 Imaging

A standard series of radiographs including standing anteroposterior (AP), lateral and Merchant view (shallow angle axial) should form the initial imaging for all the patients with suspected patellofemoral cartilage injuries. Patients should also have long length alignment films to ascertain any malalignment, which would aid surgical planning. These views will help assess for any degenerative changes, patella baja or alta, patella tilt and subluxation and trochlear dysplasia.

A computed tomography (CT) scan is also helpful in assessment in detailed anatomy of knee compartments and is also used to determine the tibial tubercle-trochlear groove (TT-TG) distance. A TT-TG distance of <15 mm is considered to be normal. A value >20 mm is abnormal, and a tibial tubercle osteotomy may need to be considered as part of the surgical plan.

Fig. 8.1 Axial and coronal MRI scan demonstrating an osteochondral lesion of the patellofemoral joint (PFJ)

Magnetic resonance imaging assessment is now largely the gold standard due to its high-resolution imaging protocols to assess for cartilage defects and a TT-TG distance measured being equivalent to the one measured using CT scans [8]. Figure 8.1 shows MRI scan of a knee demonstrating an osteochondral defect of the PFJ.

Table 8.2 Surgical indications

Indications
Characteristic of anterior knee pain
Failure of non-surgical management
Age < 55
Stable knee
Normal alignment
Lesion >0.5 cm^2

Table 8.3 Contraindications for surgical procedure

Contraindication
Malalignment (needs to be corrected)
Ligamentous laxity
Increased body mass index (BMI)
Multi-compartment arthritis

8.5 Treatment

8.5.1 Non-surgical Management

Non-surgical management in patients without significant pain and mechanical symptoms includes activity modification and physical therapy. The aim is to strengthen the muscles crossing the knee and restore soft tissue balance in the patellofemoral joint.

8.5.2 Surgical Management

Once the conservative management options have been exhausted, surgical management with careful rehabilitation can often be successful. The type of surgery depends on the size and area of the lesion, location and the status of the underlying cartilage and subchondral bone. Tables 8.2 and 8.3 show indications and contraindications for surgery, respectively.

The three broad categories of treatment options include cartilage restoration procedures, realignment procedures and patellofemoral replacement. The realignment procedures include tibial tubercle osteotomies (advancement and anteromedialisation, covered in more detail in Chap. 11). These are often combined with cartilage restoration to offload the treated lesion site. Table 8.4 shows various cartilage restoration options available depending on the underlying cartilage defect and

Table 8.4 Cartilage restoration procedures for patellofemoral chondral lesions

Cartilage restoration procedures
Microfracture
Autologous chondrocyte implantation (ACI)
Osteochondral grafting
Osteochondral auto/allograft implantation
Mesenchymal stem cell implantation

subchondral bone status. For patients with significant degenerative changes of the patellofemoral joint, a patellofemoral arthroplasty is an option as a salvage procedure (see Chap. 15). All of these procedures (Table 8.3) have their specific indications (Table 8.2), contraindications (Table 8.3) and postoperative rehabilitation.

8.5.2.1 Realignment Procedures

The absence of patellofemoral malalignment is a prerequisite for any form of cartilage regeneration procedure. With lateral patellar subluxation, there is overloading of the trochlea and patella over time with decreasing patellofemoral contact area, consequently increasing the contact stress.

The aim of realignment surgery is to correct the abnormal patellar tracking and overload to both prevent and protect the treated chondral defect. Patients require individualised (a la carte) surgery depending on their anatomy. This ranges from an MPFL reconstruction with lateral lengthening, trochleoplasty, tibial tubercle osteotomy or distal femoral osteotomy. The specifics of realignment surgery are discussed elsewhere in this book.

8.5.2.2 Microfracture

This procedure involves debridement of the damaged cartilage and perforation of the subchondral bone. It is indicated for lesions less than 2–3 cm^2. Perforations of the subchondral bone result in extravasation of blood and marrow into the defect with subsequent formation of a blood clot. Over time, the defect is filled with a reparative tissue in the form of fibrocartilage that is formed from the blood clot and mesenchymal stem cells.

Historically, microfracture has been suggested for younger patients (less than 40 years old) with small lesions (less than 2–3 cm^2). Mithoefer et al. in their systematic review determined that microfracture resulted in symptomatic improvement in the first 24 months post surgery; however the outcomes declined with time [9]. It is postulated that this is due to either incomplete filing of the defect or more likely due to inferior wear properties of the fibrocartilaginous repair tissue. Microfracture of the patellar chondral lesion is technically more difficult to perform arthroscopically due to challenging angle of approach, and therefore a mini arthrotomy approach maybe more suitable. In a study by Kreuz et al., the authors showed that the functional outcomes in patients with patellofemoral chondral lesions were worse regardless of follow-up [10]. Minas et al. also showed an increased failure of autologous chondrocyte implantation (ACI) in the setting of a previous microfracture of a chondral lesion [11].

8.5.2.3 Autologous Chondrocyte Implantation

ACI is a cartilage cell-seeded therapy with the aim of forming hyaline-like cartilage to restore normal joint function. It is a two-stage procedure that involves taking a cartilage biopsy from a non-weight-bearing area of the knee and expanding the chondrocytes in culture for several weeks. The second stage involves reimplantation of these in to the prepared cartilage lesion, which is then covered by a membrane. ACI is best suited for a large symptomatic full-thickness cartilage defects and is used as a primary treatment for patients with persistent symptoms. It is important to obtain an MRI scan to assess the subchondral bone prior to ACI as patients may require concomitant bone grafting. It is also important to note if degenerative change is present and if patients had any previous microfracture of the chondral defect as the results of ACI are inferior in these patients [11, 12].

There is now a large body of evidence supporting the clinical and cost-effectiveness of ACI in the knee [12]. Large lesions, which are not amenable to treatment with microfracture, fare well with ACI, with lesions between 2 and 8 cm^2 being the best indication. Failure rates at 10 years range between 17 and 26%, and in common with other cartilage restoration procedures, the results of ACI in the patellofemoral joint are poorer than for lesions in other parts of the knee [13, 14]. Compared with microfracture, the reoperation rate is higher (normally arthroscopic procedures for graft hypertrophy), but the rate of conversion to arthroplasty is lower [15]. Overall, practice is changing with more ACI and less microfracture being performed each year for cartilage defects of the patella [16].

Often, patellar and trochlear defects require treatment with combined procedures including correction of patellar tracking alongside ACI [17]. One recent study has demonstrated good pain relief and return to activity in a cohort of 72 patients undergoing patellofemoral ACI, of whom 66 (91%) underwent tubercle transfer at the same sitting [17]. As our understanding of patellofemoral joint biomechanics, and the place of combined procedures improves, together with an improvement in ACI techniques, better results for patellofemoral ACI have been demonstrated in recent studies [18, 19].

8.5.2.4 Osteochondral Autograft Transfer

Osteochondral autograft transfer (OAT) is a cartilage tissue-based therapy where a plug of normal autologous cartilage and bone is transferred from a non-weight-bearing area of the knee into a chondral defect. This is carried out by drilling tunnels in the defective section of the cartilage and harvesting many small cylindrical osteochondral plugs from the periphery. The benefits of this procedure are that it can be done as a single stage and there is no risk of immunological reaction. However, the disadvantages include donor site morbidity, poor lateral tissue integration with native tissue and chondrocyte death from osteochondral plug implantation. The graft should fit correctly and create a smooth articular surface in the PFJ to achieve satisfactory results after OAT. This can be challenging due to the anatomy of the patellar and trochlear surfaces.

Hangody et al. have shown good to excellent results in 79% of patients treated with OAT of the PFJ in a 10-year follow-up study [20]. However, Bentley et al. compared ACI to mosaicplasty for all types of osteochondral lesions of the knee and showed only 69% of patients had good to excellent results as compared to 88% who had ACI. The five patients who underwent the OAT for the PFJ all had poor postoperative outcomes [21].

8.5.2.5 Osteochondral Allograft Transplantation

This procedure is predominantly used as a salvage procedure in younger patients with large defects and in whom other cartilage repair techniques have failed. It can be performed as a single-stage open procedure where the chondral lesion is prepared and a similarly sized and shaped graft from donor patella or trochlea is then transplanted on to the lesion. The osteochondral allograft is harvested with 24 h of donor death and can be stored up to 28 days [22].

There is limited literature on the use of osteochondral allograft for patellofemoral cartilage defects. Jamali et al. have demonstrated up to 60–70% graft survival at 10 years follow-up [23]. More recently, Cameron et al. have shown 100% graft survival at 5 years and 91% at 10 years follow-up [24]. A recent systematic review has shown higher failure rates of osteochondral allograft in PFJ as compared to the tibiofemoral joint (50 and 24%, respectively) [25].

8.5.2.6 Mesenchymal Stem Cell Transplantation

Mesenchymal stem cell transplantation is a newer procedure for osteochondral defects. It is best suited for lesions larger than 1 cm^2 and in patients less than 55 years of age. The procedure involves a single-stage open procedure. The bone marrow is harvested from the pelvis and concentrated with density centrifugation. The concentrated bone marrow aspirate, containing high numbers of mesenchymal stem cells, is then reimplanted into the prepared lesion using a collagen-based scaffold and held in place with fibrin glue. Figure 8.2 shows intraoperative photos of a stem cell implantation.

Buda et al. developed a one-step technique for arthroscopic treatment of osteochondral lesions of the knee with bone marrow-derived cells and showed improved knee scores at a mean of 29 months follow-up [26].

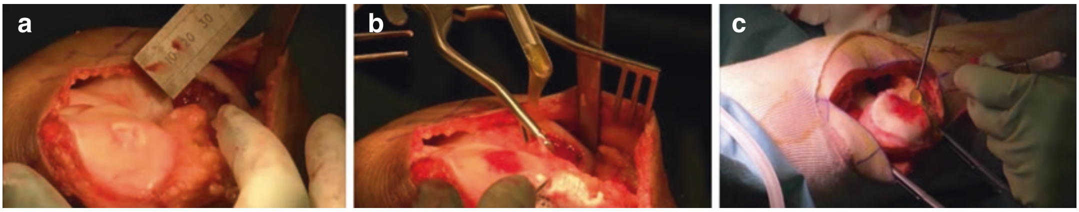

Fig. 8.2 (**a**) Shows a cartilage defect of the patella after debridement of the margins. (**b**) Shows the defect filled with collagen soaked in mesenchymal stem cells. (**c**) shows fibrin glue being used to secure the collagen in place

The largest UK series is currently being evaluated [27], and at a mean follow-up of 18 months, favourable outcomes have been demonstrated for pain and functional improvement with evidence of graft integration on cross-sectional imaging. The improvement is most marked within the first 6 months with intervention in younger patients being associated with better outcomes.

8.5.2.7 Patellofemoral Joint Arthroplasty

Patellofemoral joint arthroplasty (PFJA) was developed to replace the arthritic patellofemoral (PF) compartment whilst maintaining kinematics similar to the native knee. It preserves the tibiofemoral joint, thus allowing for a rapid recovery. Although PFJA is considered a valid therapeutic option to treat isolated patellofemoral arthritis, it is indicated in small and highly selected patients. The ideal candidate is probably someone over 50 with isolated patellofemoral arthritis without maltracking. Apart from careful patient selection, outcomes are dependent upon implant design and surgical technique. Good to excellent results have previously been reported by authors ranging from 80 to 90% at midterm follow-up [28]; however, revision rates have been reported in region of 20 to 25% [29]. The main reason for failure is progression of arthritis in adjacent compartments of the knee requiring a revision to a total knee arthroplasty. More details on PFJ arthroplasty are given in Chap. 15.

8.6 Conclusions

Cartilage lesions present a challenge to the knee surgeon, and those in the patellofemoral joint are associated with particularly poor outcomes when compared to other locations. Even in cases which appear to be straightforwardly the result of trauma, attention must be paid to patellofemoral mechanics and, particularly, to malalignment. Systematic history, examination and investigation and the correction of any underlying deformities increase the likelihood of success. In the well-aligned joint (including joints which have undergone realignment procedures), there are a number of techniques which may be used with success in these lesions. Cartilage restoration procedures continue to be the focus of research. As our understanding improves, we can be hopeful of achieving better results in this challenging group.

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9 Patellofemoral Instability: Lateral Release

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9.1 Introduction

With greater understanding of the pathology and management options in patellofemoral instability, surgical management of the symptoms of instability has become more common over recent years [1]. The introduction of procedures such as medial patellofemoral ligament (MPFL) reconstruction and trochleoplasty, as well as an increased understanding of the role and techniques of distal realignment, has given surgeons a range of procedures which can be employed on the basis of the pathoanatomy displayed by the individual patient. Lateral retinacular release, once popular as an isolated treatment for patellofemoral instability, has fallen out of favour as the evidence base grows that it is not a helpful intervention in the majority of patients with instability [2–4].

In spite of this, lateral release continues to be employed either on its own or alongside other techniques. A recent retrospective analysis of current practice in patellar instability reported the use of a lateral release in 43.7% of cases, albeit usually alongside other procedures such as MPFL reconstruction [1].

The aim of this chapter is to define the role of lateral release in the treatment of patellar instability, to describe the techniques associated with it and to report the clinical results of lateral release reported in the literature.

9.2 Anatomy and Physiology of the Lateral Retinaculum

The anatomy of the lateral patellar retinaculum was first described by Kaplan in 1957, [5] with more detailed descriptions being made by Fulkerson and Gossling and, more recently, by Merican and Amis [6, 7]. This later study described the constraining structures of the lateral retinaculum to exist in three layers: most superficially, the deep fascia, an intermediate layer containing the quadriceps aponeurosis and the iliotibial band and a deep layer comprising the capsule of the knee joint. Within this capsular layer exists a distinct condensation, the lateral patellofemoral ligament (LPFL, originally described in Kaplan's study as the lateral epicondylar ligament) [5, 8].

Whilst all three layers have an effect on patellar stability, the deep layer, and most specifically the LPFL, is the most important by virtue of the fact that it is the only layer to form a direct connection between the patella and the

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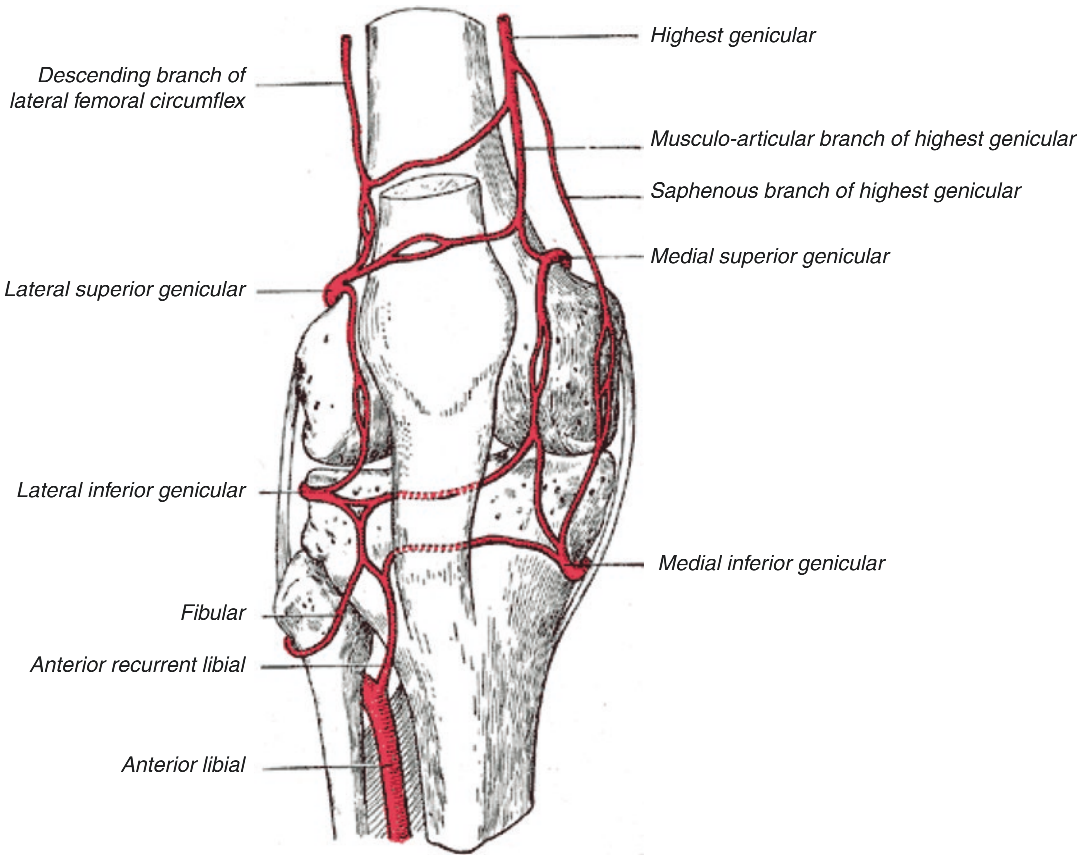

Fig. 9.1 Blood supply of the patella (from Gray's anatomy, 1918, images in public domain)

femur. The deep fascia attaches to the deep tissues laterally but not to the patella—Merican and Amis describe this layer as acting like a brace to patellar subluxation [6]. In the intermediate layer, a connection is made between the patella itself and the quadriceps tendon and iliotibial band via deep transverse fibres which are termed the iliotibial band-patellar fibres. The iliotibial band at this level is relatively fixed to both the lateral femoral condyle and Gerdy's tubercle, and as a result, iliotibial band tension plays a role in patellar tracking [6].

