Patellofemoral Pain After Total Knee Arthroplasty

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Abstract

The incidence of patellofemoral complications after total knee arthroplasty has been reported to range from 2% to 7%. Such complications include pain, subluxation, dislocation, loosening, and wear. Usually these complications are attributable to prosthetic design or surgical technique. Today, it is understood that patellofemoral prostheses must have a degree of congruence; must allow smooth, not abrupt, motion; and must restore a relatively normal size relationship between the patella and the femur. Surgical technique requires strict attention to (1) restoration of the patellofemoral spacing while avoiding "overstuffing" of the patellofemoral compartment; (2) accurate superior and medial positioning of the patellar component; (3) restoration of the rotational alignment of the femoral and tibial components; and (4) appropriate balancing of the patellofemoral soft tissues.

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Patellofemoral pain after total knee replacement can plague even patients with an otherwise well-aligned prosthesis. While the cause may sometimes be obscure, it can often be traced to improper surgical technique or questionable prosthetic design.

Early operative techniques did not include resurfacing the patella. Anterior knee pain occurred in as many as 30% of patients, and patellar malalignment necessitated reoperation to replace the patella in 5% to 10% of patients.[1] The strategy to deal with these complications was the development of femoral components that included an anterior flange. However, this design feature, which replaced only half of the patellofemoral joint, did not diminish the postoperative occurrence of anterior knee pain.

In 1974 the polyethylene dome was introduced in the Insall/Burstein Total Condylar Knee prosthesis (Zimmer, Warsaw, Ind). This first patellar replacement achieved a very high rate of clinical success and is still in use today. Patients with a resurfaced patella have a reduced incidence of anterior knee pain and perform better in stair activities when compared with patients who have not undergone knee replacement.[2]

Total Knee Prostheses

Design

Early total knee prostheses, such as polycentric and geometric designs, did not include a patellar component or an anterior femoral flange. The original Total Condylar Knee and Freeman-Swanson implants were the first to include a flat anterior flange and a central dome. The reported 6% incidence of patellar subluxation was considered to be due to a lack of joint congruity. Subsequently, many other investigators advocated a congruent articulation. In retrospect, it is difficult to ascertain whether the complication rate was in fact secondary to the incongruent femoral component or to errors in surgical technique.[3]

The minimal patellofemoral problems associated with the Total Condylar Knee replacement may have been due in part to the limited possible flexion of 90 degrees. This reduced flexion may have obscured the stresses that became apparent with newer implants, which allowed a greater flexion arc. The Insall/Burstein Total Condylar Knee prosthesis and the Insall/Burstein Posterior Stabilized prosthesis (Zimmer), which was introduced in 1977, did indeed improve motion (105 degrees and 115 degrees, respectively), but "patellar" problems necessitated design changes.[2,4] In 1983, the design of the posterior stabilized prosthesis was revised to incorporate a deeper, smoother patellar groove to enhance both stability and tracking.[5] Current designs have been characterized by further deep-

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ening of the femoral sulcus. Yoshii et al[6] have shown, on the basis of in vitro analyses, that the combination of a 4-mm-deep femoral sulcus and medial placement of the patellar component best reproduces normal patellar tracking. Also, greater attention is now given to the rotational alignment of the femoral component, since external rotation and lateral placement more closely restore normal patellar tracking.[7,8]

Current patellar prostheses are of three basic designs: the component with a central dome with or without metal backing, the anatomic component, and the component containing rotating bearings. The central-dome component is the most adaptive but has the least congruity. The advantage of this design is that it eliminates concerns about rotational alignment while maintaining contact throughout the flexion arc. Kim et al[9] have shown that the total contact area in the patellofemoral joint replacement is only 21% of that in the intact knee and that there is a tendency for the patellar component to shift medially during knee flexion.

