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Controversies and Techniques in the Surgical Management of Patellofemoral Arthritis

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An Instructional Course Lecture, American Academy of Orthopaedic Surgeons

The patellofemoral joint is a complex articulation that remains a relatively uncommon topic in the orthopaedic literature. Most studies have been of cadavers, and there have been very few in vivo or clinical measurements. The relative lack of interest in the patellofemoral joint is surprising given the fact that patellofemoral symptoms are relatively common and can be extremely debilitating.

Abnormal mechanics of the patellofemoral articulation lead to abnormal pressures on the articular surface, pain, cartilage breakdown, and severe functional limitations secondary to anterior knee pain. An understanding of basic concepts regarding patellofemoral joint kinematics, forces, and contact patterns will enhance the surgeon’s understanding of the progression of patellofemoral arthritis. Furthermore, this understanding should ultimately allow the surgeon to choose the appropriate option for each stage of patellofemoral disease.

Anatomic Considerations

The patellofemoral joint comprises the patella, the femoral condyles, and the trochlear groove. The patella is a sesamoid bone that acts to redirect the forces of the quadriceps to the distal part of the femur, functioning as a lever arm to increase the efficiency of the extensor mechanism. The femoral condyles have a dual articulation with the medial and lateral facets of the patella. Additionally, almost 75% of people have a third articulating facet on the medial ridge of the patella that articulates with the medial femoral condyle after 120° of flexion. The ridge of the lateral condyle is more prominent than the medial ridge on lateral radiographs of the knee. A deficient lateral condyle may be appreciated on lateral radiographs and may contribute to patellar instability. Between the condyles is the central sulcus, or trochlear groove. The quadriceps and the patellar tendon have a balanced, blended insertion and origin on the patella and generate the majority of forces acting on the patella.

The flexion-extension pathway of the patellofemoral joint is a complex and dynamic cycle. In full extension, the patella does not come into contact with the trochlear groove. As knee flexion is initiated, the inferior pole comes into contact with the trochlea. As knee flexion continues from 0° to 90°, the area of patellofemoral contact moves proximally on the patella, from the inferior pole toward the central portion, and finally toward the superior pole. At 90° of flexion, only the superior region of the patella is in contact with the distal aspect of the trochlear groove. After 120° of flexion, only the most medial and lateral aspects of the patella come into contact with the femoral condyles. The articular cartilage of the patella is the thickest of any in the body, an adaptation to the great pressures throughout the patellofemoral joint during knee flexion.

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Joint Forces
In early flexion, there is a small compressive force vector on the patellofemoral joint. As flexion increases, so do the compressive forces across the joint. The three major forces acting on the patella include (1) the pull of the quadriceps, (2) the tension in the patellar tendon, and (3) the joint reactive force of the patellofemoral joint. These forces must act through one point in the sagittal plane to be in equilibrium. Unlike a simple lever arm, the patella creates a changing fulcrum position for the quadriceps force. The patellar tendon force is therefore always less than the quadriceps force and is more pronounced in deep flexion. As detailed above, in early flexion this point is in the inferior pole of the patella and in deeper flexion this point moves to the superior pole. Estimates of the forces through the patella range from 1.5 times body weight at 30° of flexion to six times body weight at 90° of flexion. Some authors have suggested that contact between the quadriceps tendon and the distal part of the femur helps to dissipate contact forces after 90° of knee flexion.

Patellofemoral Contact Patterns
As the contact point of the patella migrates from the inferior pole in early flexion to the superior pole in deep flexion, the contact surface area increases. There is a steady increase in contact surface area from initial contact in early flexion to about 60°. There are mixed reports regarding the area of patellofemoral contact from 60° to 90°. After 90° of flexion, the reported amounts of contact area have varied, depending on individual anatomy, the amount of force applied by the quadriceps tendon, and the thickness of the articular cartilage. It should also be noted that the quadriceps tendon plays a large role in the transfer of load. Past 90° of flexion, the tendon transfers load to the trochlear groove of the femur, providing more contact as well.

History and Physical Examination of Patients with an Arthritic Patellofemoral Joint
Examination of a patient with anterior knee pain begins, like any other medical workup, with a thorough and detailed history. Gathering information such as the duration of discomfort, the location and quality of pain, provocative or palliative factors, and functional limitation is a key portion of the patient evaluation. The summation of these facts will give the orthopaedic surgeon important clues regarding the etiology and diagnosis of the knee pain. Patients with patellofemoral arthritis often present with anterior knee pain, which may radiate medially and/or posteriorly. The pain is often worse with prolonged flexion or when the patient is going downstairs. Knee catching, locking, or giving-way are less specific symptoms that may or may not represent pathological involvement of the patellofemoral joint. The subsequent physical examination will allow the examiner to more accurately differentiate between patellofemoral disorders and other derangements of the knee.

Physical examination of the knee, and particularly the patellofemoral joint, requires both static and dynamic assessment. It has been described as a three-part examination, consisting of standing, sitting, and supine assessments.