The LPFL itself has a broad attachment onto the patella, tapering slightly as it attaches to the femur. The precise site of attachment of the LPFL to the femur varies, with some patients having an attachment at the level of and either anterior or posterior to the epicondyle and some inserting slightly distally [8].

The other important structure to be aware of is the lateral superior genicular artery (Fig. 9.1) which enters the lateral side of the patella and which forms part of the patellar anastomosis. This artery can be inadvertently divided during lateral release, leading to a painful haemarthrosis [9].

9.3 Techniques of Lateral Release

Lateral release was first described, separately by Roux (in French) in 1888 [10], Pollard in 1891 [11] and Goldthwaite in 1895 [12], as a part of combined procedures for patellar dislocation. Interestingly, it only began being used as a stand-alone procedure in 1970 [13]; in recent years, it is this individual use which has fallen from favour, and it continues to be used in combination with other patellar realignment procedures [1].

Willner originally described an open operation through a midline incision; he described removing a strip of fascia around a centimetre in width from 6 in. superior to the patella to its inferior pole [13]. Merchant and Mercer described a more conservative procedure through a small lateral parapatellar window, incising only the retinaculum directly alongside the patella [14]. Arthroscopic lateral release was described in 1981 by McGinty, using a Mayo scissors to blindly divide the retinaculum through the lateral portal before completing the release with arthroscopic scissors well into vastus lateralis [15]. The use of diathermy was described a year later and remains the predominant technique for division of the retinaculum [16].

As lateral release is rarely used as a standalone procedure in current practice, there is little discussion of techniques in the literature. Schorn et al. describe a combined procedure of lateral release and medial reefing [3]. They describe using an arthroscopic radiofrequency hook to divide the retinaculum around 5–10 mm medially to the patella. There is more detail on techniques of lateral release following total knee arthroplasty. Strachan et al. describe a staged approach to inside-out lateral release after total knee arthroplasty (TKA), dependent on the degree of instability [17]. They start with a release of the lateral patellofemoral ligament and then perform a superolateral release from 25 mm proximal to the patella to the superior border. Then, in stages, the release is performed to the mid-patella, the inferior pole, the joint line and then Gerdy's tubercle. There is no evidence that one form of lateral release is advantageous to any other in terms of complications, recovery rate or functional outcome.

9.4 Biomechanical Effects of Lateral Release

Merican et al. performed a cadaveric study to determine the effect of sectioning various structures on the lateral side of the knee [18]. They performed a selection of extra-capsular releases, going from proximal to distal, before sectioning the capsule including the LPFL and patellomeniscal ligament. The stability of the patella reduced as the size of the release increased. Very proximal releases had no effect on medial or lateral stability. Releases distal to the distal pole of the patella led to significant reductions in medial stability. In knee flexion, middle release (i.e. continuation of the release from the proximal to the distal pole of the patella) led to the greatest reductions in patellar stability. In extension, the greatest constraint to patellar translation was the capsule itself, and in this position, the addition of a capsular release had the greatest effect on translation of all the releases.

Peretz et al. measured contact pressures at the patella in cadavers following TKA with or without lateral release [19]. They found that lateral release was effective in improving the differential between lateral and medial pressures.

Niimoto et al. performed lateral and medial quantitative stress radiography in 28 knees before and after lateral release [20]. Lateral release was performed using an electrosurgical probe, with the retinaculum being released from 1 cm proximal to the proximal pole of the patella to the level of the patellar tendon. Significant decreases were detected in resistance to medial and lateral stress following lateral release.

9.5 Clinical Results of Lateral Release for Patellar Instability

There is now a convincing body of evidence that isolated lateral retinacular release is an insufficient treatment for most cases of lateral patellar instability [2]. Colvin summarized the results of outcome studies for lateral patellar instability and concluded that lateral release was the only procedure shown definitively to be ineffective for the treatment of patellar instability [21].

One reason for the enduring popularity of lateral release, at least until recent years, is that short-term results have been reported as being satisfactory. Dandy and Griffiths reported on a series of 41 knees at between 12 and 96 months and reported excellent or good results in 90%, in spite of a third of patients having at least 1 episode of recurrent instability [22]. However, when the series was revisited 5 years later, there was a significant deterioration in results of lateral release [23].

These poorer long-term results are mirrored by more recent studies. Schorn et al. recently published the results of a retrospective study of 43 knees in patients between the ages of 9 and 44 years [3]. A total of 22 of the 43 cases had at least one recurrence during the follow-up interval; the risk of recurrence rose from 16% at 1 year to 52% after 10. Residual symptoms were present in 79% [3]. Overall, whilst there are small studies reporting better results [24], the weight of the literature supports the assertion that isolated lateral release has no role in the treatment of patellar instability in adults [25]. This is supported by expert opinion: a survey of the International Patellofemoral Study Group very strongly recommended that isolated lateral release should not be performed for patellar instability (with 89% agreement) [4].

9.6 Residual Indications for Lateral Release

Overall, the treatment of patellar instability should be focused on rectifying the pathoanatomy which led to the symptoms exhibited. Very rarely is the primary pathology tightness of the lateral retinaculum. More detail on the treatment of recurrent instability is given in chapter 6 and elsewhere in this book.

One group of patients in whom the literature is not so clear is adolescents [2]. A number of groups have reported good results for isolated lateral release for instability in this group [26, 27]. However, caution must be exercised in patients with hypermobility and those with other structural abnormalities. Whilst some surgical procedures are better indicated in adolescents (for instance, correction of angular deformities of the limb through guided growth), there is a strong argument for waiting until growth has ceased before performing bony procedures such as trochleoplasty and tubercle realignment. There may be an argument for the use of lateral release in these patients if symptoms are disabling and there is substantial growth left (see chapters 3 and 5 for more details).

Other indications for lateral release may include symptomatic bipartite patella [28–30], medial retinacular pain [31] and patellar overload with significant patellar tilt [25]. Lateral release is often performed alongside other reconstructive procedures such as tibial tubercle realignment or MPFL reconstruction [32]. However, the additional benefit accrued from addition of a lateral release into these procedures remains unclear [1, 33].

9.7 Complications of Lateral Release

Aside from recurrent instability, there are a number of described complications of arthroscopic lateral release. Acutely, the principal complication is bleeding leading to a haemarthrosis [34]. One study of lateral release placed the incidence of a painful haemarthrosis at 42%, but others have suggested it is an order of magnitude lower than this [35]. A haemarthrosis usually occurs secondary to inadvertent division of the lateral geniculate artery, and risk factors include tourniquet use (reducing the visibility of the artery) and use of a postoperative drain (preventing tamponade of the bleeding) [9, 35]. The use of diathermy to make the lateral release (which is now almost universal) appears to reduce the incidence of haemarthrosis [35]. However, cases have been described where the use of diathermy without adequate visualization has led to cutaneous burns in lateral release [9].

Other complications of lateral release include under- or over-release [9]. Over-release can lead to symptomatic medial instability, weakness and pain [36, 37]. Those performing lateral release are advised to proceed with caution, only performing sufficient release to ensure patellar tracking returns to normal and in particular avoiding excessive distal release. In those with symptomatic pain or medial instability, various procedures have been described to improve symptoms. Heyworth et al. describe 22 patients with pain following lateral release who underwent open lateral retinacular closure with satisfactory results [37]. Moatsche et al. report the results of lateral patellotibial ligament reconstruction for instability using combined patellar tendon and iliotibial band grafts [36]. They describe high levels of patient satisfaction with improvements in patient-reported outcome measures.

9.8 Conclusions

Whilst lateral retinacular release is straightforward to perform and has reasonable early reported results, the weight of literature and expert opinion states that isolated lateral release does not have a role to play in treatment of patellar instability in adults. Lateral release is associated with a not insignificant rate of complications, recurrent instability and iatrogenic medial instability. The precise indications for lateral release remain uncertain—whilst some indications such as symptomatic bipartite patella or symptomatic lateral retinacular tightness appear to have good results, others, such as in combined procedures for instability, have little evidence to support their use. Treatment of patellar instability should be individualized to the patient, focusing on the pathoanatomy leading to the symptoms demonstrated.

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10 Patellofemoral Instability: Proximal Realignment and Trochleoplasty

Maureen Monda and Antony Palmer

10.1 Introduction

Patellar instability is frequently multifactorial. Treatment of patellar instability should focus on the anatomical or physiological abnormality presented, and therefore a number of procedures can be used either alone or in combination.

In this chapter, we focus on three procedures which may be used to treat patellar instability: femoral osteotomy, used in patients with rotational deformities, trochleoplasty for patients with trochlear dysplasia, and proximal soft tissue procedures.

10.2 Femoral Osteotomy

Excessive femoral anteversion or torsion generates a more laterally directed force across the patellofemoral joint and contributes to patellofemoral instability [1]. This rotational malalignment is a common and often under recognised factor in patellofemoral instability [2], included as part of the 'miserable malalignment' syndrome [3]. When there is a suspicion of a rotational abnormality of the femur in association with patellar instability, computerised tomography (CT) or magnetic resonance imaging (MRI) is indicated for formal evaluation. On axial slices, the femoral neck to horizontal angle and the posterior condyles to horizontal angle are measured. The difference between these values represents the femoral anteversion or torsion, although it does not identify the level of the deformity. The terms femoral anteversion and torsion are often used interchangeably, but femoral anteversion describes anterior tilt of the femoral neck, whereas torsion refers to rotation of the femoral shaft [4].

It is not clear which patients with patellofemoral instability and associated rotational femoral malalignment are most likely to benefit from a derotation femoral osteotomy. Further research is required to establish patient-specific thresholds for femoral osteotomy and when it should be performed alongside other stabilisation procedures [5, 6]. Derotation osteotomies warrant consideration when anteversion is greater than 20–25° in the setting of recurrent patellofemoral instability [5–7]. It can be performed in the intertrochanteric, diaphyseal or supracondylar region depending on the level of the deformity. The rotational malalignment is most frequently femoral torsion below the level of the lesser trochanter [8].

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When femoral rotational malalignment is not recognised and addressed, outcomes of distal realignment or soft tissue procedures for patellofemoral instability are worse [6, 9]. Studies demonstrate improved patient-reported pain scores and no further patella dislocations with at least 1-year follow-up after femoral rotational osteotomies accompanied by distal realignment or soft tissue procedures [10, 11]. Even in the absence of patella instability, knee pain improves when correcting excessive femoral anteversion [12]. Potential complications must be taken into account including nonunion and compensatory deformities in the coronal plane.

10.3 Proximal Realignment Procedures

Isolated proximal realignment through quadricepsplasty was first proposed by Insall in 1976 and has since received multiple modifications [13]. Although optimising the function of vastus medialis obliquus to enhance patellofemoral joint stability is a critical element of nonoperative management, it is less frequently the target of realignment surgery. During this procedure, vastus medialis is separated from the quadriceps tendon and advanced distally and laterally, in combination with a release of vastus lateralis fibres to allow this realignment.

Advantages of quadricepsplasty over some alternative realignment procedures include that it can be performed in skeletally immature individuals, and as a result, it is most frequently used in paediatric patients. Reported clinical outcomes are limited to historical case series and vary greatly between studies [14–16]. Although not widely used, proximal realignment through quadricepsplasty remains an important treatment option in select cases.

10.4 Trochleoplasty

Trochleoplasty is a surgical procedure undertaken to reshape the dysplastic femoral trochlea while preserving the articular chondral cartilage. Radiographic evidence of trochlear dysplasia is present in 96% of knees with patellar instability as opposed to 3% in normal knees, and trochleoplasty is the only intervention to directly address trochlear dysplasia [17].

While the medial patellofemoral ligament (MPFL) is the main patella stabiliser in extension and initial stages of flexion [18, 19], the morphology of the femoral trochlea represents the main static stabiliser of the patellofemoral joint beyond 30° of knee flexion [18]. In the dysplastic trochlea, there is loss of the groove with flattening and even convexity as a result of morphological abnormalities of the femoral condyles and patella facets [17, 20]. This causes patellar tilt and lateral shift, affecting both transverse and proximodistal patella glide with loss of normal medial patella tilt during flexion [17, 21]. As a result, the forces required to displace the patella are greatly reduced [22]. There is also an increase in patellofemoral contact forces and which can result in damage to the articular cartilage and early degenerative change [21, 23].

10.4.1 Planning Trochleoplasty

Imaging for trochlear dysplasia is covered in detail in Chap. 2. Plain radiographs are an excellent screening investigation for dysplasia. The presence of the ‘crossing sign’ on the true lateral radiograph at 30° of flexion is pathognomonic of dysplasia [20]; axial radiographs taken with the knee in 30° of flexion allow for assessment of the sulcus angle. This is defined as being dysplastic if it measures >145°; other parameters assessed are trochlear bump >5 mm and trochlear depth < 4 mm and trochlear tilt >20° [17]. For planning of trochleoplasty, MRI, is particularly helpful for identifying cartilage lesions, and CT allows 3D reconstructions and calculation of lateral trochlear inclination [24, 25].

10.4.2 Indications and Contraindications for Trochleoplasty

The indication for trochleoplasty is symptomatic trochlear dysplasia. However, trochleoplasty is simply part of an armamentarium in treating the multifaceted nature of patellofemoral instability.

The decision to proceed to trochleoplasty is based on clinical history, clinical examination and radiological investigations. Clinical history includes history of patella luxation/instability including voluntary or habitual dislocation despite attempted conservative management, a thorough enquiry into family history including a query of collagen disorders [26]. Clinical examination findings include positive apprehension test, abnormal patella tracking with or without demonstration of J sign, pain, functional disability and a lack of confidence in the knee. It is important to assess for hypermobility in these patients and quadriceps function/dysfunction as these may affect outcomes of surgery. Radiological findings include high-grade trochlear dysplasia (Dejour B and D) [17, 25], with no or little evidence of patellofemoral osteoarthritis and a normal or corrected rotational profile.

Trochleoplasty is contraindicated in children due to the risk of growth arrest; however, in older adolescents with closed or soon-to-close physes, good results have been reported with no major complications [27].

10.4.3 Techniques of Trochleoplasty

The aim of trochleoplasty is to restore patellofemoral congruency, improve patella tracking and decrease contact stresses within the patellofemoral joint.

Pollard was the first to describe a form of trochleoplasty for patellar instability in 1890, followed by Drew in 1908. Both believed the primary deformity was elevation of the trochlear groove, and both described techniques where the groove is widened and deepened by directly cutting and removing the trochlear cartilage [28, 29].

Albee in 1915 described an osteotomy and elevation anteriorly of the lateral trochlear facet to act as a mechanical block to lateral patella translation [30]. He believed the underlying dysplasia was not necessarily due to an elevated trochlear groove in the midline, but to a depressed lateral trochlear facet. This technique was abandoned when it became clear that the resultant elevation in patellofemoral contact pressures led to accelerated degenerative change. The first modern trochleoplasty was described in 1978 by Masse [30, 31].

In current practice there are three main techniques of cartilage-preserving trochleoplasty: sulcus deepening trochleoplasty, subchondral deepening trochleoplasty (the Bereiter technique) and recession wedge trochleoplasty.