These alterations in knee kinematics may be a reason for polyethylene wear. In addition, the contact stresses on nonconforming central-dome components have been shown to exceed the yield strength of ultra-high-molecular-weight polyethylene, leading to creep and wear.[10] Interestingly, although a "conforming" deformation type of wear has been noticed almost universally on these prosthetic domes, it has not yet been associated with clinical problems.

This type of conforming polyethylene wear was influential in stimulating the development of the "Mexican hat" patellar design, which is characterized by a concave peripheral lip that articulates with the convex femoral condyles. This configuration distributes the patellofemoral compressive forces more evenly in flexion.[11]

The more congruent anatomic patellar component lowers the contact stresses, but may increase shear stress at the bone-prosthesis interface. This concern was the impetus for the design of the congruent-contact, metal-backed patellar component with rotating bearings, which permits dynamic tracking of the patella by motion between the metal base plate and the polyethylene surface.[12] The rotating-bearing patellar component maintains spherical area contact on the medial and lateral facets when the component is congruent with the femoral groove. Buechel et al[12] reported an overall complication rate of only 0.6% with this implant design. Long-term retrieval studies have demonstrated continued mobility and minimal wear.

The initial dome design with a patellar button with a central lug has had a complication rate of less than 7% in 15-year clinical surveillance studies. However, the central lug has always been suspected of enhancing patellar fractures. Subsequently, smaller central lugs were used, but the design provided insufficient fixation. Currently, three-pegged fixation is preferred with the central-dome polyethylene button. Mason et al[13] reported on the use of the three-lug patellar component in 577 knees and found no loosening an average of 3 years after surgery.

Indications

The routine use of patellar resurfacing devices remains a topic of debate because of the potential complications, including patellar fracture, patellar instability, implant loosening, component breakage, and rupture of the extensor mechanism.[14-16] Many surgeons favor universal resurfacing of the patella. The suggested indications include inflammatory arthritis[17] and significant Outerbridge grade III or grade IV patellofemoral arthritis, especially when associated with patellar subluxation or dislocation. Obese patients are more likely to have patellar symptoms after total knee arthroplasty, especially during activities involving knee flexion.[18] This increased incidence is attributable to greater patellofemoral-joint reaction forces, which may reach three to four times the patient's body weight during knee-flexion activities. A review of the literature suggests that the archetypal patient who does not need patellar resurfacing is short and relatively thin and has a congruous patellofemoral joint and less than grade III arthritic changes.[11]

Surgical Considerations

Restoration of patellofemoral mechanics in total knee arthroplasty is greatly influenced by the position of the femoral and tibial components. Since the objective is a knee that has equal medial and lateral soft-tissue tension in flexion and extension, appropriate soft-tissue releases are often unquestionably necessary to correct fixed deformities. The rotational position of the tibial and femoral components is also essential to the outcome of patellofemoral joint replacement.

The landmarks for assessing femoral rotation are the femoral epicondyles, the posterior femoral condyles, and the trochlea. Reestablishing external rotation of the femoral component improves the patellar tracking by lateralizing the anterior flange. Internal rotation of the femoral component is to be avoided, since this positions the patellofemoral groove medially, which makes it more difficult for the laterally placed patella to track in the trochlear groove, leading to subluxation or dislocation. From a practical perspective, the transverse axis of the medial and lateral femoral epicondyles provides a safe landmark when preparing the femur for component placement. Varying bone loss from the posterior condyles can result in an unpredictable landmark; the result most often is that the femoral component is misplaced in an internal rotational position.

The position of the tibial component is also critical to restoration of the extensor mechanism. While posterior placement on the plateau is still recommended,[16] contemporary tibial designs usually cover the entire plateau, which makes rotational positioning of the tibial component more difficult. Internal rotation of the tibial component relative to the tibia will cause external rotation of the tibia when the knee is in extension, resulting in lateral displacement of the tibial tubercle. This displacement increases the valgus forces and the tendency of the patella to lateral subluxation or dislocation. It is recommended that the posteromedial corner of the tibial tray be placed as far back on the tibia as possible, so that if the tibial component is symmetrical and correct rotation is achieved, the posterolateral corner will overhang on the tibia.