The initial examination begins with the patient standing. Assessment of the stance position and visual gait analysis are important. The axial alignment of the lower extremities should be noted, as abnormalities of the pelvis, femur, or tibia can result in patellofemoral disorders. At the knee, genu varum and valgum alter the mechanics of the patellofemoral articulation. Measurement of the Q angle provides a key piece of information in an evaluation of a patient with knee pain, especially when the patellofemoral articulation is the suspected culprit. Briefly, the Q angle is the angle between two lines, one drawn from the middle of the tibial tubercle to the patella and the other drawn from the patella to the anterior superior iliac spine. The normal Q angle ranges from 10° to 20°, but a number of variations have been described. Freeman described a normal Q angle of 10° to 20° in females and 8° to 10° in males. Aglietti et al. described a normal Q angle of 17° in females and 14° in males. Hughston believed that a Q angle of >10° in either gender was abnormal and should be corrected. Despite these variations, large deviations from these ranges are definitely considered relevant. An increased Q angle may lead to an increased valgus force on the patella. This may cause lateral patellar subluxation or tilt and increased compression of the lateral patellar facet. Pelvic geometry is also an important element in the examination, as a widened pelvis may increase the Q angle. The pelvic geometry in women differs slightly from that in men, as women tend to have a wider, gynecoid pelvis. Femoral anteversion may also cause increased knee valgus. This is indirectly indicated by the presence of an inward pointing, or “squinting,” patella. To ensure accurate examination of the patella, it is imperative that the patient’s feet be pointing forward and aligned. After observation of the axial alignment, gait is assessed. An antalgic, or painful, gait may cause a shortened stance phase of the affected lower limb. This confirms the side of the knee disorder. Limb-length inequality as well as varus or valgus thrust should also be noted if present. Lastly, the patient may be asked to squat and hold that position for a few seconds. This is the half-squat test, and if it recreates anterior knee pain it strongly suggests a patellofemoral etiology.

The second part of the assessment is performed with the patient seated with the legs over the side of the examination table. The lower limbs should be visually inspected first. Thigh muscle girth should be evaluated for bilateral symmetry. Atrophy of the vastus medialis muscles, evidenced by flattening, contributes to patellofemoral symptoms. The anatomic position of the patella should be carefully observed as it may give clues to the cause of pain. Patella alta, or superior displacement of the patella, is common in patients with
a patellofemoral disorder, particularly instability. The clinical finding of “grasshopper eyes,” in which the patellae are displaced proximally and are externally rotated has been described. Patella alta is radiographically confirmed with use of the Insall-Salvati ratio. Rotation al malalignment is assessed by observing the relationship of the superior patellar pole to the inferior patellar pole. Most commonly, the inferior pole is lateral to the superior pole, and deviations from this are important as they may suggest patellar maltracking. Skin depressions medial and lateral to the inferior pole of the patella are normal. Their absence can signify a knee effusion, suggesting an intra-articular disorder as opposed to a patellofemoral disorder. Palpation of the knee is performed next. The important structures to evaluate include the patellar margins, the femoral epicondyles, the tibiofemoral joint line, the Gerdy tubercle, and the fibular head. Tenderness in any one or a combination of these areas may suggest a pathological entity outside of the patellofemoral articulation.

The third portion of the examination requires the patient to lie supine. This position allows a number of tests to be performed to evaluate the forces acting on the patella. The patient is first asked to flex and extend the knee. Activation of the quadriceps complex permits visual recording of patellar tracking. Normally, in terminal extension, the patella lies laterally within the femoral sulcus. As the knee is flexed past 30°, the patella engages the middle of the femoral sulcus. Lateral subluxation of the patella in terminal extension is known as the “J sign.” As the knee is subsequently flexed and extended, the patella may appear to jump in and out of the femoral sulcus. Another test is the active quadriceps pull test, in which the knee is extended and the patient is asked to contract the quadriceps muscles. Normally, the patella tracks superiorly in a straight line; lateral deviation of the patella is considered abnormal. To perform the patellofemoral grind test, the examiner depresses the patella in the femoral sulcus and then asks the patient to contract the quadriceps. Pain elicited from this test may represent articular injury. To elicit the patellar apprehension sign of Fairbank, another indication of patellar instability, the patient is asked to flex the knee to 20° and the examiner then applies a laterally directed force on the patella. At this time, the patient may fear patellar dislocation and instinctively contract the quadriceps and extend the knee to guard against it. The passive patella glide test is performed by flexing the knee 20° to 30°. The examiner then visually divides the patella into three vertical segments, manually displaces the patella medially or laterally, and measures the degree of displacement. If the patella displaces more than three segments laterally, the medial retinaculum is probably incompetent. If the patella displaces less than one segment medially, the lateral retinaculum is tight. Both of these instances predispose the patient to lateral patellar subluxation and resultant pain. For the passive patellar tilt test, the examiner extends the patient’s knee and then lifts the lateral edge of the patella away from the lateral femoral condyle. Normally, the patella will lift off slightly from the lateral femoral condyle, representing a positive tilt angle. An inability to lift the patella represents a neutral or negative tilt angle and is consistent with a tight lateral retinaculum.

The physical examination of a patient with anterior knee pain is comprehensive and, when done correctly, can give valuable clues regarding the presence or absence of a patellofemoral disorder. The clues can then be used to determine whether further evaluation is needed.

Nonoperative Management of Patellofemoral Arthritis

Physical therapy that includes quadriceps strengthening has been the cornerstone of nonoperative management. The goal of any strengthening program is to improve the function of the limb while not overloading the damaged patellofemoral articulation. Recently improved understanding of more generalized therapy approaches has shifted focus away from just the patellofemoral joint to overall body balance and stability.