The sulcus deepening trochleoplasty was described by Dejour in 1987 and is consequently known as the Lyon technique [20]. It is a modification of the technique described by Masse in 1978 [31]. A midvastus medial approach is used, and the patella is everted and displaced laterally. Articular surfaces are inspected. The trochlea is fully exposed by elevation of the periarticular synovium. A new trochlea sulcus is drawn extending from the intercondylar notch and extended proximally to the osteochondral edge at an angle of 3–6° valgus. A ridge of cortical bone is elevated from the osteochondral edge using sharp osteotomes to gain access to the underlying cancellous bone. This cancellous bone is removed to fashion a new sulcus. A drill with 5 mm depth guide is used to ensure uniformity of the osteochondral flap raised. The flap must be thin enough to be moulded but not fracture. Once the new sulcus is completed, the osteochondral flap is gently tapped into the sulcus with a punch. This is then held with two anchors or staples on either side of the trochlea. The peritrochlear synovium and periosteum are then sutured back.

The Bereiter subchondral deepening technique [32], described by Von Knoch et al. in the English literature [33], uses a lateral subvastus approach to the knee. While similar to the Lyon technique, the osteochondral flap fashioned is concave in shape and mimics more the normal trochlear shape as opposed to the Lyon sulcus deepening technique which results in an osteochondral V-shaped flap. The flap is created using curved osteotomes, and a burr is used to remove subchondral bone and deepen the groove to form a curved contour. The cartilage flap is allowed to plastically deform to the contoured groove. It is held in place with anchor sutures.

Recession wedge trochleoplasty was described by Goutallier in 2002 [34]. It is indicated when there is an abnormal bump thought to cause anterior knee pain. It does not alter the patellofemoral congruence, nor the shape of the trochlear, but reduces the bump. The approach is usually a lateral approach extending from the superior pole of the patella proximally past the tibial tubercle to the anterior tibia distally. A reciprocating saw is used to make the initial cut in an anterior to posterior direction approximately 5 mm above the trochlea. A posterior cut is then made in a lateral to medial direction ending 5 mm from the sulcus terminalis. A third cut is made connecting the two cuts. The bone wedge is prised out and the wedge closed and held with screws.

10.4.4 Outcomes of Trochleoplasty

The widespread use of trochleoplasty is a relatively recent development; as a result the literature comprises mainly short- and midterm case series with small numbers [35, 36]. There are few long-term studies [34, 37]. In many cases, the trochleoplasty is one of a number of procedures being performed, and so it is difficult to interpret the degree of improvement attributable to the trochleoplasty itself [36].

Nevertheless, several studies have reported improvement in postoperative functional scores [35, 36]. Testa et al. conducted a systematic review of outcomes of trochleoplasty, demonstrating clinically and statistically significant improvements in outcome scores following surgery [38]. Mean Kujala score improved from 46.9 to 88.8, and Lysholm score improved from 59.9 to 91.1. Rates of recurrent instability were low with recurrent subluxation in 5–6% and recurrent dislocation in 2%. Reoperations were common, occurring in up to a quarter of cases, but many of these were simple removals of fixation devices. McNamara et al. in their series reported that 67% of patients played sport postoperatively [35]. Metcalfe et al. reported good patient satisfaction 88% and 90% symptom relief with the Bereiter technique [37]. They however reported an 8% rate of persistent instability. In addition, trochleoplasty did not prevent the progression of secondary osteoarthritis 7.7% at 5-year follow-up [37].

Complications described following trochleoplasty are rare but include chondral damage or detachment of chondral flap [33, 37], knee stiffness and arthrofibrosis [31, 33, 34], persistent patellofemoral instability (1–11%) [39], further surgery (15–25%) [35, 37, 38], secondary osteoarthritis [35, 37], wound problems and deep vein thrombosis.

10.5 Conclusions

Recurrent patella instability is often multifactorial, and all factors contributing to the instability should be characterised and corrected. In the presence of femoral malrotation, soft tissue procedures such as MPFL reconstruction are less likely to be successful, and a rotational osteotomy should be considered when anteversion or torsion exceeds 20°. Quadricepsplasty is a valuable option to realign the extensor mechanism in select cases and is most often used in the skeletally immature paediatric population. Trochlear dysplasia is one of the principal risk factors for recurrent patellar instability, and trochleoplasty allows direct correction of this risk factor. There is a growing body of outcome data for trochleoplasty which suggests that it is an important intervention in patellar instability.

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11 Patellofemoral Instability: Distal Realignment

Suroosh Madhanipour, Kostas Michail, and Sam Oussedik

11.1 Introduction

In 1888 Roux first published his results on distal patellofemoral realignment. The Roux-Goldthwait procedure comprised splitting the patella tendon and reattaching the lateral third deep to the medial two thirds, in order to improve patellar tracking by assuming a more medial position in the trochlear groove.

Since then other realignment techniques have been described in the literature including the Elmslie-Trillat procedure published in 1964. This involves tibial tuberosity osteotomy in the coronal plane and reattachment in a more medial and distal position, shifting the patellar tendon and therefore altering the patella position. Modifications of the original technique have also been described [1].

Maquet proposed a similar method of distal displacement of the patella through manipulation of the tuberosity and anteriorisation [2]. These two techniques combined to reduce the Q angle and tibial tubercle-trochlear groove (TT-TG) distance in order to treat instability whilst attempting to reduce contact pressures in the patellofemoral joint.

In 1992 Fulkerson described his findings of distal realignment of the patellofemoral joint and gave treatment recommendations [3]. The procedure involved a combination of medial and distal positioning of only a part of tibial tuberosity with the most distal part remaining intact. Screw fixation was used for the stabilisation of the proximal part.

The most common radiographic signs associated with patellofemoral instability are high patella (patella alta), trochlear dysplasia, lateral tilt of patella or lateral position of the tibial tuberosity [4]. It is vital therefore to assess these parameters in order to inform the surgical goals of distal realignment procedures.

Several methods exist to determine patella height using measurements on a lateral radiograph of the knee, demonstrated in Fig. 11.1.

Biedert described a new method based on sagittal MRI using a true measurement of the patellotrochlear cartilage, arguing this to be more reliable than using lateral radiographs where articular cartilage is not visible [5]. The measurements are taken with the knee in 0 degrees of flexion and the foot in 15 degrees of external rotation.

Biedert et al. recently published a literature review quoting described cutoff values for patella alta [6]. The most commonly used radiographic measures for patellar alta were the Insall-Salvati index on lateral radiographs with

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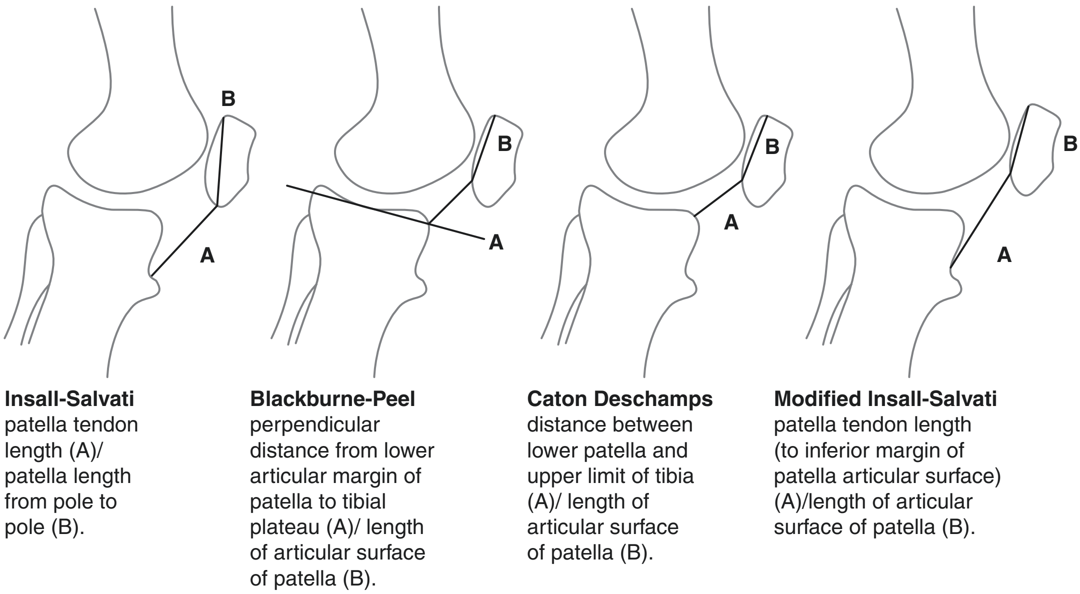

Fig. 11.1 Patella height measurements

cutoff values ranging from >1.2 to >1.5 and the Caton-Deschamps index with cutoff values from >1.2 to >1.3. On sagittal MRI, the patellotrochlear index was most used with cutoff values ranging from <0.125 to 0.28.

The surgical goals of distal realignment are to correct the biomechanical factors contributing to instability through reduction of the Q angle, reducing the lateralising vector produced by quadriceps contraction, as well as reduction of the tibial tubercle-trochlear groove distance, improving patellar tracking [7].

The aim of this chapter is to focus on the surgical technique of performing a distal realignment and the biomechanical factors that guide decision-making for patellar positioning.

11.2 Distalisation: Surgical Technique

11.2.1 Surgical Exposure

With the patient in a supine position, the incision extends from the distal point of tibial tubercle up to 4–5 cm distally [1]. The insertion of the patellar tendon is identified and protected (Fig. 11.1).

11.2.2 Osteotomy

The tibial tubercle is exposed through the same incision. Using a saw blade and osteotome sequentially, it can be detached from the tibial shaft and mobilised. The tubercle, with patella tendon still attached, can then be repositioned in a more distal or medial position or a combination of the two [1, 2]. The optimal goal is to correct the alta position (Fig. 11.2) and improve tracking and patellofemoral engagement at 20–30° of knee flexion (Fig. 11.3) [7–9].

11.2.3 Fixation

The tubercle is fixed to its new position with two anteroposterior bicortical lag screws (Fig. 11.4). Care must be taken to avoid penetrating beyond the posterior cortex with drill bit or screw. Soft tissue realignment to the new orientation is advised prior to closing the wound in layers [9].

Figure 11.5 shows an arthroscopic view of patellofemoral engagement in knee flexion after distalisation. In Fig. 11.6, screw fixation of tibial tubercle to the new position is shown. Figure 11.7 shows a postoperative radiograph with a normalised Caton-Deschamps ratio. Distalisation

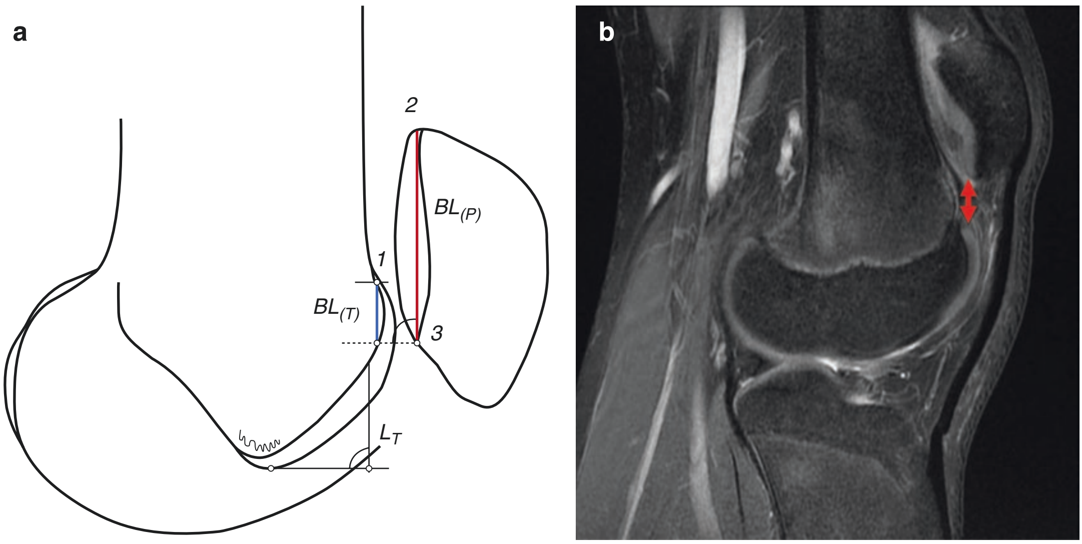

Fig. 11.2 (**a**) Biedert et al. Patellotrochlear index measurement. BL_P baseline patella (*2* superior most aspect of articular cartilage to *3* inferior most aspect); BL_T baseline trochlea (length of trochlear articular surface from *1* superior most aspect with respect to *3* the inferior most aspect of the articular patellar cartilage using a right angle and parallel lines); *Ratio* BL_T BL_P calculated in percentages; L_T length of trochlear cartilage (superior most aspect to inferior most aspect of trochlea using a *vertical line*), (**b**) Patella alta and a short trochlea leading to a negative patellotrochlear index (red arrow)

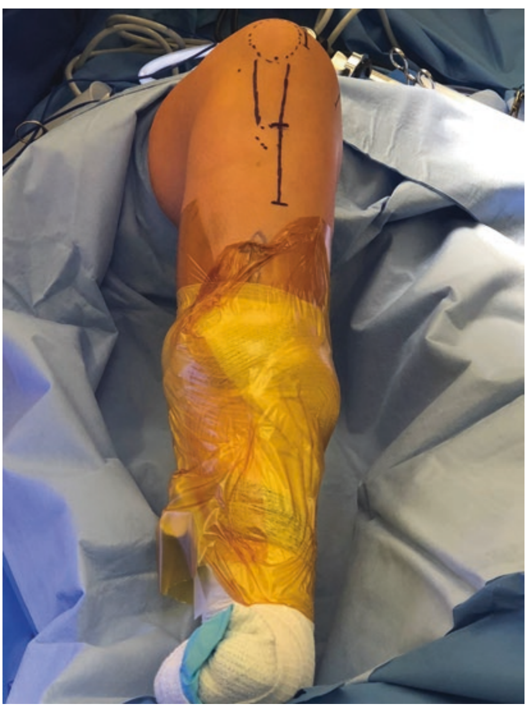

Fig. 11.3 Identification of anatomical structures borders and marking the incision site

Fig. 11.4 Determining the resection of the distal bone block

has been augmented by a medial patellofemoral ligament reconstruction in this case.

11.2.4 Postoperative Rehabilitation and Evaluation

Weight bearing with the knee immobilised in an extension splint is advised postoperatively, with isometric quadriceps muscle exercises and

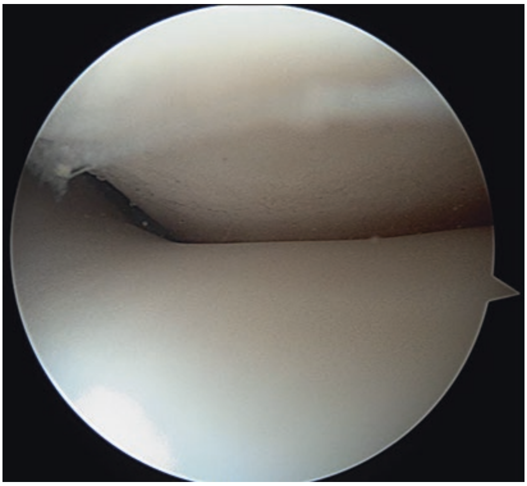

Fig. 11.5 Arthroscopic view of patellofemoral engagement in knee flexion after distalisation

Fig. 11.6 Screw fixation of tibial tubercle to the new position

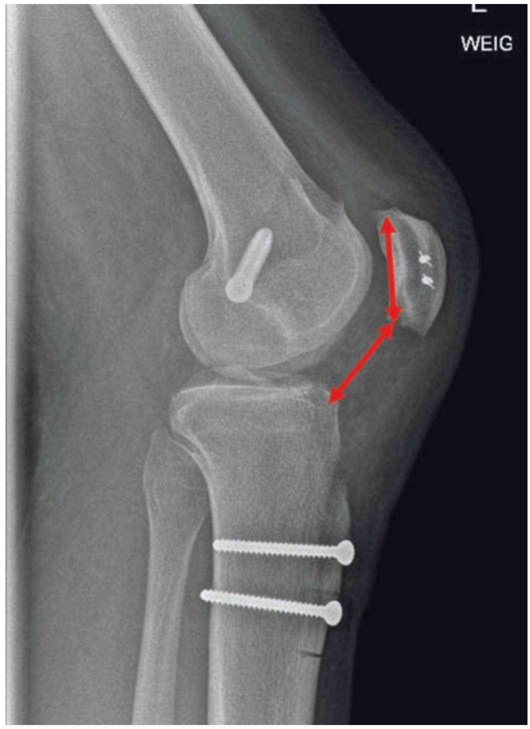

Fig. 11.7 Postoperative radiograph showing a normalised Caton-Deschamps ratio. Distalisation has been augmented by a medial patellofemoral ligament reconstruction in this case

gentle range of motion exercises. After 6 weeks, patients should have greater than 90 degrees of flexion and have regained good quadriceps control, allowing commencement of weight bearing in flexion. Rehabilitation can take around 3 months before satisfactory postoperative results are achieved [10].