Patellar preparation is another critical factor for success. During exposure of the knee, the patella is everted, and the redundant synovium is resected from both the undersurface of the quadriceps tendon and the adjacent medial capsule (Fig. 1, A). Since reproduction of the patellar thickness is influential in the final outcome, the patella should be measured with a caliper prior to resection (Fig. 1, B). Until recently, this measurement was neglected, which unquestionably resulted in "overstuffing" of the patellofemoral compartment. In general, the line of patellar resection should be from the margin of the medial articular surface to the margin of the lateral articular surface. A common error is to resect only the lateral or medial facet, which results in oblique placement of the patellar component. The use of patellar reamers seems to allow more precise resection of the patella.

In preparing the patella, marginal osteophytes are excised so that the patellar reamer can be accurately positioned. The surface guide of the patellar reamer is used as a template and should fit snugly around the patella. The patella is reamed so that the bone-prosthesis composite will have a thickness equal to or 1 to 2 mm less than the original thickness of the patella (Fig. 1, C). The cut patellar surface should be level and in line with the undersurface of the quadriceps tendon, so that there is a smooth transition from bone to tendon.

Use of a bone-prosthesis composite that is thicker than the original patella increases the tension of the lateral retinaculum, resulting in patellar tilt—a situation that undoubtedly has contributed to many of the problems associated with "design failure." It is rather amazing that more failures have not been reported, since the importance of patellofemoral spacing has only recently been recognized.

Once the surface has been prepared, the three lug holes are drilled such that the patella sits in a more medial and superior position on the residual bone. This position recreates the height of the central ridge of the patella and improves patellar tracking. With the component in place, patellar tracking should be tested observing the "rule of no thumb." According to this rule, the patella should remain in place through the full range of motion without being held. To reduce laxity along the extensor mechanism, a clamp can be used to place longitudinal traction on the quadriceps tendon (Fig. 2). The knee is then flexed,

A B C

Fig. 1 Patellar preparation. **A,** The synovium is resected from the undersurface of the quadriceps tendon, preventing later impingement. **B,** The patellar thickness is measured before cutting the bone. **C,** The thickness of the bone-prosthesis composite should be equal to or slightly less than the original thickness of the patella.

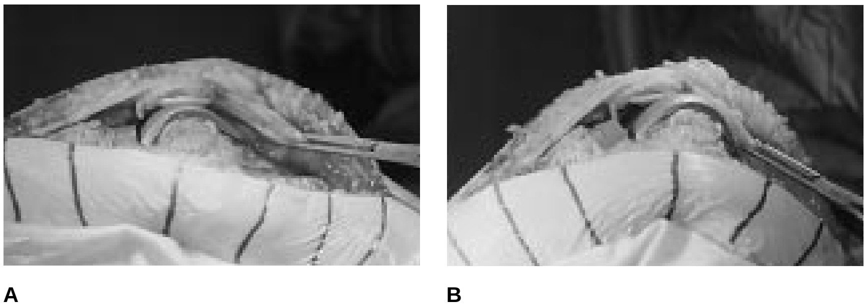

Fig. 2 A clamp on the quadriceps tendon provides longitudinal traction on the extensor mechanism and more closely reproduces patellar tracking during extension **(A)** and flexion **(B)**.

and patellar tracking is observed. If the patella tracks laterally or tilts during flexion, a lateral release should be performed. Sometimes reducing the patellar thickness slightly can diminish the need for a lateral release.