Stretching is a simple modality that may be beneficial in the management of patellofemoral arthritis. The goal of stretching is to restore passive soft-tissue balance of the patella. In most cases, the lateral tissues of the anterior aspect of the knee have become excessively tight. A directed patella-mobilization program focusing on releasing the lateral tissues surrounding the patella may help to decrease excessive pressure on the lateral facet. Although attempts at relaxation of the lateral tissues may ultimately prove unsuccessful, the low morbidity associated with patellar mobilization and capsular stretching makes its inclusion in nonoperative regimens simple.

Strengthening of the vastus medialis obliquus is a classic physical therapy modality for treatment of lateral patellar maltracking. Dysplasia of the vastus medialis obliquus has been reported in patients with problems due to excessive lateral patellar tracking. Most physical therapy regimens involve an attempt to selectively strengthen the vastus medialis obliquus to increase medially directed forces across the patella. Despite the association between dysplasia of the vastus medialis obliquus and patellar maltracking, the utility and success of selective strengthening of the vastus medialis obliquus have not been overwhelmingly supported by the current literature.

Physical therapy ideals have shifted away from a focus on local muscle control and joint function to a focus on limb control and body positioning. In that respect, so-called core strengthening is an excellent approach to the treatment of a patient with patellofemoral arthritis. Core strengthening focuses on abdominal muscle control, trunk balance, and limb control. Exercises designed to improve limb balance focus on the hip and the knee to maximize the efficiency of the limb. In this way, alignment and balance are improved, which hopefully leads to decreased pressures on the patello-
femoral articulation and improved function. One key benefit of using core-strengthening principles during rehabilitation is the avoidance of excessive repetitive strengthening exercises about the knee, which may exacerbate symptoms.

The patellar McConnell tape technique can be useful when excessive lateral patellar translation and tilt are part of the clinical presentation. This technique depends on having sufficient mobility remaining in the patellofemoral articulation to medialize the patella passively. A standard taping regimen requires understanding of the taping system, and the skin must be able to withstand multiple applications of adhesive tape.

Several braces have been designed to alleviate anterior knee pain emanating from the patellofemoral joint. Most braces are used in an attempt to drive the patella medially during the knee flexion cycle and offload the lateral facet. The success of these braces is variable and depends on the willingness of patients to reliably apply the brace each day. Some patients may also experience lessening of symptoms as a result of the heat retained by many neoprene knee braces. There are limited clinical data on patellofemoral bracing, but the easy application of such braces makes their use in a nonoperative approach reasonable.

The rigors of land-based therapy may aggravate the problems at the patellofemoral articulation, thereby reducing any potential benefits. In such cases, water exercises may prove helpful. Obese patients may benefit the most from water therapy programs, as joint forces are reduced during these exercise programs. Principles similar to those used during land-based therapy should be emphasized, including global core strengthening focusing on abdominal, hip, and knee balance.

When patellofemoral pain has elements of complex regional pain syndrome (hypersensitivity, burning pain, and pain at rest), aggressive pain management is recommended. Pertinent modalities include desensitization therapy, gabapentin (Neurontin) or pregabapentin (Lyrica), local application of a lidocaine patch, and formal consultation with a pain management specialist.

**Surgical Procedures**

**Role of Arthroscopy and Soft-Tissue Realignment**

**Arthroscopic Débridement**

When a patient presents with mechanical symptoms and a loose body is suspected or confirmed on imaging studies, an arthroscopic débridement may be warranted. A chondroplasty may also temporarily relieve discomfort and disability when patellofemoral arthritis is present and associated with swelling, crepitus, and synovitis. Removal of loose cartilage from the patella or femur may limit mechanical irritants as well. The surgeon must realize that these measures may have only temporary effects on symptoms and if underlying mechanical factors have contributed to the progression of the disease they will continue to contribute to the clinical progression of symptoms as well.

**Arthroscopic Lateral Retinacular Release**

This procedure is frequently utilized and is most effective for treatment of isolated lateral patellar tilt. When clinical and radiographic examinations confirm excessive lateral tilt, lateral facet arthritis may ensue (Fig. 1). Release of the lateral retinacular structures may decrease pressure on the lateral facet and decrease pain. The tight lateral retinaculum should be confirmed on physical examination and by radiographs in a patient for whom conservative measures have failed. The procedure may be useful in patients with lateral facet arthritis with lateral tilt but no subluxation.

When this procedure is performed, care should be taken not to release the tendinous portion of the vastus lateralis muscle from the suprolateral aspect of the patella. This may cause quadriceps weakness and dynamic imbalance. Release of the lateral structures may also improve tracking, but when performed in the face of malalignment the results are less reliable unless concurrent tightening of the medial retinacular structures is performed. Medial imbrication procedures are traditionally utilized for treatment of patellar maltracking, and they may not be appropriate in the face of arthritis of the patellofemoral joint. In the arthritic situation, a medial imbrication may increase forces on the medial facet of the patella and on the medial condyle and lead to overload of the medial aspect of the joint. Lateral release has not been shown to provide long-term benefit for patients with patellofemoral arthritis.