11.2.5 Discussion

The most common indication for distal realignment involve a Caton-Deschamps index of more than 1.4, indicating a patella alta, in the presence of recurrent patellar instability [11, 12]. The most common contraindication is skeletal immaturity with an open tibial apophysis, giving rise to the possibility of growth arrest and recurvatum deformity.

Cox et al. reported that 88 out of 108 cases had good or excellent results after extensor realignment using the Elmslie-Trillat technique, showing the importance of correcting patellar malalignment and the subsequently offloading the retropatellar surface [13]. Accuracy of reconstruction is crucial to the overall success and patient satisfaction postoperatively [14]. There is also evidence that in cases with significant patellofemoral degeneration, worse results are seen following a realignment procedure [2, 10, 14].

The medialisation of the tibial tubercle alone provides a counterbalance for the lateral forces acting in patellar surface giving more stability of the joint. Most authors agree that optimal tibial tubercle-trochlear groove distance is set at approximately 12–15 mm [15, 16]. However, medialisation has also been associated with an increased incidence of late degenerative changes subsequent to increased contact pressures, with more recent stabilisation procedures therefore focussing on distalisation alone.

11.3 Outcomes of Tibial Tuberosity Distalisation Surgery

The role of pure medialisation of the tibial tubercle has come under scrutiny. Kuroda et al. demonstrated in the cadaveric setting that medialisation alone could result in significant increase in patellofemoral contact pressure [17]. Further cadaveric studies have demonstrated that the resultant force vector on a medialised tibial tubercle can externally rotate the tibia, altering the tibiofemoral kinematics, and apply undue pressure to the tibiofemoral cartilage [18].

Patella alta has been noted to play a significant role in lateral instability [4]. In cases of instability associated with patella alta, distalisation has become the procedure of choice in many centres [12]. Whilst no randomised controlled trial exists to determine the effectiveness of any distal realignment procedures, distalisation has been shown in the literature to prove an effective technique for preventing recurrent instability.

Magnussen et al. recently performed a systematic review reporting on the outcomes of distalisation [12]. Five studies with a mean follow-up of 6.8 years demonstrated a low recurrence level ranging from 0 to 4.9%. Patella alta was demonstrated via the Caton-Deschamps index [19] or Insall-Salvati ratio [20]. There were several cases of overcorrection of the patella height, but none below the threshold for patella infera. The complication rate was also low, with 2 reported osteotomy nonunions and 1 proximal tibial fracture out of 203 knees in 168 patients. Importantly however, these studies report on the outcomes of distalisation with concurrent, differing, procedures including vastus medialis advancement, medial patellofemoral ligament reconstruction and medial retinacular plication. Clearly there is a need for higher-level evidence on the outcomes of distalisation vs. anteromedialisation. However, biomechanically and clinically, distalisation procedures have been shown to have effective outcomes. It has been demonstrated that in cases of recurrent postoperative patella instability in isolated anteromedialisation, patella alta has been in the sole radiographic predictor of failure [21]. As such the authors would recommend careful preoperative determination of patella height and TT-TG using plain radiographs and MRI before a case-by-case selection of procedure most likely to succeed given the patient's anatomical features.

11.4 Complications

Distal realignment procedures involving osteotomy carry inherent risks, with complication rates reported as high as 37% [22].

11.4.1 Fracture

Fracture can occur at differing sites following tubercle osteotomy. The tibial tubercle fragment itself can fracture if the osteotomised fragment is too thin or due to overtightening of the screw fixation [22, 23]. Diaphyseal fracture can occur as a result of stress riser formation. A 'notched' distal segment of the osteotomy can give rise to resultant tibial fracture. As such a tapered distal osteotomy has been recommended in order to minimise this risk [24, 25]. Fractures have been reported at a mean time postoperatively of 5.5–7 weeks in early and immediate weight-bearing case series [26, 27]. However even following protective brace wearing and conservative progressive increase in weight bearing, Eager et al. were unable to prevent late fractures occurring with a mean time of 25 weeks post surgery [24].

11.4.2 Patella Baja

This is a serious complication which can arise as a result of distalisation as well as medialisation procedures. Over correction can result in pain and PFJ dysfunction. Fulkerson recently demonstrated in a cadaveric study that this can be exacerbated by poor quadriceps tone and non-compliance with postoperative rehabilitation protocol.

11.4.3 Nonunion

This is a rare complication [28]. Various techniques have been described to reduce the risk. Using an osteotome rather than an oscillating saw to complete the osteotomy can avoid thermal damage. The distal end of the osteotomy may not be wholly completed, allowing for a ‘greenstick fracture’ effect [29].

11.4.4 Hardware Irritation

Irritation from screw heads can be avoided by choosing low-profile screw heads and ensuring adequately countersunk cortex; however metalwork removal remains a common reason for reoperation though it has been reported as less frequent with the Elmslie-Trillat technique (26.8%) than with the Fulkerson technique (49%) [30].

11.4.5 Recurrence

A recent systematic review of distal realignment procedures quoted an overall 7% recurrence rate of patella instability [2].

11.4.6 Vascular Injury

Vascular injury is a rare but serious complication. The risk to posterior vascular structures arises through bicortical tibial drilling for screw placement. Kline et al.’s cadaveric study determined that during Fulkerson osteotomy, the bifurcation of the popliteal artery was at a mean distance of 8.3 mm from the superior drill bit as it perforated the far tibial cortex. The inferior drill bit has a mean distance of 9 mm from the posterior tibial artery [31]. Henderson et al. described the most common complications after extensor realignment for patellofemoral instability [11]. Specifically they described absence of infection postoperatively, compartment syndrome that was temporary and fully resolved in a few months and arthrofibrosis that was fully resolved with an arthroscopic release. During second-look arthroscopy, they also had the opportunity to compare their findings with the preoperative condition and the improvement in patellar tracking in the trochlear groove. In terms of overall outcomes, they described that over 80% of patients treated had good or excellent results depending on postoperative symptoms and return to sporting activities without any problems.

A similar study performed earlier by Cox et al. suggested similar results with around 70% of the patients treated appear to have excellent or good results depending on similar postoperative factors [15]. The clinical findings also resemble the ones of the previous study during second-look arthroscopy revealing a significant improvement in patellar tracking and similar patellofemoral joint arthrosis with the preoperative state.

Vivod et al. attempted to compare the long-term outcomes between differing operative techniques including nonoperatively managed knees [8]. The clinical findings suggested significant recurrent dislocation rates and significant arthrosis of the joint among the different realignment techniques. The clinical performance of the operated knees was better than the non-operated ones, but without a statistically significant difference. They concluded that the varying operative techniques did not deliver the expected long-term clinical outcomes and increased the likelihood for patellofemoral osteoarthritis.

Wang et al. describe in their study that distal realignment with tibial tubercle release in combination with lateral retinacular release seems to be the more effective method to treat recurrent patellar instability with patellofemoral malalignment, also supported by earlier studies [16, 19–21]. As the study suggests in all cases, the individual patient needs to be taken into account to decide the combination of procedures to achieve patient satisfaction.

Similar findings with the later study can be drawn by Longo et al. [4]. Again the combination of distal realignment with proximal procedures gives better outcomes both clinical and functional. In addition the complications descried postoperatively including dislocation or patellar maltracking are well below the average.

11.5 Conclusion

Patients presenting with recurrent patellofemoral instability should undergo rigorous assessment through thorough clinical examination, including measures of hypermobility and medial patellar laxity, radiographic assessment of patellar height and patellofemoral congruence and MRI assessment of trochlear morphology, patellotrochlear index and chondral integrity.

In the presence of patella alta and recurrent instability, patellar distalisation is a reliable and powerful tool in preventing recurrence. It should be used in combination with other measures when necessary to optimise patellofemoral congruence through early engagement of the patella into the trochlear groove.

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12 Patellofemoral Instability: Medial Patellofemoral Ligament (MPFL) Reconstruction

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12.1 Introduction

The medial patellofemoral ligament (MPFL) runs between the medial patella and a triangular region on the femur, centred between the adductor tubercle, the medial epicondyle and the gastrocnemius tubercle [1]. It is the primary static constraint to lateral translation and is most important in full extension and the early degrees of flexion; these are the positions where patellar instability tends to present [2]. In patellar dislocation, the MPFL is frequently ruptured, and its reconstruction has been well described [3, 4]. A number of surgical procedures for reconstruction of the MPFL have been published [5]. In this chapter we will assess the effectiveness, results and complications of the various techniques described, both in children and adults.

12.2 Surgical Techniques of MPFL Reconstruction

The basic principles underlying the surgical technique of MPFL reconstruction are well known (Fig. 12.1). However, there are different variations on the basic technique reported in the literature with different results [6–9].

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12.2.1 Graft Choice

A number of grafts are available for MPFL reconstruction including allografts, synthetic grafts and various autologous grafts. McNeilan et al. produced a systematic review of the results of MPFL reconstruction with different grafts [10]. They found no difference in the rate of recurrent instability between different graft types, but the overall number of patients with recurrent instability was low.

The most common graft for MPFL reconstruction is autologous semitendinosus or gracilis [5]. In 2013 Wagner et al. [11] analysed 50 patients with chronic patellofemoral instability treated with MPFL reconstruction using an autologous gracilis tendon (Fig. 12.2). MRI demonstrated good integration of the reconstructed MPFL and a decrease of patella tilt (16.1° to 11.2°). A negative relationship was observed between the degree of trochlear dysplasia and the outcomes. Eighty per cent of patients could return to the same or higher level of physical activity. The re-dislocation percentage was 2%.

Weinberger et al. examined the effect of different surgical variables on outcome following MPFL reconstruction and found that autograft reconstructions were associated with greater postoperative improvements in Kujala scores when compared to allograft (32.2 vs. 22.5), but there was no difference in recurrent instability (5.7% vs. 6.7%). Double-limbed reconstructions

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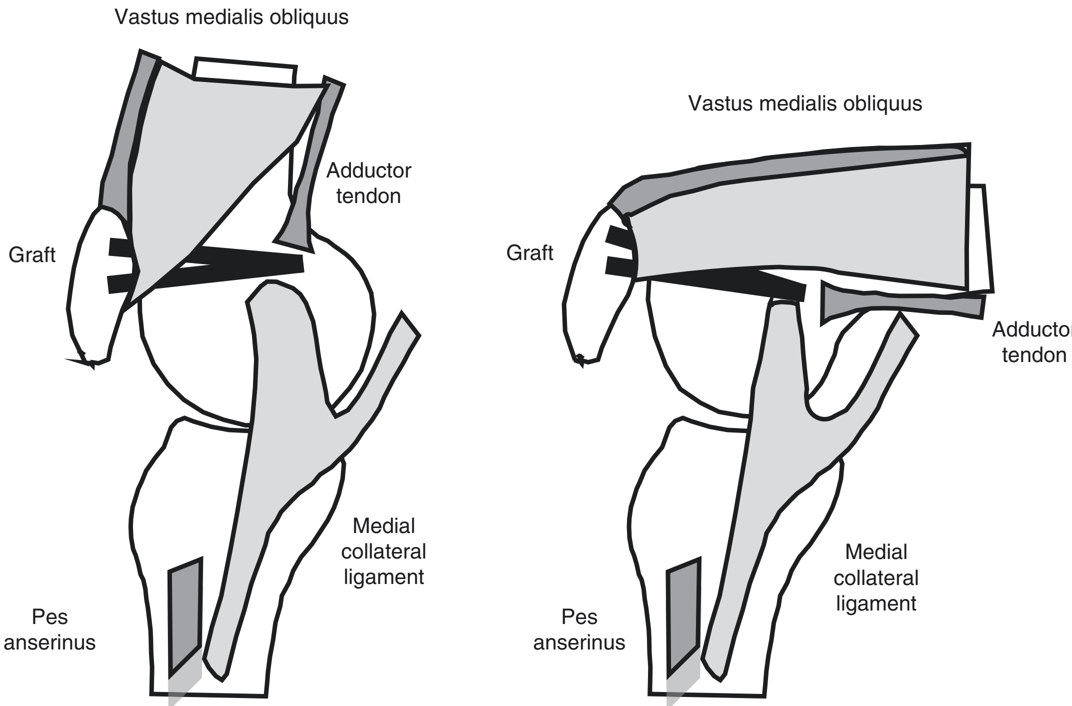

Fig. 12.1 A schematic of the basic principles of medial patellofemoral ligament (the basic surgical technique of MPFL reconstruction is shown). Autograft or allograft is used to reconstruct the MPFL resorting the primary medial stabilizer of the patella and preventing lateral dislocation (left, knee in full extension; right, knee in 90º flexion)

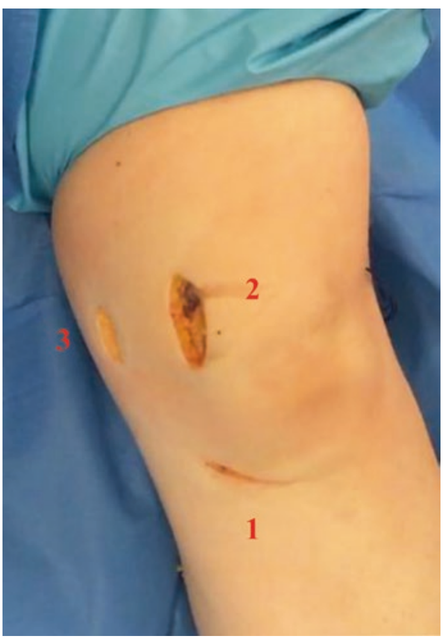

Fig. 12.2 Photograph of the three incisions made during MPFL reconstruction using a free gracilis tendon graft (left knee). (*1*) Incision over the pes anserinus to harvest the tendon; (*2*) incision to expose the medial border and anterior aspect of the patella; (*3*) medial incision to identify the adductor tubercle of the medial femoral condyle

were associated with both improved postoperative Kujala scores (37.8 vs. 31.6) and lower failure rate (10.6% vs. 5.5%). One group in whom allograft is preferred is patients with connective tissue disorders. Due to fears about grafts stretching, leading to recurrent instability, allograft is preferred in this group [12].

12.2.2 Identification of the Femoral Insertion

Studies of Schöttle's fluoroscopic measurement method have demonstrated that it can produce reproducible and accurate anatomical positions for the femoral tunnel [13] (Fig. 12.3). However, Sanchis-Alfonso et al. have reported that an accurate anatomic femoral tunnel position could not be accomplished with the radiographic method [14], particularly in female patients with severe trochlear dysplasia. They recommend that surgeons expose and directly visualize the adductor tubercle, even if it requires a larger surgical incision.