When performing a lateral release, an "inside-out" or "outside-in" technique may be utilized. Whichever technique is used, it is desirable to minimize disruption of the vascular insult to the patella. For this reason, the lateral retinaculum is cut proximally into the tendon of the vastus lateralis and distally to the joint line.[19] The lateral superior geniculate vessels are isolated and preserved. If the vessels continue to act as a tether, they should be cauterized and cut.[19] While this theoretically threatens the patellar blood supply, it fortunately has not resulted in clinical problems. Patellar tracking is then reassessed. If there is still lateral tracking, the position of all components should be reevaluated, especially with respect to rotational position. A proximal patellar realignment may occasionally be necessary to restore central tracking of the patella. In performing the proximal realignment, the medial capsule and vastus medialis are pulled laterally and imbricated over the patella and quadriceps tendon (Fig. 3).

Restoration of the natural or normal joint line has always been an important consideration in total knee arthroplasty. This is more critical in posterior cruciate ligament–retaining designs, because the ligament must be balanced properly to achieve a good range of motion. It is possible to have an ideally aligned knee in which the position of the joint line after arthroscopy is different from that of the natural knee. However, this change in the joint line affects the patellar height, which can be further influenced by several factors. A patient may have preoperative patella infera. If the femoral component is too far anterior or is undersized in the anteroposterior dimension, a large flexion gap is created, and the collateral ligaments are unbalanced in extension. When this situation is created, more bone must be resected from the distal femur; this results in the need for a thicker tibial component, which elevates the joint line and decreases the patellar height. When a large flexion gap is present, an alternative is to utilize a femoral component with a larger anteroposterior dimension and to augment the posterior condyles.

Valgus deformities also influence the flexion gap and potentially cause secondary patellar problems. Correction of an excessive valgus deformity accompanied by elongation of the medial collateral ligament requires release of the iliotibial band and lateral collateral ligament. In order to maintain stability in flexion, it is desirable, if possible, to preserve the popliteus. The resultant extension gap usually requires a thicker tibial component, which elevates the joint line. With the posterior stabilized prosthesis, the joint line may be elevated as much as 10 mm without problems. When the joint-line elevation is excessive, the patellar component will impinge on the anterior margin of the tibial articular surface, a situation readily apparent during trial reduction.

Etiology of Postoperative Patellofemoral Pain

Several factors are responsible for postoperative patellofemoral pain after total knee arthroplasty (Table 1). These are patellar instability, patellar fractures, soft-tissue im-

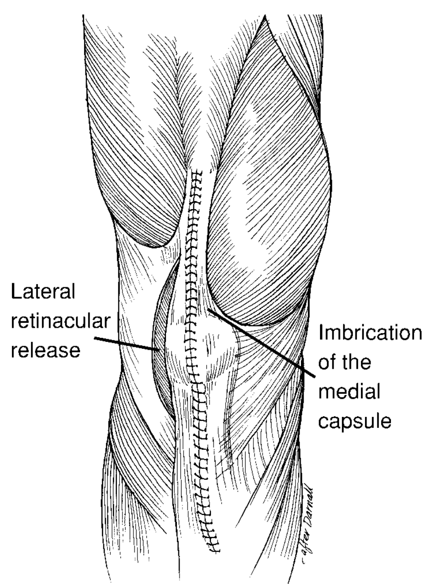

Fig. 3 Proximal patellar realignment and lateral retinacular release. At the time of arthrotomy closure, the medial flap is imbricated over the quadriceps tendon.

Table 1
Etiology of Patellofemoral Pain Following Total Knee Arthroplasty

Patellar instability
Patellar fractures
Soft-tissue impingement
Breakage of the patellar component
Loosening of the patellar component
Rupture of the extensor mechanism

pingement, breakage of the patellar component, loosening of the patellar component, and rupture of the extensor mechanism.