**Lateral Patellar Facetectomy**

In patients with long-standing patellofemoral disease, excessive lateral tilt and/or translation may lead to the formation of a large lateral osteophyte visible on the Merchant radiograph (Fig. 2). Some authors, including Yercan et al.16, support excision of the lateral facet overgrowth and retensioning of the lateral tissues. Lateral patellar facetectomy may provide pain relief and decrease the lateral overload in the patellofemoral compartment, but it may decrease bone stock necessary for future replacement.

**Proximal Soft-Tissue Realignment**

Proximal soft-tissue realignment procedures have also been advocated as a way to unload the lateral facet and improve patellar tracking. One of us (J.P.F.) reported limited success with this procedure (a 62% failure rate when signs of degenerative joint disease were present) and believes that other alignment procedures offer more reliable results in patients with patellofemoral arthritis17.

These procedures are focused on arthritis affecting the lateral facet and have limited utility for patients with more generalized arthritis. In particular, disease of the trochlea or medial facet may lead to an increase in pain following lateral release procedures. For patients with continued symptoms emanating from the lateral aspect of the joint, more aggressive alignment procedures may be required. Soft-tissue realignment procedures alone are also indicated for skeletally immature pa-
tients with a history of recurrent dislocations. The mature patient with a high congruence angle and minimal arthritis may benefit from proximal soft-tissue realignment if therapeutic measures have failed. A Q angle of <10° has also been associated with better outcomes.

This technique involves a midline incision from just above the superior pole of the patella to the medial aspect of the tibial tubercle. A release of the lateral patellofemoral ligament and a retinacular release are performed, leaving the synovial tissue intact to isolate the joint. The lower fibers of the vastus lateralis are released as well, and the release is carried down to the level of the tubercle. Medially, the vastus medialis is elevated from the underlying capsule about 10 cm from its insertion. It is then advanced to the lateral free edge of the vastus lateralis, creating a sleeve around the patella. A compression dressing is applied, and knee motion is begun at seven to ten days after the surgery. Insall et al. reported an 81% rate of good or excellent results after 3.5 years of follow-up.

**Distal Realignment**

**Osteotomy for Realignment and/or Resurfacing**

Tibial tubercle transfer is recommended for treatment of patellofemoral arthritis in patients in whom unloading of discrete areas of patellar and femoral disease can lead to clinical success. Requisite for this procedure is healthy cartilage onto which patellar loading and tracking can be transferred. Tibial tubercle transfer, when combined with cartilage resurfacing, holds great promise and may reduce the need for early patellofemoral arthroplasty. Through physical and radiographic examinations, the surgeon must first determine which part of the patellofemoral joint is involved in the disease process and thus needs to be unloaded. Radiographs made with the knee in 45° of flexion combined with precise lateral radiographs, magnetic resonance imaging scans, and arthroscopy all help the surgeon to make this determination, and he or she should make sure that all of the imaging studies correlate.

**Fig. 1**

Radiograph showing arthritis of the lateral facet accompanied by excessive lateral patellar tilt.

**Fig. 2**

A large lateral osteophyte is visible on this Merchant radiograph. This is often a finding in end-stage patellofemoral disease, and it is caused by excessive lateral tilt and/or translation of the patella.
with the findings on physical examination.

To select the correct osteotomy, one must understand that moving the tibial tubercle anteriorly decreases the flexion of the patella within the trochlear groove and therefore shifts contact on the patella more proximally so that this area is loaded earlier in the flexion arc. The most common areas involved in patients with malalignment are the lateral and distal articular regions. Anterior and medial transfer of the tibial tubercle would thus be appropriate in these patients. It should be realized that dysplasia or atrophy of the quadriceps may also be present in patients with malalignment, and therefore a combined proximal realignment may be necessary.

There are two main indications for tibial tubercle transfer:
1. The need to realign the patella by establishing proper alignment. This may also be accomplished with medial imbrication and lateral release, but that “pulls” the patella posteromedially and risks adding excessive load on the medial facet.
2. When degenerative disease is limited and a realignment osteotomy can unload the affected area. The benefits provided by recent advances in allograft and autograft cartilage resurfacing procedures may also be enhanced by simultaneous tibial tubercle transfer to unload the affected areas.

Relative and absolute contraindications to tubercle transfer include inadequate patient health or obesity, poor bone quality, diffuse patellar or trochlear chondral degeneration, proximal patellar lesions (crush injuries), reflex sympathetic dystrophy or diffuse pain, poor motivation on the part of the patient, and an inadequate trial of nonoperative measures.

Anterior or Elevation Osteotomy of the Tibial Tubercle
This procedure, known as the Maquet osteotomy, is designed to unload the more distal areas of the patella and decrease overall forces within the joint itself. It is particularly effective in younger patients with distal patellar articular degeneration, but it does not address alignment issues in and of themselves. In general, soft-tissue release should be attempted prior to osteotomy. Contraindications include diffuse involvement of the proximal pole regions of the patella.