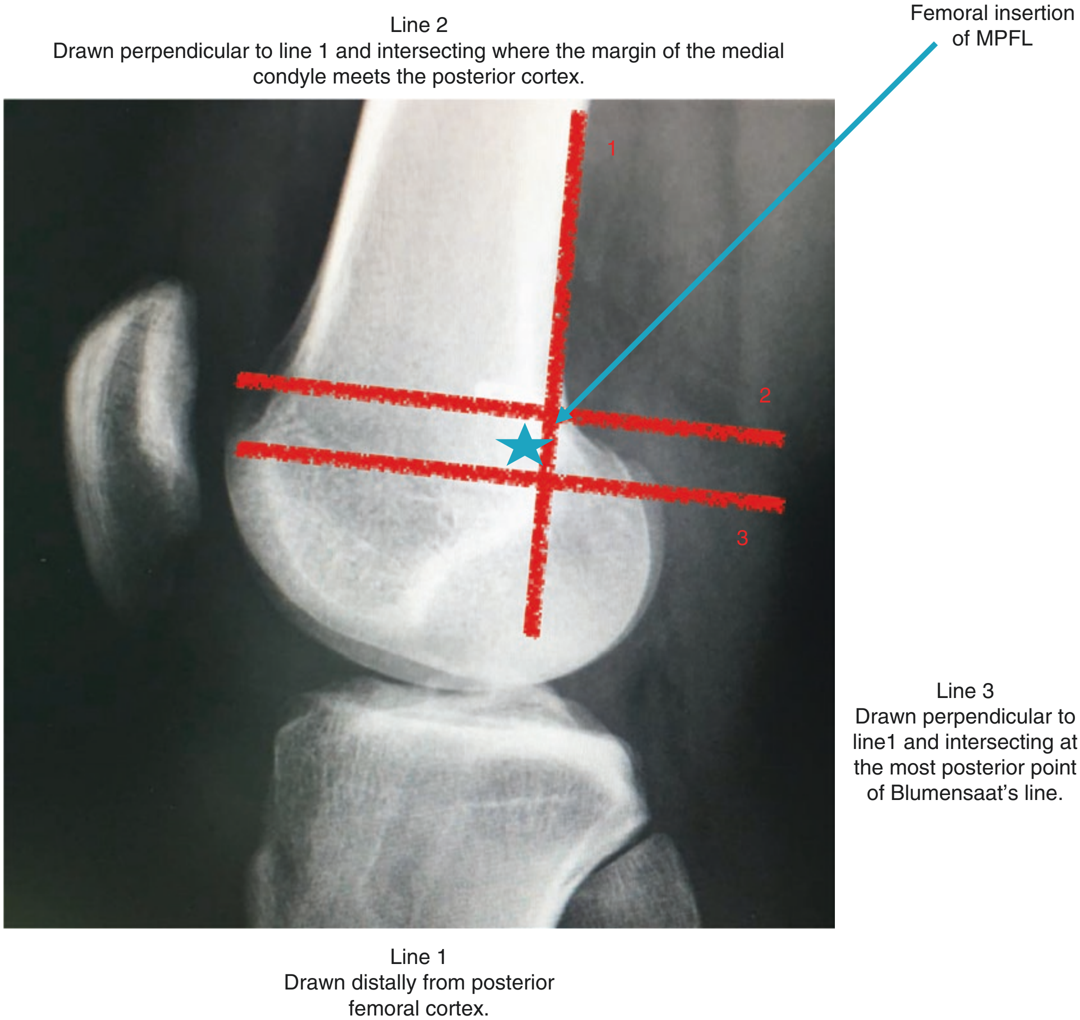

Fig. 12.3 Schottle's point

12.2.3 Y-Graft Technique and C-Graft Technique

Kang et al. [15] compared the outcomes of two techniques of double-bundle MPFL reconstruction. In the Y-graft technique (45 patients), the graft is fixed in the femur with the bundles tensioned individually in the patella; in the C-graft technique (45 patients), the graft is fixed primarily in the patella, and the two arms are tensioned together. No episodes of recurrent dislocation or subluxation were encountered in either group. CT scans demonstrated that congruence angle, patellar tilt angle, lateral patellar angle and lateral displacement had been restored to the normal range in both groups. There were statistically significantly better functional outcomes (Lysolm and Kujala scores) in the Y-graft group, although the difference was less than the minimal clinically important difference (MCID) of the scores, limiting the clinical relevance of the findings of the study.

12.2.4 Dynamic vs. Static Reconstruction

In 2014 Becher et al. [16] compared dynamic and static reconstruction. The static technique consisted of a rigid fixation of the gracilis tendon

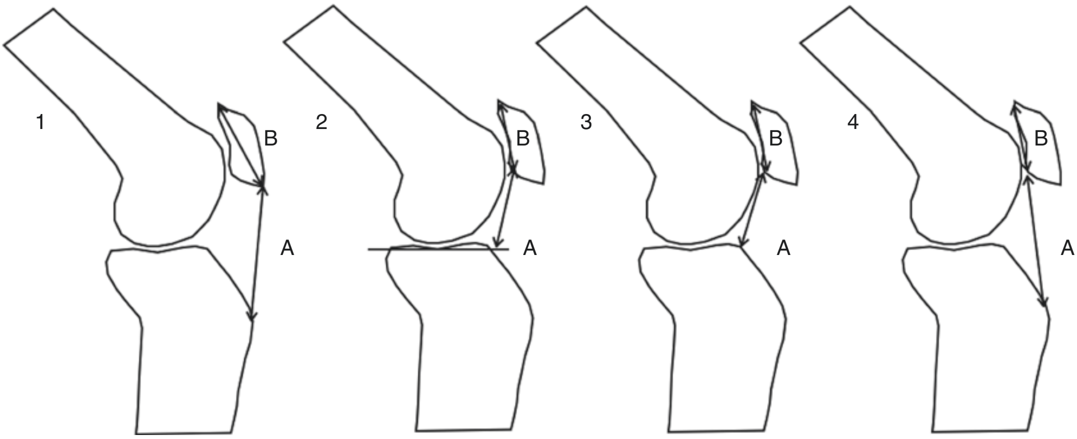

Fig. 12.4 Patella height measurements. These are measured on lateral knee X-ray or sagittal MRI with the knee ideally flexed at 30 degrees: (*1*) Insall-Salvati, patella tendon length (*A*)/patella length from pole to pole (*B*); (*2*) Blackburne and Peel, perpendicular distance from lower articular margin of the patella to tibial plateau (*A*)/length of the articular surface of patella (*B*); (*3*) Caton-Deschamps, distance between the lower patella and upper limit of the tibia (*A*)/length of the articular surface or patella (*B*); (*4*) modified Insall-Salvati, patella tendon length (to inferior margin of patella articular surface) (*A*)/length of articular surface of patellar (*B*)

at the anatomic femoral MPFL insertion and the superomedial border of the patella; the dynamic technique consisted of the detachment of the gracilis tendon at the pes anserinus; then it was fixed to the proximal medial patellar margin by means of a tunnel transfer diagonally across the patella. Thirty patients surgically treated for recurrent lateral patellar dislocation were analysed. Patients were divided into 2 groups of 15 patients. The following parameters were assessed: Kujala, Lysholm and Tegner scores, pain level and pre- and postoperative radiographic changes of patellar height (Fig. 12.4), bisect offset (Fig. 12.5) and patellar tilt (Fig. 12.6). No significant between-group differences were observed in mean Kujala, Tegner, Lysholm and visual analogue scale (VAS) scores or radiographic measurements. There was one case of resubluxation in the dynamic group.

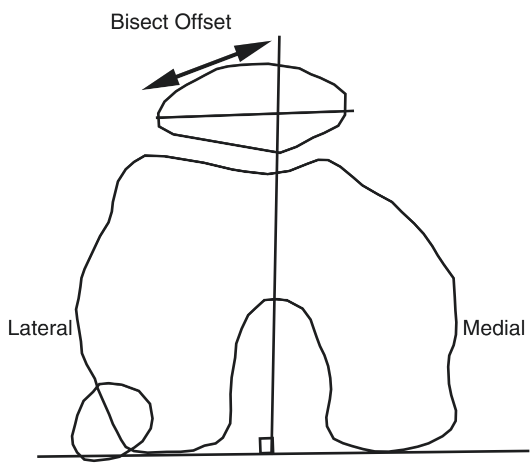

Fig. 12.5 Bisect offset describes the medial/lateral position of the patella and is the percentage of the patella lateral to the midline of the femur

12.3 Results of MPFL Reconstruction

12.3.1 Complications

Whilst MPFL reconstruction has a high rate of success, there is a not insubstantial rate of complications. In a systematic review of outcomes of MPFL reconstruction, Shah et al. reported an overall complication rate of 26% [6]. The most common complication was recurrent apprehension, which comprised 32% of all complications, followed by loss of range of motion (13% of complications). The most serious complication, patellar fracture, occurred in four cases out of 629 [6]. Similar complications are reported in the systematic review of Fisher et al. [5]; the most frequent complications were quadriceps dysfunction (31%),

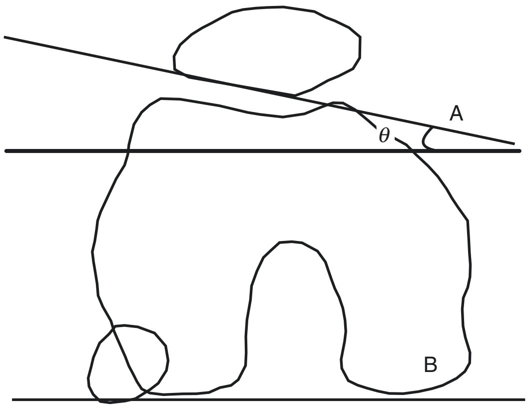

Fig. 12.6 Patellar tilt: angle between line along lateral facet of the patella (*A*) and line parallel along posterior femoral condyles (*B*)

positive apprehension (20.6%) and stiffness range of motion (18%). A third meta-analysis put the rate of complications at 12%, again with stiffness being the most common complication [17].

12.3.2 Functional Outcomes

Favourable outcomes have been reported by a number of primary studies and systematic reviews of patients undergoing MPFL reconstruction. A meta-analysis of 320 MPFL reconstructions in 2013 by Singhal et al. reported a mean postoperative Kujala score of 92 [17]. A second meta-analysis by Schneider et al. [18] reported a mean Kujala score of 85.8 with 84% of patients returning to sport following surgery. The total risk of recurrent instability after surgery was 1.2%, with a positive apprehension sign risk of 3.5% and a reoperation risk of 3%. As techniques improve, complications are becoming less common, but functional outcomes appear to be similar. Stupay et al. reported that the major complication rate has dropped from 2% in older studies to 0.5% in newer studies, with the minor complication rate dropping from 6% to 4% [19]. Failure rates have fallen from 9% to 5%, but Kujala scores have not changed significantly. No differences were noted in terms of outcome by graft choice or fixation type.

12.3.3 Factors Affecting Outcome

A number of factors affect the rate of recurrent instability. Kita et al. examined 44 knees undergoing isolated MPFL reconstruction at a mean follow-up of 3.2 years [20]. They found that trochlear dysplasia and increased tibial tubercle-trochlear groove (TT-TG) distance were the main predictors of failure following MPFL reconstruction. By contrast, Liu et al. reported good outcomes in patients with trochlear dysplasia as long as patella height and TT-TG distance were normal [21]. Satisfactory patient-reported outcomes were observed by Matsushita et al. [22] following MPFL reconstruction in the majority of the patients. However, patients who only had mild pain preoperatively tended to have worse subjective outcomes, and a caution may be required when carrying out MPFL reconstruction on these patients.

Regarding revision MPFL reconstruction, Chatterton et al. [23] observed that although the procedure established reasonable patellar stability, the subjective results following revision MPFL reconstruction did not ameliorate significantly and were poorer than following primary MPFL reconstruction.

12.3.4 Results of Combined Procedures

12.3.4.1 MPFL Reconstruction and Tibial Tuberosity Transfer

Burnham et al. [24] performed a systematic review of outcomes of combined MPFL reconstruction and tibial tubercle (TT) transfer in 92 knees at a mean follow-up of 38 months. Postoperative scores (Lysholm, Kujala, International Knee Documentation Committee, Knee Injury and Osteoarthritis Outcome, visual analogue scale) were equivalent to those previously published for isolated MPFL reconstruction, and complication rate was low (<15%). Complications of the combined procedure included wound infection, hardware irritation and stiffness.

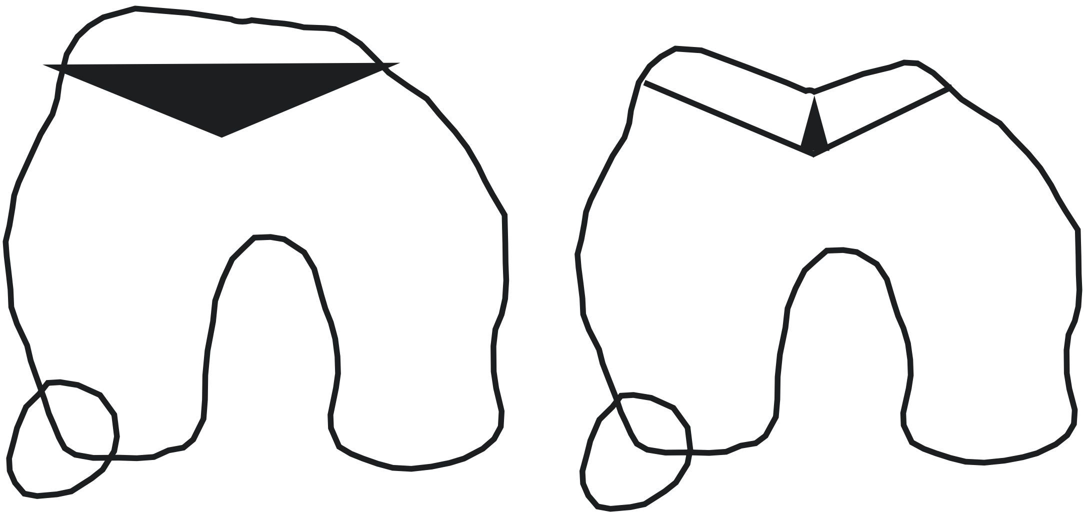

Fig. 12.7 Axial view schematic of trochleoplasty. A trochleoplasty is performed by reshaping the distal aspect of the femur. In this circumstance, guide pins are placed along the undersurface of the trochlea cartilage surface, and a saw is used to undermine the articular cartilage. A V-shaped groove is then prepared in the distal femur, and the articular cartilage is positioned down into the V to reconstitute the bony groove

12.3.4.2 MPFL Reconstruction and Trochleoplasty

In patients with trochlear dysplasia, MPFL reconstruction may be combined with trochleoplasty (Fig. 12.7). A number of series have now been published. Nelitz et al. [25] reported on 26 knees at a mean follow-up of 2.5 years. Kujala scores improved significantly from 79 to 96, IKDC (International Knee Documentation Committee) scores from 74 to 90 and VAS (Visual Analog Scale) scores from 3 to 1, and high levels of satisfaction were reported.

Blond and Haugegaard [26] performed combined arthroscopic deepening trochleoplasty and reconstruction of the MPFL in 31 patients (37 knees) with recurrent instability and trochlear dysplasia grade B or more. Results at a mean of 29 months demonstrated improvements in Kujala score (from 64 to 95), Tegner (4 to 6) and KOOS (knee injury and osteoarthritis outcome) scores (pain 86–94; symptoms 82–86; ADL (activities of daily living) 91–99; sport 40–86; QDL 25–81). Similar degrees of functional improvement and satisfaction were found in the series of Banke [27] et al. and von Engelhardt et al. [28].

12.4 MPFL Reconstruction in Paediatric Patients

MPFL reconstruction in children is challenging due to the presence of open physes and the potential for growth disturbance.

Nelitz et al. [29] have published their results of physis-sparing MPFL reconstruction in 21 children. They used fluoroscopic guidance to introduce a bioresorbable interference screw just distal to the physis without violating it. They reported good outcomes (the Kujala score improved from 72.9 preoperatively to 92.8 postoperatively) and no cases of recurrence or growth disturbance. Lind et al. [30] described a technique using a soft tissue femoral fixation technique. Rather than fixing the graft to the femur, the gracilis autograft was looped around the adductor magnus tendon insertion and through drillholes in the proximal medial patella edge. The rate of complications were low and the outcomes were good (Kujala score improved from 61 to 81). However, the rate of recurrent instability was greater than that seen in adult controls who underwent a conventional technique using bony tunnels.

12.5 Conclusions

In adult patients, several systematic reviews have not found significant differences between different fixation techniques and different options for graft constructs. Schöttle's fluoroscopic measurement method has proved to be reliable in creating reproducible and precise anatomical femoral tunnel positions. The literature appears to indicate that a combined approach (trochleoplasty and MPFL reconstruction) should be limited to severe dysplasia and patients with high TT-TG distance and that bony procedures are associated with increased morbidity. In children and adolescents, MPFL is the treatment of choice. However, postoperative patella stability is worse than in adult patients. Distal bony realignment procedures should be reserved for skeletally mature patients.

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13 Patellofemoral Osteoarthritis: Intra-articular Injections

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13.1 Introduction

Osteoarthritis (OA) is a multifactorial degenerative disease that affects more than 250 million people worldwide. The expectation is that this number will increase as the population ages, and risk factors such as obesity become more prevalent [1].