Patellar Instability

Today patellar instability after total knee arthroplasty is usually due to an error in surgical technique or results from secondary trauma.[20,21] The most common preventable causes include failure to perform a lateral release, excessive genu valgum, excessive thickness of the resurfaced patella, and rotational malalignment of the tibial and femoral components. Patellar instability is manifested more frequently as recurrent subluxation than as dislocation, but neither responds well to nonoperative treatment. Although the reoperation rate for patellar instability is reported to be less than 1%, the cause of instability must be understood in each case, and the treatment must be directed to that specific cause. Furthermore, the precise cause of the instability must be identified at the time of surgery, since lateral release alone may not correct the problem. It may be necessary to revise all components, especially if there is internal rotation of the femoral or tibial components.[7,8] When an overly thick patella is causative, more patellar bone should be resected such that the bone-prosthesis composite is no bigger than, and preferably is slightly smaller than, the original patella. In general, a composite thickness of 19 to 22 mm is appropriate. This reduces the tension on the lateral retinaculum and, in combination with a lateral retinacular release, improves patellar tracking.[22]

Proximal patellar realignment and lateral retinacular release have been helpful in restoring patellar tracking in situations in which there is laxity of the medial supporting structures or there are recurrent patellar dislocations with normally aligned components. Merkow et al[20] reported no recurrence after use of this technique. Distal realignment with an osteotomy of the tibial tubercle has also been recommended, but this is associated with an increased risk of rupture of the patellar tendon.[23]

Patellar Fractures

The incidence of patellar fractures after total knee arthroplasty ranges from less than 1% to 21%.[24] Fractures can occur in both resurfaced and nonresurfaced patellae. Many factors have been implicated in the causation of these fractures, including obesity, high activity level, poor component design, and less than optimal bone quality. Excessive bone resection during preparation of the patella also is associated with this complication, especially if the patella is cut too thin or is cut asymmetrically.[25] On the basis of in vitro experiments, it has been recommended that at least 15 mm of residual patellar bone be maintained to minimize strain on the patella. However, our clinical experience in more than 500 cases has shown that leaving as little as 12 mm of residual patellar bone does not increase the risk of fracture.

While lateral release with sacrifice of the superior and inferior lateral geniculate vessels theoretically can contribute to devascularization of the patella, the relationship to fracture has been thought by some to be minimal.[26] In a recent study, Tria et al[19] suggest that routine lateral release sacrificing the superior and inferior lateral geniculate arteries carries an increased risk of fracture. Therefore, if one performs a routine lateral release, an attempt to preserve the superior lateral geniculate artery must be made. Of course, tracking is paramount, and if lateral release is necessary for successful patellofemoral tracking, it must be performed. The contribution of the fat pad to patellar vascularity also has been reviewed as a possible etiologic factor. One study reported a potential compromise with radical excision[27]; another found no difference.[28]

Goldberg et al[29] have classified the patterns of patellar fracture and their influence on clinical outcome. The type I pattern is a transverse fracture through the middle or superior pole of the patella without disruption of the implant or the quadriceps tendon. Type II fractures disrupt the quadriceps tendon or loosen the patellar component. Type III-A fractures occur at the inferior pole of the patella with disruption of the patellar tendon. Type III-B fractures also occur at the inferior pole of the patella, but the patellar tendon remains intact. The type IV pattern is a lateral fracture-dislocation. Fracture patterns without disruption of the extensor mechanism or loosening of the patellar component can be treated nonoperatively with 3 to 6 weeks of immobilization. In general, these fractures have a satisfactory clinical outcome.

Most fractures should initially be immobilized in extension, until the patient can do a straight-leg raise. Surgical intervention is confined to those situations in which there is a severely displaced transverse fracture or a comminuted fracture in which the extensor mechanism is disrupted. When surgical repair is contemplated, elaborate means of internal fixation should be avoided. A partial patellectomy with repair of the extensor mechanism can be a successful alternative. A loose patellar component requires excision. If the bone stock is adequate, a new component can be reimplanted. Otherwise, the patella may be left without resurfacing after removal of all the methylmethacrylate.