The technique is performed through a medial parapatellar incision that is extended past the tubercle. The joint, along with the fat pad, is inspected and debrided to allow mobilization of the tendon. A 2.5 by 5-cm section of iliac crest is then harvested for the procedure. The osteotomy can be performed with use of multiple small drill holes or a thin oscillating saw blade ≥8 cm from the superior aspect of the tubercle distally in the coronal plane. Once mobilized, the proximal segment is displaced anteriorly, allowing plastic deformation of the bone at the distal attachment. The iliac crest graft is then fashioned to allow 1.5 to 2 cm of anteriorization at the tubercle. More than 1.5 cm of anteriorization, however, is associated with a higher prevalence of skin problems postoperatively. If necessary, a cancellous screw can be utilized for supplemental fixation through the tubercle and the graft, into the metaphyseal aspect of the tibia. Postoperative care involves use of crutches and partial weight-bearing and passive motion. Full weight-bearing is allowed at six weeks, when the osteotomy site is usually healed. Maquet reported a 95% rate of successful results in his series, but rates as low as 31% have been reported in other series (Fig. 3).

Medial Tibial Tubercle Transfer
This operation, known as the Elmslie-Trillat procedure, is a direct medial transfer procedure. It is effective for controlling instability and lateral tracking. The operation is mainly indicated for patients with an excessive Q angle, lateral instability, and patellar and/or trochlear cartilage with grade-II or less severe lesions. The procedure is contraindicated for patients with chondral lesions with a grade of greater than II, a normal Q angle, or an open proximal tibial physis.
The technique is performed with use of a lateral parapatellar incision extending from the proximal pole to the distal aspect of the tibial tubercle. The lateral patellofemoral ligament is then released along with the lateral retinaculum, leaving the underlying synovial layer intact and preserving the lateral geniculate blood supply to the patella. The tubercle is then cut in the coronal plane with use of osteotomes and drill holes to aid in the osteotomy. The periosteal sleeve is left intact, and the tubercle is medialized and then fixed with a cancellous lag screw. After the surgery, the limb is immobilized for six weeks and partial weight-bearing is allowed. After six weeks, when radiographic evidence of healing has been noted, motion and strengthening exercises are begun. The rate of satisfactory results in published series has been ≥80%. 

Anteromedial Tibial Tubercle Osteotomy
This osteotomy, known as the Fulkerson procedure, involves the transfer of the tubercle to a more anterior and medial location (Figs. 4-A, 4-B, and 4-C) and is more effective in diminishing or eliminating load on the distal and lateral aspects of the patella. When performing a tibial tubercle transfer, the surgeon should beware of proximal lesions or medial facet or condylar lesions, as transfer procedures will increase load on the proximal part of the patella and on the medial facet and medial condyle. Thus, intact proximal and medial cartilage is required to obtain the maximum benefit from this procedure.

The technique is performed through an incision from the lateral inferior part of the pole of the patella to the anterior ridge of the tibia 5 cm distal to the tubercle. The lateral patellofemoral ligament and the retinaculum are released, leaving the underlying synovium intact. A small arthrotomy is used distally to inspect the joint. The tubercle is then exposed so that a set of drill holes can be made, starting from anteromedial to the tubercle and the tibial ridge and directed posterolaterally. A thin oscillating blade saw can then be used to perform the osteotomy, with angling of the proximal-lateral aspect above the tubercle and leaving the distal bone in continuity with the anterior ridge of the tibia. The tubercle is then moved medially along the osteotomy, plastically deforming the bone attached to the anterior ridge of the tibia. Once the new position of the tubercle is determined, it is fixed with two cortical screws. After the surgery, the knee is immobilized and the patient is allowed partial weight-bearing. Passive range of motion is encouraged, assuming proper fixation. At four to six weeks, when radiographic evidence of healing has been noted, motion and strengthening exercises are begun. The rate of satisfactory results in published series has been ≥80%.
of healing has occurred, weight-bearing is advanced along with strengthening therapy. Reports have described satisfactory results in more than two-thirds of patients at five years after the surgery. Anterolateralization of the Tibial Tubercle

This procedure may be a good therapeutic option when there is a medial lesion resulting from overimbrication during a previous medialization of the tibial tubercle. This lesion may or may not be associated with medial subluxation. Anterolateralization may also be an effective salvage procedure following failed anteriorization of the tibial tubercle. It can help to realign a medially tracking patella, unloading a medial lesion that was over-loaded as a result of a previous medial tubercle transfer, and can be selectively combined with resurfacing of the patella. Anterolateralization requires an intact lateral facet.

Autologous Cartilage Resurfacing

Autologous chondrocyte implantation may be indicated for the management of focal chondral defects in the knee of a young patient. The procedure may be considered when an intact joint space has been documented on radiographic examination and the lesion has well-shouldered margins, and when there is no diffuse involvement of the remaining portion of the patella. It is critical that the etiology of the cartilage defect and the underlying abnormal biomechanics of the patella be accurately identified before the decision is made to move forward with this procedure. Having a proper diagnosis as well as correcting the underlying biomechanical abnormalities are paramount for a successful outcome of autologous chondrocyte implantation. The workup for these patients should include a thorough review of the history and a careful physical and radiographic examination of the axial alignment of the lower extremity as well as the patellofemoral joint. A routine series of radiographs, including anteroposterior standing, 45° posteroanterior flexion weight-bearing (Rosenberg), lateral, and skyline (Merchant) radiographs as well as a standing full-length lower-extremity axial alignment radiograph, is made for all patients. When maltracking is suspected on clinical examination, a computed tomography scan should be performed, with the leg in extension. Computed tomography scans are then obtained with and without quadriceps contraction to assess lateral patellar subluxation, the presence of dysplasia of the trochlea, and patellar height. All of these findings are extremely useful in determining the appropriateness of this procedure.