Patellofemoral (PF) OA is (Fig. 13.1) present according to different series between 4.6% in people over 55 years of age and 28% of the population over 65 years [2]. A degree of patellofemoral OA appears to be a normal consequence of ageing: a post-mortem study of 203 cadavers with a median age of 84 years reported at least grade II patellofemoral OA in 75.9% of cases [3].

Abnormal PF joint alignment and abnormal trochlear morphology (patella alta and patellar tilt), kinetic and kinematic abnormalities (quadriceps muscle size, strength and force), ACL (anterior cruciate ligament) ruptures and reconstruction, female gender, age and body mass index have shown to be risk factors for progression of PF cartilage deterioration [3].

Although partial or total knee replacement surgery provides an effective solution for severe OA, in the earlier stages, a range of nonsurgical interventions have been used for treatment of OA. These include lifestyle modifications, physical therapy and rehabilitation (see chapter 7), non-steroidal anti-inflammatory drugs and intra-articular (IA) injections. In this chapter we will discuss the injectable treatments available and the guidelines for their use.

Fig. 13.1 Patellofemoral (PF) osteoarthritis (OA). X -ray lateral view

13.2 Types of Intra-articular Injection

IA injections can be divided in several groups: corticosteroids (CS), hyaluronic acid (HA), platelet-rich plasma (PRP) and mesenchymal stem cells (MSCs).

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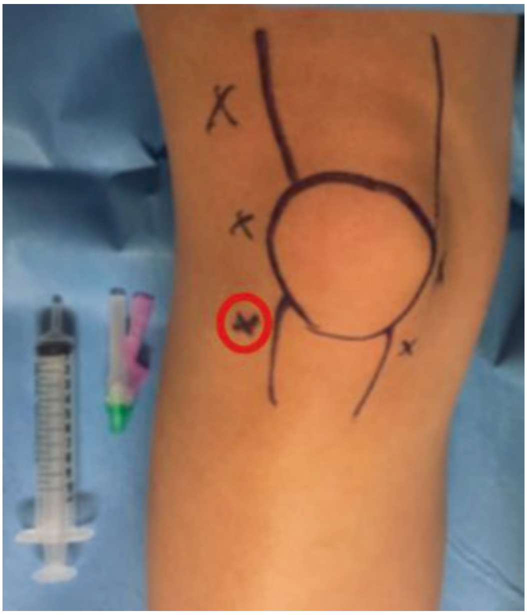

Fig. 13.2 Knee approaches for intra-articular injections

For all injections, injection technique is similar. The knee can be accessed through an anterolateral or superolateral approach without the need for ultrasonography (Fig. 13.2).

13.2.1 Corticosteroids

In the initial phase, OA of the knee is often associated with a painful inflammatory process. In these patients, IA corticosteroid can provide meaningful relief from pain for a variable period of time. The two most widely used preparations are crystalline triamcinolone, noncrystalline prednisolone and methylprednisolone. The mechanism of action is to inhibit peripheral phospholipase, which decreases the pain-aggravating products from the cyclooxygenase and lipoxygenase pathways.

Guidelines published by the American College of Rheumatology (ACR) and the Europe-based Osteoarthritis Research Society International (OARSI) have different recommendations for the use of IA corticosteroids. ACR guidelines include a weak recommendation in patients unresponsive to basic treatment (exercise programmes as well as weight loss), while OARSI recommends the use of IA corticosteroids, whatever the OA subtype and comorbidities [4, 5].

A Cochrane review on the topic, last updated in 2015, found that corticosteroids produced more effective pain relief compared to controls in patients with severe pain at 1–2 weeks postinjection; this effect had disappeared by 26 weeks. However most of the identified trials were considered small, and quality of evidence for the major outcomes was graded "low" [6]. No recommendation is given for one preparation of corticosteroid over any other in terms of efficacy or duration of effect.

A separate published meta-analysis and systematic review for knee OA incorporating more than 32,000 patients concludes that the effect of IA corticosteroids at 3 months is superior to the effect of intra-articular placebo, oral placebo and oral paracetamol [7]. Tian et al. [8] performed another meta-analysis of four randomised controlled trials (739 patients), reporting that intra-articular methylprednisolone injection was associated with improvements of pain and physical function in patients with knee OA. Additionally, no severe adverse effects were observed.

13.2.2 Hyaluronic Acid (HA)

Hyaluronate is a high molecular weight molecule present within the cartilage and synovial fluid. Its functions in the joint include lubrication, serving as a space-filler and assisting the regulation of cellular activities such as binding of proteins. Application of intra-articular hyaluronic acid purports to have two mechanisms of effect: firstly, improvements of load absorption through viscosupplementation and, secondly, promotion of formation of new endogenous hyaluronic acid. The strongest current evidence supports clinically important and significant treatment effects with intra-articular hyaluronic acid formulations between 1500 and > 6000 kDa [9].

The European Viscosupplementation Consensus Group (EUROVISCO) has published a set of recommendations to optimise the outcome of hyaluronic acid injections, in terms of patient selection, technique and formulation [10]. They suggest that the best results are obtained in patients with a BMI < 30, moderate arthritis (with a Kellgren and Lawrence score of III or less) with pain refractory to non-pharmacological therapies and non-steroidal anti-inflammatory drugs. They also recommended that poorer outcomes could be expected in cases of isolated patellofemoral OA compared to other patterns of arthritis [10]. It should be stressed that these recommendations are the result of a consensus meeting of 11 individual surgeons and are not based on evidence from high-quality clinical trials.

A retrospective study of over 50,000 patients has suggested that repeated injections of HA are safe and may be associated with decreased rates of total knee arthroplasty (TKA) at 3 years [11]. For the specific case of PF OA with patellar tilt (grade III–IV), Fosco et al. propose a protocol performing in 28 patients an arthroscopic lateral retinacular release followed by periodic or isolated infiltrations of HA within 1 month of the intervention with significant clinical improvement [12].

Several studies exist which compare the effects of HA with corticosteroid injection. Two meta-analyses have been performed. One was a non-inferiority study demonstrating similar outcomes for corticosteroid and HA in pain and function over 26 weeks [13]; the second reports a difference with corticosteroids being more effective in the short term (up to 1 month), while HA is more effective in the longer term (up to 6 months). The safety profile of each is similar, but there are more local adverse effects with HA [14].

A number of international bodies have published recommendations on whether HA should be used in OA. In the UK, the National Institute of Health and Care Excellence (NICE) recommended in 2014 that HA should not be used for patients with OA [15]. The American Academy of Orthopaedic Surgeons (AAOS) concurs, strongly recommending against the use of HA in osteoarthritis of the knee [16]. The European League Against Rheumatism suggests that HA can be effective in knee OA but confers little benefit over corticosteroid [17]; OARSI reported that there was not enough evidence to guide us either way [5].

13.2.3 Platelet-Rich Plasma (PRP)

Biological therapies based on PRP have gained popularity in recent years in the treatment of early stages of knee OA. IA injections with high concentrations of platelets in low volume have shown the release of mediators or growth factors (insulin growth factor-1 [IGF-1], platelet-derived growth factor [PDGF], epidermal growth factor [EGF], vascular EGF [VEGF], transforming growth factor-b [TGF-b], and others) that can participate in tissue regeneration.

There are few high-quality prospective randomised studies to guide us in the use of PRP in knee OA. There is little consensus regarding the volume injected, preparation time and temporal sequence of its application (Fig. 13.3). One randomised trial demonstrated superiority of PRP over placebo, with no difference between one and two doses of PRP; however, the statistical analysis in this study has been questioned [18]. A meta-analysis of clinical and non-clinical studies suggests that PRP may be effective—basic science studies support the claim that it improves the environment within the joint—but what clinical evidence there is suggests only a short-term benefit if any [19]. More guidance will be provided by the placebo-controlled RESTORE trial for which the protocol has recently been published [20].

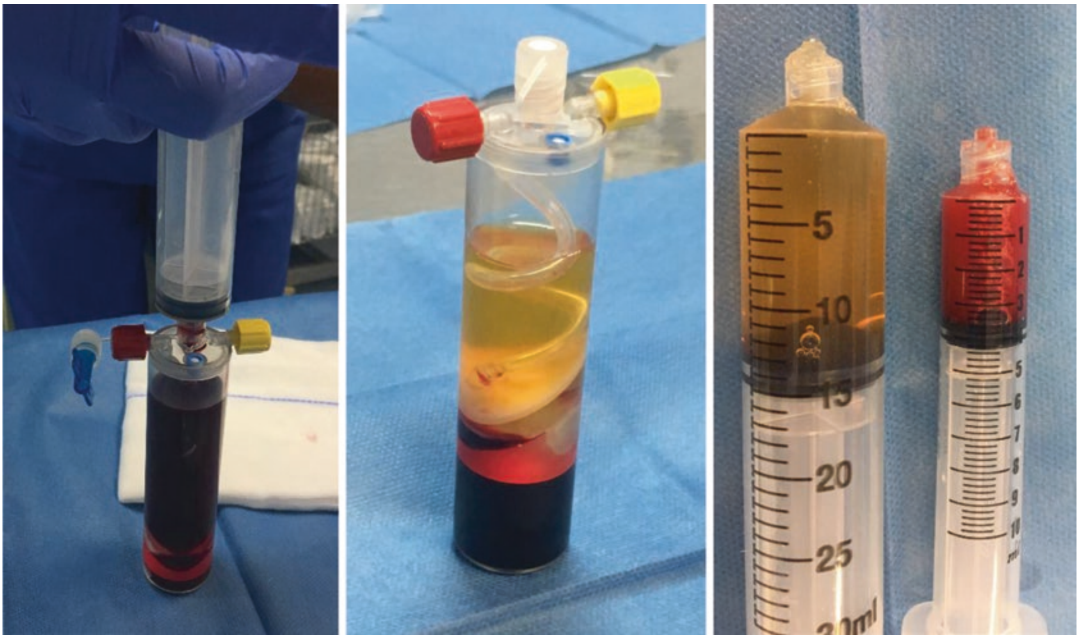

Fig. 13.3 PRPs Kit-30 mL blood extraction. From left to right: platelet poor plasma, platelets and white blood cells (buffy coat), red blood cells

Comparison of HA with PRP again gives uncertain results, with little evidence of superiority of either technique overall [21]. Some patient groups, such as more active patients with milder degrees of OA appear to benefit more from PRP compared to HA, but again there are few studies to support this [22]. Again, PRP appears to be less successful in isolated patellofemoral OA than in tibiofemoral disease [23].

13.2.4 Bone Marrow Aspirate Concentrates-Mesenchymal Stem Cells (MSCs)

Mesenchymal stem cells (MSCs) are becoming more popular in the treatment of early OA. MSCs can differentiate into the muscle, bone and cartilage and have a theoretical benefit in cartilage repair in early OA.

MSCs are present at several locations, including bone marrow, muscle, synovium, periosteum and adipose tissue. Adipose-derived mesenchymal stem cells (ADSCs) are attractive as they are plentiful and accessible. ADSCs are usually harvested from the buttock or abdomen; following centrifugation the stromal vascular fraction (SVF) is used for injection [24]. Most of the evidence for the use of ADSCs is in the form of small case series; a recent systematic review reported the results of six non-randomised comparative studies, totalling 250 patients. Two studies compared ADSCs to PRP finding no significant difference between the interventions; two compared different preparations of ADSC and two compared ADSCs to placebo controls, with both finding significantly better results in terms of pain and function in the ADSC group [24]. Similarly, for bone marrow-derived MSCs, there is little high-quality evidence available [25], with the studies that there are found to be at high risk of bias [26]. There is a need for further high-quality studies before the use of injectable MSCs can be recommended in OA [27].

13.3 Conclusions

The use of IA therapies for OA of the knee remains controversial. Despite the development of new biological therapies (for instance, PRP and MSCs), there is little high-quality evidence to recommend their use. It is necessary to generate protocols and clinical guidelines that guarantee their correct use as well as studies with a higher level of scientific evidence. Efforts should be made to identify the characteristics of and selection criteria for the OA population likely to benefit from these therapies. The best evidence base exists for the use of corticosteroid and HA, although the effect in terms of relief of symptoms and functional recovery is only temporary and depends upon the degree of OA present. For all injectable therapies, PF OA predicts inferior clinical results compared to patients with tibiofemoral OA.

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14 Patellofemoral Osteoarthritis: Partial Lateral Patellar Facetectomy

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14.1 Introduction

Patellofemoral osteoarthritis (OA) is a relatively common problem, afflicting up to 24% of women and 11% of men over the age of 50 years who have painful patellofemoral OA [1]. Isolated OA of the patellofemoral joint happens in 9% of patients over 40 years of age [2]. Mild isolated patellofemoral OA has been also associated with pain, stiffness, and functional restriction [3]. A range of treatment strategies exist with varying degrees of evidence base [2–4]. Conservative treatment, including patellar bracing [5], physical therapy [6, 7], and intra-articular injections of corticosteroids [8, 9] and hyaluronic acid [9], has been shown to be effective in early osteoarthritis; however, a large proportion of patients with the condition eventually require surgery [10]. Although isolated patellofemoral OA can impact on any or both of the patellar facets (medial and/or lateral), up to 89% of all isolated patellofemoral cases involve the lateral facet [11].

Isolated patellofemoral OA can have a significant effect on activities of daily living, chiefly anterior knee pain during ambulation and stair climbing [12, 13]. Patients who have failed conservative management and who still have significant symptoms may require surgical interventions including either patellofemoral arthroplasty (PFA) or total knee arthroplasty (TKA) [14]. In a proportion of cases with isolated lateral facet OA, partial lateral facetectomy has been used as an alternative to arthroplasty.

This chapter reviews current indications and results of partial lateral patellar facetectomy in isolated patellofemoral OA.

14.2 Principles and Indications

Partial lateral patellar facetectomy involves the resection of the lateral part of the patella with its osteophytes with the aim of reducing contact pressures by way of decreasing the tension in the lateral retinaculum [15]. It is indicated in isolated end-stage symptomatic patellofemoral OA associated with lateralization of the patella and development of lateral osteophytes creating an overhang over the lateral femoral condyle [10, 16, 17]. In cases where there is erosion of the lateral facet, rendering PFA difficult, there is a particularly strong indication [17].

Partial lateral facetectomy can be performed open or using arthroscopic techniques (Fig. 14.1) [10].