Once a patient is considered a candidate for autologous chondrocyte implantation, arthroscopic ex-
amination is performed to assess the geometry of the lesion and any pathological motion of the joint. A cartilage biopsy specimen is also obtained from the non-weight-bearing portion of the superior aspect of the intercondylar notch. This specimen is processed and utilized for cell culture. Approximately 200 to 300 mg of articular cartilage is sent in a sterile transport medium to be commercially cultured and cryopreserved.

The transplantation procedure is then performed as a second procedure. The chondrocytes are injected beneath a periosteal patch secured with resorbable sutures and fibrin glue.

The rehabilitation after the surgery includes non-weight-bearing and the use of continuous passive motion for six to eight hours per day for six weeks. The patient is allowed to progress to full weight-bearing by four months after the surgery, but inline impact activities (running) are not permitted for twelve to eighteen months and cutting sports are not allowed for at least eighteen months.

Minas and Bryant performed a seven-year, prospective cohort study of forty-five patients who had undergone autologous chondrocyte implantation for treatment of full-thickness chondral defects of both the patella and the trochlea, or of one surface of the joint. The average age of the patients at the time of surgery was 36.9 years, and the average duration of follow-up was 47.5 months. The patients were surveyed, and 71% were satisfied with the outcome, 16% were neutral, and 13% were dissatisfied. Eighty-seven percent of the patients said that they would have the surgical procedure again under similar circumstances. Seventy-one percent of the patients rated the result as good to excellent and only 7%, as poor. The Short Form-36 (SF-36), the Knee Society Score, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the modified Cincinnati knee score all showed large significant improvements (p = 0.0016). Typically, patients started to have pain relief by four to six months after the surgery, and they were allowed to return to non-impact sports activities at nine months postoperatively. Full-impact activities were begun by eighteen months after the surgery. The grafts failed in eight patients (18%). Peterson et al. reported similar results, up to ten years after autologous chondrocyte implantation, regardless of whether patellar maltracking had been addressed at the time of, or corrected prior to, the time of the implantation.

Patellectomy

Patellectomy has been performed for over a century as one of the surgical treatments of severe anterior knee pain. Its popularity has waxed and waned over time, with mixed results and opinions regarding its effectiveness. One of us (J.P.F.) found that patellectomy provided adequate pain relief but with permanent loss of knee extensor power. In the end, the results had deteriorated with time in the majority of cases.
of patients. The operation should be viewed as a salvage procedure, and the surgeon should warn the patient against unrealistic expectations concerning the outcome. Historically, the best results have been noted in patients with severe arthrosis of the patellofemoral joint. The technique basically involves a midline incision with a sharp dissection of the patella. Care should be taken to repair the retinaculum to prevent an extensor lag after surgery, and tracking of the quadriceps tendon should be checked to make sure that a proximal realignment procedure is not necessary. The patient then is allowed early mobilization and weight-bearing after surgery.

**Replacement Patellofemoral Arthroplasty**

There has been a recent resurgence of interest in patellofemoral arthroplasty. It has been indicated for end-stage patellofemoral arthritis, when deterioration of the patellofemoral joint is diffuse (Figs. 5-A through 5-E). Short-term reports have shown a high level of effectiveness, particularly when alignment issues are corrected. Patellofemoral arthroplasty can work well in patients of normal stature with isolated patellofemoral disease and no secondary gain issues.

Isolated patellofemoral arthritis occurs in up to 10% of patients who have osteoarthritis of the knee. Over the years, several different patellofemoral implants have been designed and previous reports of different patellofemoral implants have shown variable results. The Lubinus prosthesis was reported to have a 50% failure rate at eight years in a study of seventy-six cases. The main reasons for failure were malalignment, wear, impingement, and disease progression. The Avon patellofemoral arthroplasty was a second-generation design with features designed to improve alignment and wear.

The first Avon patellofemoral implants were placed in September 1996 and entered into a prospective review. Outcomes were assessed with use of pain scores, Bartlett’s patella score, and the Oxford knee score. To date, 307 knees have been treated and 159 knees have been reviewed at two to five years postoperatively. The median pain score improved from 15 of 40 points preoperatively to 36 of 40 points at five years. The Bartlett patella score improved from 10 of 30 points to 26 of 30 points at five years. The Oxford knee score improved from 19 of 48 points to 39 of 48 points at five years. Malalignment developed in four knees (1.3%), one of which required distal soft-tissue realignment. There have been no cases of deep infection, fracture, wear, or loosening. Evidence of disease progression developed in eighteen knees (6%), fifteen of which underwent revision to a total knee replacement.
The technique involves a medial parapatellar approach to the knee and alignment of the anterior femoral resection guide (Fig. 5-C). The alignment of this cutting block is paramount to ensure that no femoral notching or undersizing of the trochlear implant occurs. Most newer designs include an extension of the trochlear implant into the notch of the femur. This area is resected manually with either a template (Avon; Stryker Orthopaedics, Mahwah, New Jersey) or, in some systems, with a template and router (Journey; Smith and Nephew, Memphis, Tennessee). Peg holes are then drilled for the template, and the patella is addressed in the usual total-knee-resurfacing fashion. Care should be taken not to allow excessive overstuffing of ≥4 mm since this may affect postoperative motion. Postoperatively, patients are allowed full weight-bearing and motion is initiated immediately.

Results to date suggest that the improved designs have minimized the previous problems of malalignment and early wear. The functional results are comparable with those of a total knee replacement. Complication rates are low, and there is an excellent postoperative range of motion. Although disease progression remains a potential problem, these prostheses offer a reasonable alternative to total knee replacement in the small group of patients with isolated patellofemoral disease.

**Total Joint Arthroplasty**

The use of total knee replacement to treat severe isolated patellofemoral arthritis that is recalcitrant to therapeutic measures has been well established for older patients. The procedure is not advocated for younger patients with isolated patellofemoral arthritis, but it can be used with reliable results in patients in their eighth decade of life. Total knee replacement should not be considered until nonoperative management has failed. The exact age at which total knee arthroplasty becomes a viable option for the treatment of patellofemoral arthritis is debatable and case-dependent, but certainly an age younger than fifty-five years should be considered a relative contraindication. Careful adherence to proper techniques and component alignment is well recognized as being crucial to the success of any total knee arthroplasty, and this is no different for patients with patellofemoral arthritis. There are areas that need more emphasis in these patients to ensure a properly aligned knee replacement. Particular attention must be directed toward the correction of extensor mechanism alignment. This is evidenced by the reported rates of retinacular release in these patients, which are as high as 68% and a threefold increase compared with the rates associated with standard total knee arthroplasty.

Complications involving the extensor mechanism and the patellofemoral joint remain the primary noninfectious indications for revision total knee arthroplasty. Specifically, imbalance of the extensor mechanism and resultant poor patellar tracking are the most common causes of pain after total knee arthroplasty. Patellofemoral complications include patellar subluxation or dislocation; wear, loosening, or failure of the patellar component; and patellar fracture. Component positioning, especially rotational alignment of the femoral and tibial components, is critical to patellofemoral stability. Component malrotation is one of the most frequent causes of patellofemoral complications. Any surgical alteration that abnormally increases the tension in the lateral retinaculum or increases the Q angle and produces a laterally directed muscle vector will cause lateral maltracking of the patella and instability of the patellofemoral joint after total knee arthroplasty (Fig. 6). Positioning of the femoral and tibial components is of supreme importance. Valgus angulation of the femoral component will increase the Q angle and produce a laterally directed muscle vector. This alignment error is more common in patients with degenerative arthritis who have a preoperative valgus deformity of >10° combined with loss of bone stock of the distal part of the lateral femoral condyle.

Technically, the distal femoral cut should be made perpendicular to the mechanical axis of the limb (6° of valgus angulation with respect to the anatomic axis of the femur). There are a number of pitfalls to avoid during component positioning. A medially placed prosthesis will cause increased contact stresses between the lateral flange of the femoral component and the lateral border of the patellar component, resulting in patellar subluxation (Fig. 7). The femoral component should be lateralized as much as possible to reduce tension on the lateral retinaculum and reduce shearing stresses placed on the patella.

Component malrotation is the predominant cause of patellofemoral complications in patients with normal axial alignment. The epicondylar axis (a line from the lateral epicondylar prominence to the medial sulcus on the medial epicondyle) is the most reliable guide to ensure correct rotational alignment of the femoral component. The anterior and posterior femoral cuts should be made parallel to the epicondylar axis. Internal rotation of the femoral component with respect to the femur will rotate the trochlear groove medially, increase tension on the lateral retinaculum, and cause lateral patellar maltracking. Eerring on the side of slight external rotation should improve patellar component tracking.

Whiteside’s line (drawn from the deepest part of the patellar groove anteriorly to the center of the intercondylar notch posteriorly) is another reliable guide for rotational alignment. The anterior and posterior femoral cuts should be made perpendicular to this line. The least reliable landmark for rotational alignment of the femoral component is the posterior condylar line. It is internally rotated relative to the epicondylar axis. If the posterior condylar line is used as a reference, posterior deficiency of the lateral femoral condyle (and valgus deformity) may cause the femoral component to be substantially internally rotated. This will cause lateral patellar maltracking. Studies have demonstrated that a femoral component set parallel to the pos-
terior condylar line is more likely to be malrotated and more likely to require a lateral retinacular release to correct patellar maltracking. Internal rotation of the tibial component will also cause patellar maltracking by forcing the tibia into external rotation and increasing the Q angle. The correct placement of the tibial component is rotational alignment of the middle of the component’s anterior border with the tibial crest or the medial one-third of the tibial tubercle. The combined amount of internal rotation of the femoral and tibial components is directly proportional to the severity of patellofemoral instability: 1° to 4° should be used when there is lateral tracking and patellar tilting; 3° to 8°, when there is patellar subluxation; and 7° to 17°, when there is early patellar dislocation (at less than two years) or late failure of the patellar prosthesis (at two to six years).

The patellar component should be placed on the medial portion of the patella, mimicking the normal anatomy of a medially oriented sagittal ridge. A laterally placed patellar button will increase the tension in the lateral retinaculum and cause lateral patellar maltracking. A centrally placed patellar component more frequently requires a lateral retinacular release to track normally than does a medially placed component.