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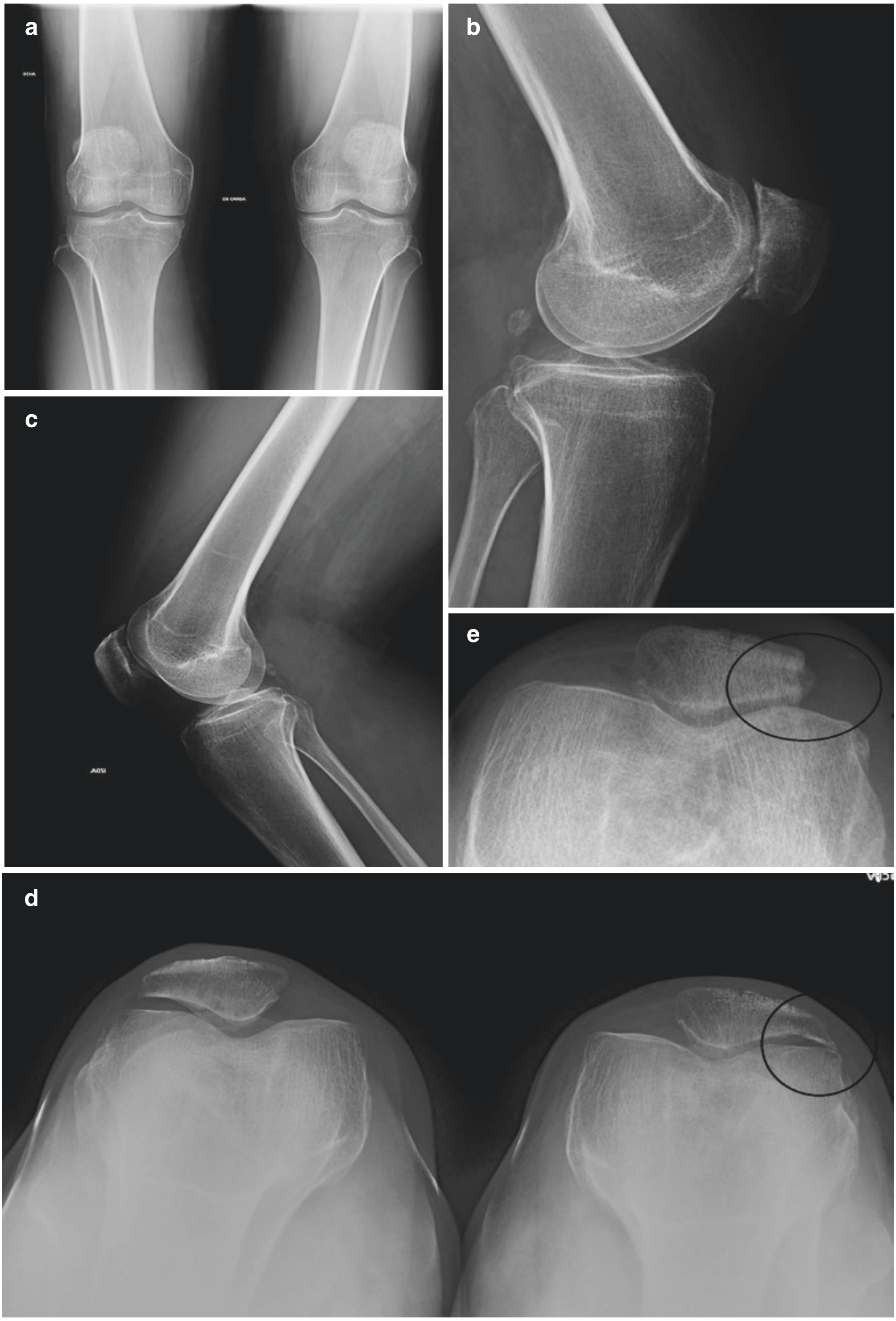

Fig. 14.1 (**a**–**e**) Radiographs of a 51-year old male with isolated patellofemoral osteoarthritis. The patient had anterolateral knee pain in his right knee that did not respond to conservative treatment. Partial lateral patellar facetectomy by open surgery was indicated: (**a**) Anteroposterior radiograph of both knees. (**b**) Lateral view of the right knee. (**c**) Lateral radiograph of the left knee. (**d**) Skyline view of both knees. Note patellofemoral osteoarthritis predominantly at the lateral patellar facet of the right knee (circle). (**e**) Skyline view of the right knee after partial lateral patellar facetectomy (circle). (**f**) Skyline view of both knees 2 years after partial lateral patellar facetectomy of the right knee

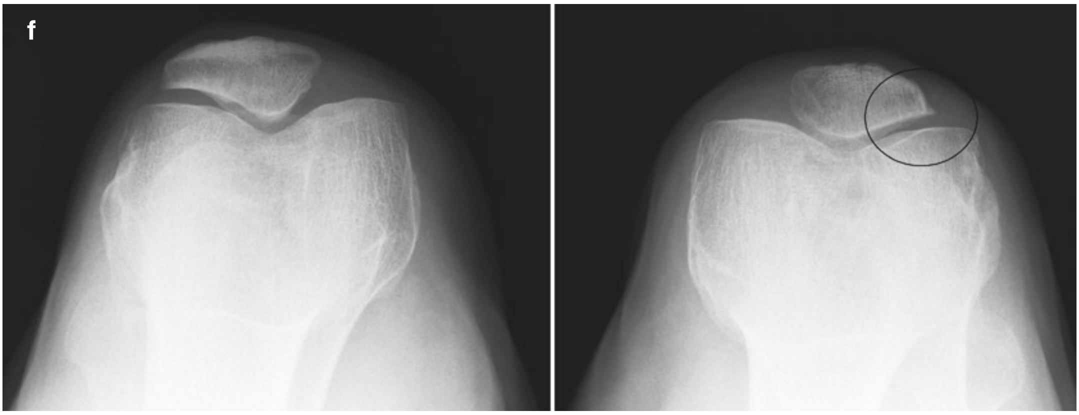

Fig. 14.1 (continued)

14.3 Results of Lateral Patellar Facetectomy

14.3.1 Isolated Partial Lateral Facet Patellectomy

A number of studies exist demonstrating the outcomes of isolated partial lateral facetectomy. A review of these outcome studies in 2014 reported that the overall quality of evidence was poor, but that overall the rate of failure and conversion to arthroplasty was substantial at around 26% at 10 years [18].

In the largest study of functional outcomes of partial lateral facetectomy, Wetzels and Bellemans analyzed 155 consecutive patients (168 knees) at a mean follow-up of 11 years [17]. Again, a high rate of failure was reported with 62/168 knees undergoing conversion to TKA (60 cases), PFA (one case), or patellectomy (one case) during the study period, with reoperations occurring at a mean of 8 years following the index surgery. Overall survival was given as 85% at 5 years, 67.2% at 10 years, and 46.7% at 20 years, respectively. However, functional outcomes of surviving knees were satisfactory with 79/106 unrevised knees (74.5%) being rated as either good or fair. Overall, around 50% of patients were unrevised with good or fair outcomes, suggesting that, as a simple intervention, it was a reasonable management strategy, particularly in elderly low-demand individuals [17].

Other, smaller studies support the findings of the Wetzels study. Paulos et al. report the outcomes of 66 knees undergoing lateral release and partial lateral facetectomy reporting an improvement in mean Kujala score from 45.6 to 72.0 [19]. Fifty-six percent of patients were satisfied and 9/66 went on to be revised to TKA. Martens and De Rycke reported good to moderate outcomes in 18/20 patients undergoing lateral facetectomy at 2 years, with the poor outcomes being attributed to advanced tibiofemoral OA [16]. They reported the advantages of the procedure being the promise of significant functional improvement with minimal risks and faster recovery compared to arthroplasty alternatives and without compromising the ability to perform further arthroplasty procedures [16], a stance supported by the Yerkan's study of 11 patients [20].

Lopez-Franco et al. reported the outcomes of a retrospective, long-term study of 39 knees (28 females, mean age at surgery 61 years old) with a minimum follow-up of 10 years [21]. A significant proportion (33/39) reported significant pain relief; the mean Knee Society function score increased from 71.4 points to 83.6 points following surgery. There were no significant complications. The authors concluded that the surgical technique was minimally invasive, relatively simple, and effective in selected patients. Therefore they stated that it was a valid early option to more complex surgical procedures and did not preclude further reconstructive surgery in case of disease worsening [21].

No study has been undertaken to compare arthroscopic to open techniques of partial lateral facetectomy, but the arthroscopic studies of Ferrari et al. [10] and Paulos et al. [19] report that the advantage of the arthroscopic technique is that it allows assessment and management of other concurrent joint problems as well as being less invasive than open surgery.

14.3.2 Partial Lateral Facet Patellectomy with Patellar Realignment

In addition to Paulos's study of combined lateral release and partial lateral facetectomy, partial lateral facetectomy has been described in combination with tibial tubercle osteotomy and soft tissue realignment procedures.

Becker et al. report a retrospective series of 50 patients (51 knees) with isolated patellofemoral OA treated with partial lateral facetectomy, lateral release, and medialization of the tibial tubercle [4]. The results were only given in the short term, with a minimum follow-up of 7 months (mean, 20.2 months; range, 7–32 months). Most patients reported an improvement in their patellofemoral pain, but the authors noted that the results of their study were no better than previous results of isolated partial lateral facetectomy. In addition, the addition of tuberosity realignment may compromise subsequent arthroplasty. On the basis of their results, they do not recommend the combined procedure [4].

Monserat et al. have reported their outcomes of combined partial lateral facetectomy and soft tissue reconstruction using Insall's procedure in two separate studies [22, 23]. In the first, the authors report the outcome of 87 cases, 43 of which had long-term follow-up of between 10 and 14 years [22]. Failure, classed as revision to arthroplasty, occurred in 26.4% at a mean of 9.2 years post-op. Of those 43 surviving at between 10 and 14 years, substantial and enduring pain relief was achieved [22].

In the second study, a survival analysis is performed for all 87 patients with identification of risk factors for failure. At 13 years (the time of the last failure), the cumulative survival was 59.3%. The survival figure was similar to that reported by other studies of isolated partial lateral facetectomy. Significant risk factors for failure were baseline medial tibiofemoral pain, fixed flexion deformity, and the presence of tibiofemoral OA. Higher preoperative Knee Society scores, the absence of a joint effusion, a higher Caton-Deschamps index, and lateral position of the patella were found to protect against failure [23].

14.4 Conclusions

A satisfactory outcome after partial lateral patellar facetectomy for isolated patellofemoral OA can be expected in about half of the cases at 10 years follow-up. Partial lateral patellar facetectomy, being minimally invasive, relatively simple, and effective in selected patients, is a valid early option to more complex surgical procedures and does not preclude arthroplasty if failure of symptomatic relief occurs. Because of the minor surgery and quick recovery, this operation presents a valid alternative to more complex operations such as patellofemoral arthroplasty (PFA).

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15 Patellofemoral Osteoarthritis: Patellofemoral Arthroplasty

Farhad Iranpour, Arash Aframian, and Justin P. Cobb

15.1 Introduction

The reported prevalence of patellofemoral joint (PFJ) arthritis of knee varies widely, with one systematic review reporting 25% in population-based cohorts, rising to 39% in the symptom-based cohorts [1]. Isolated PFJ osteoarthritis (OA) is present in 32–36% of radiographs in those age over 60 years old with knee pain [2]; isolated patellofemoral OA has been shown to be more common than isolated tibiofemoral OA [3, 4]. Detection and reporting rates of PFJ OA vary more in magnetic resonance imaging (MRI) studies with no universally agreed MRI definition for PFJ OA. The overall presence of isolated PFJ OA in a recent radiographic meta-analysis was reported as 7% in population-based studies, rising to 19% in symptomatic (knee pain) populations [5]. This paper also demonstrated that there was more evidence of medial than lateral facet PFJ OA and that it was seen more commonly in men than in women in both symptomatic and asymptomatic groups. The presence of OA, with or without symptoms, in the PFJ appears to be an almost universal occurrence with ageing: a survey of 100 necropsy examinations revealed that patellofemoral arthritis was seen in 79% of cadaveric specimens (average age 65 years old) [6]. PFJ pain is significantly more common in women and is normally bilateral (reflecting the main aetiological factors, dysplasia and/or instability), with unilateral cases usually being the result of trauma [7].

Operative treatment options for isolated patellofemoral arthritis include arthroscopic debridement, lateral release, partial lateral facetectomy, patellectomy and osteotomies, which are covered in other parts of this book. Arthroplasty options are total knee replacement and patellofemoral joint replacement, the latter of which we discuss in detail here.

15.2 Indications for Patellofemoral Arthroplasty

The indications for patellofemoral arthroplasty (PFA) are particularly important given the complex nature of the PFJ and lack of full understanding of variations in knee biomechanics. As with any unicompartmental surgery, it is important to confirm that there is isolated noninflammatory PFJ arthrosis. The patients report pain affecting

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activities of daily living and a decline in quality of life, typically with activities that involve knee flexion or squatting (e.g. getting out of a chair or stair activity).

As with any surgery, the importance of keeping the indications in mind is reflected in the reasons for revision—the outcomes recorded in the National Joint Registry are discussed separately later in this chapter. For most patients, a trial of unsuccessful conservative management with physiotherapy should have been attempted first. Some surgeons also prefer to give local anaesthetic/corticosteroid injections as both diagnostic and therapeutic interventions (the knee joint being confirmed as the causative factor if an injection of local anaesthetic immediately relieves the pain, albeit temporarily, with or without lasting benefit from the steroid injection). The caveats to this being cellular studies showing negative effects of local anaesthetic on chondrocytes [8] and concerns about the risk of infection associated with steroid injections prior to arthroplasty—it has been suggested that beyond 3 months, this is likely to be negligible [9] although a recent systematic review found limited evidence for this, with some publications reporting no significant differences in infection rates at all [10].

Significant malalignment or instability is unlikely to be resolved with a standard PFA alone, and further consideration needs to be given to address these factors prior to or at the same time as the PFA. Patients with obesity should be advised as part of preoperative counselling that some studies have shown that they are at particular risk for dissatisfaction and higher rates of revision surgery [11, 12].

The group who have the lowest levels of progression to tibiofemoral arthritis and therefore the lowest risk of revision from PFJ arthroplasty are those patients with preoperative trochlear dysplasia [13] and isolated PFJ noninflammatory arthrosis. The newer generation PFA designs means that they can also be used for the treatment of patellofemoral instability along with stabilisation measures such as medial patellofemoral ligament reconstruction [14] and outcomes for these patients may even be better than in isolated PFJ arthrosis [15, 16].

15.3 The History and Development of Patellofemoral Arthroplasty

The origins of patellofemoral surgery can be dated back to at least the end of the nineteenth century, when surgeons reported on the use of interposition arthroplasty with sheets of various materials (including glass, magnesium, aluminium, tin, nickel, celluloid, rubber and ebonite, a form of vulcanised rubber) in the patellofemoral space to relieve patients from ankylosis [17]. In 1955 McKeever reported on his use of a patellar prosthesis made from Vitallium (cobalt-chromium-molybdenum alloy) [18].

First-generation devices utilised inlay implants set ‘into’ the native trochlea, relying on a standard shape to suit all patients. The implants did not match the normal anatomy of the trochlea creating mismatch with the rest of the trochlea surface especially in patients with trochlear dysplasia. A short anterior flange, narrow width and highly constrained trochlear groove resulted in maltracking, component malpositioning and excessive wear leading to high rates of failure and reoperation [19–23]. Examples of this generation of implants include Richards II (Richards, Memphis, TN, USA), Lubinus (Waldemar Link, Hamburg, Germany), Autocentric (Depuy, Warsaw, Indiana) and LCS (Depuy, Warsaw, Indiana).

Second-generation devices built on the findings from their predecessors and are mainly onlay designs. The onlay designs replace the whole of the anterior surface of the trochlea, with instrument jigs providing cuts similar to TKA surgery with the PFJ implants set ‘onto’ the anterior femur. These wider implants which also expand more proximally than the native trochlea reduced many of the previous issues with trochlea surface mismatch and maltracking seen with the first-generation inlay implants. Surgeons can choose to increase the external rotation of the trochlear implant with the anterior cut to improve patellar tracking within the constraints of providing a smooth transition between the implant and native trochlea for stable patellar tracking.

Second-generation designs can be divided into two major groups based on the position of the trochlear groove. Designs with a symmetrical trochlear groove include Avon (Stryker, Newbury, UK), FPV (Wright Medical Technology, Arlington, TN, USA) and Natural Knee II (Zimmer, Warsaw, IN, USA). The group with an asymmetric trochlea include the Journey (Smith & Nephew, Andover, MA, USA), Vanguard (Biomet, Warsaw, IN, USA), Hermes (Ceravor, Roissy-en-France, France) and Gender Solutions (Zimmer, Warsaw, IN, USA). A more anatomical, asymmetric trochlear groove aims to improve patella tracking and lateral stability with an elevated lateral flange [24].

The second generation of implants have better instrumentation, allowing more reproducible surgical outcomes, which are more adaptable to each patient's specific needs and account for the improvements in surgery and therefore patient (as well as surgeon) satisfaction.

15.4 Surgical Considerations

Examination of the trochlear profile of total knee arthroplasty (TKA) implants shows that they do not match the native knee geometry in either mechanically or kinematically aligned knees [25]. Although TKA implants have been used for isolated PFJ arthrosis with good midterm results, these are complex cases with high rates of malalignment requiring formal correction procedures [26]. This is also true with specifically designed patellofemoral joint implants with lateral and medial trochlea under- and over-stuffing, respectively. This is more prominent in symmetrical designs.

Research performed at the Musculoskeletal (MSK) lab at Imperial College, London, has shown that using a 3D PFA planner to achieve near normal geometry resulted in variable alignment measurements (Fig. 15.1) [27].

Given that PFA is a relatively bone-conserving procedure, revision often results in a primary TKA without the need for stems or augments. Functional outcomes and revision rates are poorer compared to a primary TKA, however this might be partly due to selection bias and also higher rate of infection [28]. PFA has the benefit over TKA in that it offers an alternative with preservation of ligaments and bones, and hence restoring a more normal kinematic profile.