During patellar preparation, more bone must be removed from the thicker medial facet, with the patellar cut kept parallel to the plane of the medial and lateral poles of the patella. A common mistake involves resection of too much of the lateral facet and too little of the medial facet with a resultant lateral tilt of the patellar component (Fig. 8).

The current literature seems to favor patellar resurfacing. Multiple studies have demonstrated success with patellar resurfacing, with good relief of pain and good overall outcomes. However, other studies have shown success without insertion of a patellar component. Ideally, a patient treated without patellar resurfacing should have no patellar arthritis, and a femoral component that was designed to accommodate the native patella should be utilized.

“Overstuffing” of the patellofemoral joint by using a femoral component that is too large (especially in the anteroposterior dimension) or resecting an inadequate amount of the patella increases tension on the lateral retinaculum. The mismatch of the implant and the resected bone may also increase the circumference of the arc that the quadriceps tendon will travel in flexion and this can affect motion as well. The patellar resection should equal the thickness of the patellar component, while maintaining at least 12 mm of bone to minimize the risk of fracture. The goal should be to maintain the overall thickness of the patellofemoral joint in the anteroposterior dimension.

Alternative surgical approaches such as the subvastus, or “southern,” approach potentially offer less disruption of the extensor mechanism, fewer required lateral releases, less patellar...
maltracking, and preservation of the medial vascular supply to the patella\textsuperscript{63}. The technique may be difficult, however, in heavier patients or those with scarring, contractures, or large osteophytes.

Patellofemoral stability may be assessed with use of either the no-thumbs test or the single-suture technique. The patella should track centrally in the trochlear groove without lateral subluxation or lateral tilt through a full range of motion. Ideally, these tests should be performed with the tourniquet deflated, as binding of the extensor mechanism may lead to perceived maltracking of the patellar component.

With the no-thumbs test, the knee is taken through the full flexion arc without closing the medial arthrotomy and without applying any medial force with the thumb to keep the patella located. If there is patellar tilting or slight subluxation with the no-thumbs test, the single-suture technique can be used, thus avoiding an unnecessary lateral release. With the single-suture technique, the medial tension vector of the extensor mechanism is simulated by reapproximating the medial retinaculum at the superior pole of the patella with a single number-0 suture. If the suture does not break through a full range of flexion of the knee, then a lateral release is not necessary.

Lateral retinacular release is commonly used to correct maltracking of the extensor mechanism\textsuperscript{47}. The tight retinaculum is released approximately 2 cm lateral to the lateral patellar border, with the release extending from the vastus lateralis muscle to the proximal part of the tibia. Care should be taken to preserve the superior lateral geniculate artery. There are numerous possible complications of lateral retinacular release, including substantial vascular compromise (evident on a technetium bone scan), osteonecrosis of the patella, patellar fracture, prolonged wound-healing and wound slough, an increased risk of infection, increased postoperative pain and swelling, and prolonged rehabilitation.

Patellar fracture has even been shown to be more likely after lateral release, whether or not the superior lateral geniculate artery is preserved. Mesh expansion release of the lateral retinaculum is an alternative to traditional retinacular release, with the potential benefit of less disruption to the patellar blood supply.

The results of total knee arthroplasty for the treatment of isolated patellofemoral arthritis have been very good and have included reliable pain relief. However, a high rate of residual postoperative patellar tilt, asymmetrically resurfaced patellae, and residual subluxation has been reported in the literature\textsuperscript{46}. These findings emphasize the need to adhere to the technical principles reviewed in this section to properly handle the inherent complexity of these cases. Studies\textsuperscript{43-46} have demonstrated good-to-excellent results in terms of pain relief, and these results were superior to those achieved in comparison groups in which total knee arthroplasties had been performed for other conditions. It should be pointed out that anterior knee pain in patients with isolated patellofemoral arthritis was greater than that in patients with tricompartmental arthritis. One may view total knee replacement for arthropathy of an isolated patellofemoral articulation as excessive; however, total knee arthroplasty currently remains the most proven and predictable single procedure for this specific population of older patients with patellofemoral disease\textsuperscript{43-46}.

**Future Directions**

Increased interest and improvement in computer-assisted navigation systems...
for total joint arthroplasty have the potential to improve the accuracy of component alignment\(^{66,67}\). This may reduce patellofemoral complications\(^{68,69}\). It is important to note that there has not yet been any reported improvement in accuracy or variability when computer navigation, rather than conventional techniques, has been used for the critical step of rotationally aligning the femoral component in the operating room\(^{67}\).

**Overview**

Patellofemoral arthritis is a common cause of anterior knee pain. When the disease is in its early stages, a careful and complete course of nonoperative treatment may provide sufficient pain relief and functional improvement. If surgery is required, limited soft-tissue procedures such as arthroscopic lateral release and débridement may work well if the lateral portion of the joint is primarily affected. Tibial tubercle transfer, particularly anteromedialization, is a powerful way to correct malalignment and offload the lateral and distal parts of the patella. The indications for tubial tubercle transfer may expand if it proves to be a successful adjunct to cartilage resurfacing procedures.

For more severe disease, patellofemoral arthroplasty has evolved into a safe and reliable alternative. When a patient is older or when the arthritis is more diffuse, total knee arthroplasty is a reliable and reproducible way to improve function and decrease pain. Care must be taken to properly position components to avoid problems with the patellar component after the surgery.

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### References