15.5 Current Practice

According to the latest (15th) National Joint Registry (NJR) report of over 1 million knee replacement operations, patients for patellofemoral arthroplasty were typically 12 years younger (median 58, interquartile range 50–67 years old) than those having TKA, with PFA forming 1.2% of the total number of reported knee arthroplasty operations reported within the registry, down from a peak of 1.5% a decade ago [29]. Given that the meta-analyses revealed a prevalence of PFJ OA in men, it is intriguing that they form only 22.5% of the patients having PJF arthroplasty in the registry dataset, who are younger than not only TKA but even in comparison to medial and lateral unicompartmental knee arthroplasty (UKA) patients. The proportionately smaller rates of PFJ replacement compared to other implant types is likely also related to the higher revision rates, being higher than TKA and UKA at every reported milestone (1, 3, 5, 10, 12 and 14 years postoperatively), with 14-year cumulative revision rates of 24.4% for PFJ replacement, compared to 16.9% for UKA and 4.5–5.6% for different TKA fixations in the NJR dataset. When gender and age are included in the NJR analysis, this rises to 24.1% revision rate at 10 years for men compared to 17.6% for women aged 55–64 years old at time of primary surgery; 18.9% and 17.7%, respectively, when aged 64–75 years old; and 7.4% and 9.7%, respectively, for those aged >75 years at time of primary surgery. There is acknowledgement however that some of these values rely on smaller numbers (less than 250 cases) in all but one subgroup. Brands are listed individually in the NJR if more than 1000 have been implanted; there are five brands with this level of use. Of the five, four have been used between 1300 and 2100 times, with the fifth, the most popular implant, being used in more than 5000 cases. This implant, the

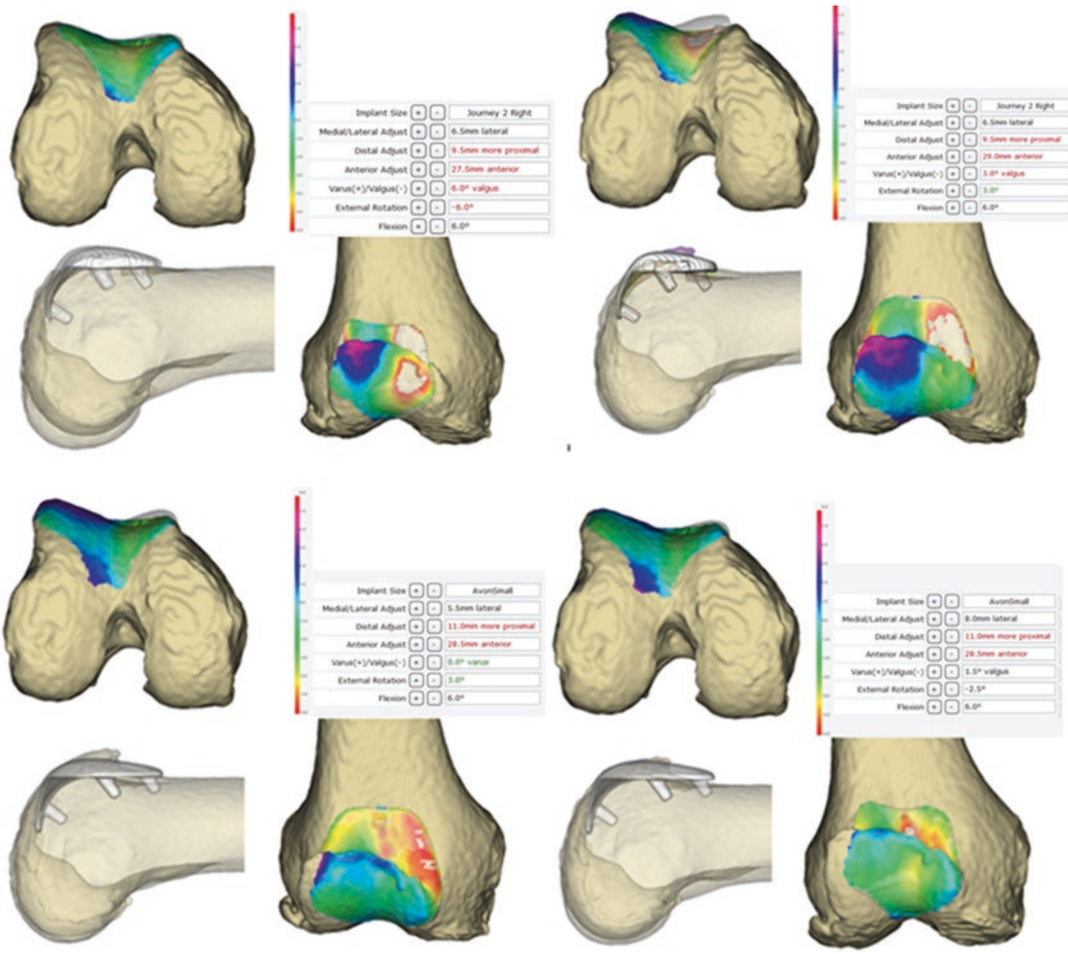

Fig. 15.1 Patellofemoral planning using Avon and Journey implants using two different methods: 1) based on the manufacturers surgical technique 2) to achieve best match with the trochlear surface

Avon PFJ, has the longest track record in the NJR with 14 years of outcome data and at nearly all time points has equivalent or lower revision rates than other products in the report.

The designers of the Avon have recently published their long-term results for this implant in 558 cases, quoting a rate of implant survival of 77.3% (95% CI 72.4 to 81.7) at 10 years and a mean Oxford Knee Score (OKS) of 35 at latest follow-up. Most revisions (58% of the total) were for progression of arthritis to the tibiofemoral joint [30]. An independent series of 103 Avon PFAs supported these findings, with a 5-year survival of 89% and a mean OKS of 36 [31].

The main reasons for revision in the NJR are implant wear, instability, malalignment and 'other indication' with the latter being the most commonly cited reason accounting for over one third of cases. Perhaps because the NJR is not designed around compartmental joint replacement, no data is given for progression of arthritis in other compartments, so this would seem likely (particularly in light of the data from published series) to form a large part of the 'other indication' group (and perhaps some of those listed as 'implant wear'). When compared to revised TKAs and UKAs, the rates of re-revision for PFJ arthroplasty were lower at all time points [29].

15.6 The Future of Patellofemoral Arthroplasty

Both patient-specific implants [32] and patient-specific instruments [27] have been used to improve the design of implants and tools, respectively, to match individual patient needs. Newer-generation customised prostheses such as the KineMatch custom PFR (Kinamed, Camarillo, USA) have pushed these boundaries further, and when the operation can be delivered reliably and repeatably, some results reveal a marked reduction in revision rates with few failing—there are reports of 100% midterm survivorship (range 2.7–9.9 years) although long-term results are still awaited [16].

Computer navigation and robotic surgery have also been used to more reliably deliver the preoperative surgical plan, using computed tomography (CT) scans with which the surgeon can plan the operation [33] with improvements in component alignment. Although implant design and positioning are important as extensor mechanism malalignment and patella maltracking are present in a high majority of these patients, there is need for intraoperative assessment of patellofemoral tracking and contact patterns.

15.7 Conclusion

Only 60 years ago, Waldius stated that there was little place for arthroplasty of any kind in the knee, where arthrodesis should be preferred: 'The knee was found to be the joint in which it was exceedingly difficult to achieve successful arthroplasty, owing to its complicated structure and the great mechanical stress to which it is exposed' [17].

In the patellofemoral joint, increased understanding of indications for surgery (in particular, focussing on those with risk factors for isolated patellofemoral arthritis such as dysplasia and maltracking and avoiding those with tibiofemoral osteoarthritis), together with improvements in implants and instrumentation, will improve the results of surgery. Improvements in the functional outcomes and revision rate of PFA will allow the advantages of partial knee replacement (including more normal kinematics and a lower rate of early complications) [34] to be extended to those with isolated patellofemoral disease.

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Patellectomy in Patellofemoral Joint Problems

16

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16.1 Introduction and History

Patellectomy is a radical procedure reserved for extreme cases. It is a palliative procedure that should only be used when the patella cannot be salvaged [1]. While it was previously most often employed for the treatment of highly comminuted patellar fractures, in recent years, due to the high number of total knee arthroplasties (TKA) performed, it is more common for the treatment of large patellar defects [2]. Other indications include infection and tumors [3].

Historically, the role of the patella in knee function has been a subject of controversy [4, 5]. In his classic 1937 paper, Brooke [5] concluded that patella was almost unnecessary for the knee function and that it can be released if needed. Other luminaries of the time including Ernest Hey Groves and Reginald Watson-Jones considered the patella to inhibit quadriceps function and declared that the function of the knee could be improved by patellectomy. As a result, patellectomy becomes more and more widely used, especially given the absence of sophisticated reconstructive techniques for patellar fracture. In the 1970s, accelerated tibiofemoral degenerative changes were described after patellectomy, and the use of this technique decreased [6, 7]. Accelerated wear occurs due to the excessive force (up to 15% to 30% extra) applied at the knee joint to achieve full extension when the patella is absent [8]. As a result, in contemporary practice, patellectomy is considered to be the last resort for the treatment of patellar problems.

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16.2 Physiological Consequences of Patellectomy

The patella is essential to optimize the action of the quadriceps in knee extension. In a study lead by Kaufer [8], forces needed for full extension of the knee after patellectomy increase up to 30%. This is well tolerated in patients with no concurrent problems (as was usually the case when patellectomy was performed as a primary treatment for patellar trauma). However, when an extensor lag is present preoperatively or in elderly patients with reduced muscle mass, the loss of the fulcrum provided by the patella will lead to failure of the quadriceps to extend the knee.

The patella confers a mechanical advantage by producing anterior displacement of the extensor mechanism (quadriceps tendon-patella-patellar tendon). It increases the lever arm of the quadriceps, optimizing its function. It also displaces the tendons away from the tibia and femur, allowing free tracking of the tendons, avoiding impingement and abrasion against distal femur and proximal tibial surfaces. This abrasion may

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result in tears, deformities, and thinning of the tendon [3, 9]. As a consequence of the changes in knee biomechanics, menisci and cruciate ligaments are also in risk of injury [10]. Without an overlying patella, the trochlear cartilage is also more exposed to direct injuries.

16.3 Surgical Techniques

Many techniques of patellectomy have been described [7, 10]. There is a lack of evidence to guide which is superior, given the small numbers which are performed in current practice [2, 3]. Randomized controlled studies comparing techniques are absent.

The classical technique of patellectomy was described by West and Soto-Hall in 1958 [11]. They describe 24 patellectomies in 20 patients, performed either for recurrent dislocation of the patella or patellofemoral osteoarthritis; the oldest patient was 62 years of age, the youngest 11. After a transverse skin incision (in modern practice, a midline longitudinal incision would be used), a transverse incision is made in the extensor mechanism which is then dissected off the patella. The remaining tendon is double breasted, and the vastus medialis obliquus advanced toward the suture line.

After resection of the patella, the defect in the extensor mechanism can be repaired in a transverse or longitudinal fashion. Kaufer's, in a cadaveric study of patellar physiology [8], compared longitudinal to transverse repair. Transverse repair has the effect of shortening the extensor mechanism, conferring a mechanical advantage over longitudinal repair. While a transverse repair increases the force to achieve full extension by 15%, forces up to 30% of increase are needed for full extension in longitudinal repair. However, transverse repair has disadvantages. In transverse repair, the suture line is under greater tension, and therefore, a prolonged period of immobilization is needed to protect the repair. For this reason and secondary to the creation of an iatrogenic contracture of the extensor mechanism, patients may fail to achieve preoperative levels of knee flexion, and function may be poorer overall.

Following repair, various techniques have been proposed to reinforce the extensor mechanism. Advancement of parts of the quadriceps muscle through the patellar defect improves cosmesis and confers protection to the trochlear cartilage; it may also limit anterior instability and avoid lateral subluxation of the tendon [11] (Fig. 16.1). Either vastus medialis, vastus lateralis or both can be advanced to fill the patellar defect [11, 12].

16.4 Results of Patellectomy

A systematic review of 31 studies of the outcome of patellectomy was reported by Cavaignac et al. [1]. A total of 1416 knees were included, with the principal indications being chondromalacia (486 knees, 34%), fracture (443 knees, 31%), and osteoarthritis (297 knees, 21%). Comparisons were performed between longitudinal and transverse incisions and between patients with and without reinforcement of the extensor mechanism. The relative obsolescence of patellectomy is demonstrated by the age of the included papers, which ranged from 5 to 76 years old at the time of publication, with a mean age of 34 years.

Overall, at a mean follow-up of 7 years (range, 2–20), good or excellent results were reported in 68.8% of patients. Results were better with reconstruction than without (following reconstruction, good to excellent results were reported in 85%); there was a trend to better function in those with a longitudinal incision, but this was not statistically significant. A high overall rate of complications was reported (20%) with the main complications being calcification, tibiofemoral osteoarthritis, and stiffness. Complications were lower in patients who had undergone reconstruction and those who had a longitudinal incision. Revision was necessary in 3.7%.

While reasonable long-term survival can be expected following TKA in patients who had previously undergone patellectomy [13], these results are inferior to patients undergoing TKA with an intact patella. A meta-analysis of seven studies reported three times more excellent or good outcomes in patients with an intact patella

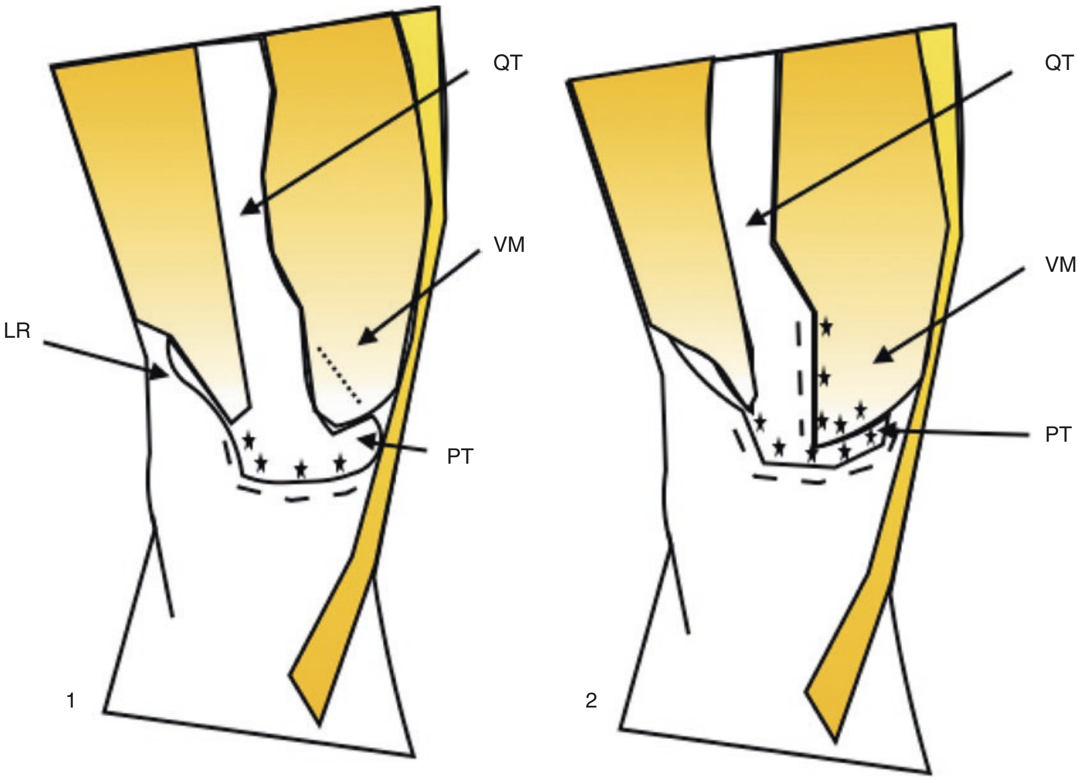

Fig. 16.1 West and Soto-Hall surgical technique of patellectomy. (*1*) First part of the procedure; (*2*) Second part of the procedure. *LR* lateral release, *QT* quadriceps tendon, *VM* vastus medialis, *PT* patellar tendon

and double the risk of complications in patients with a previous patellectomy, with the main complication being instability [14].

16.5 Conclusion

Patellectomy is a palliative procedure that should only be used when the patella cannot be salvaged. However, when performed for the correct indications and when performed in conjunction with reconstruction of the extensor mechanism, it can produce satisfactory results, at least in the short term.

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