Soft-Tissue Impingement

After total knee arthroplasty, a prominent fibrous nodule may develop on the undersurface of the quadriceps tendon at its junction with the patella. Despite restoration of central patellar tracking, such a nodule may catch or "clunk" as the knee flexes and extends.[30] The patient often will complain that the knee gets painfully stuck as it is extended from a flexed position. This usually occurs at 30 to 45 degrees of flexion. This soft-tissue impingement problem originally appeared to be unique to the posterior stabilized prosthesis, especially the original design, but more recently it has been reported with other implant designs. Factors that have been implicated include abrupt changes in the radius of curvature of the femoral component, use of a patellar component that is too large, and irritation of the quadriceps tendon. Patellar catching problems are attributed to the configuration of the femoral component at the anterior margin of the intercondylar notch and impingement of a fibrotic nodule that is usually located on the undersurface of the quadriceps tendon proximal to the patella. When a patellar clunk is diagnosed early, the patient may respond to an exercise program that concentrates on repetitive flexion and extension, such as one that calls for use of an exercise bicycle. Cases that do not respond and continue to be painful have benefited from arthroscopic debridement of the fibrous nodule.

Disruption of Metal-Backed Patellar Components

The use of metal-backed patellar components has been plagued by failure and breakage. Since a porous coating can be applied only to a metal-backed component, uncemented patellar components are prone to failure because of lack of material bonding and because the component thickness is less than 1 to 2 mm.[31]

It is not unusual for heavy, active patients with good flexion to present 1 to 2 years after surgery with the sudden onset of pain and gradual swelling. The presence of a broken or dissociated metal-backed patellar component can be diagnosed on the basis of the audible metallic grating that occurs as the knee flexes and extends. There is usually a sterile effusion with a murky appearance.

The thin peripheral polyethylene may delaminate and shed polyethylene particles, which in turn creates a foreign-body reaction that results in osteolysis and loosening of the patellar component. Further polyethylene wear leads to exposure of the metal backing, which abrades the femoral component, releasing metal debris. An axial radiograph will often show the metal backing articulating with the femoral component. Sometimes radiopaque particles are shown on the radiograph, or the polyethylene component is seen to be free in the joint. The metal-backed patellar component should be used cautiously, if at all, until a better means of bonding the polyethylene to the metal base plate is designed.

Treatment of a broken patellar component involves removal of the metal backing and replacement. If satisfactory bone stock remains, implantation with a cemented polyethylene component is preferred. Many times the metal debris, whether titanium or cobalt chromium, is associated with proliferative darkly stained synovium, which should be completely excised. If the metal backing of the patellar component has caused abrasion and fretting of the femoral component, the femoral component should also be revised, as it could disrupt the new patellar component.

Loosening of Cemented and Noncemented Components

The incidence of loosening of non-metal-backed patellar implants has been reported to range from 1% to 3%.[32] If loosening occurs, the treatment options, depending on symptoms, are (1) observation, (2) arthroscopic excision, (3) reimplantation, and (4) patellectomy.

Surprisingly, not all loose polyethylene patellar components cause symptoms; if there are no symptoms, observation is acceptable. If a loose component is causing symptoms, simple removal is often an option and can be done arthroscopically. The skin and capsule must be enlarged for removal of the component; this is usually less traumatic when done through a superior and lateral incision. The presence of a fibrous layer enveloping the remaining patella often results in painless motion; therefore, removal of the component is preferable to patellectomy, especially in an older arthritic patient. The decision to perform reimplantation is strictly dependent on whether there is sufficient bone stock. Reimplantation probably should be reserved for the more active patient. When performing reimplantation, the surgeon should follow the routine principles of patellar bone preparation previously presented. Patellectomy is rarely required; however, if it is necessary, we recommend a Compere-type procedure, which enhances quadriceps function and anterior knee cosmesis.

Cementless total knee arthroplasty presents somewhat different problems. With the implant designs used, metal backing of the patellar component has been necessary to provide a porous surface for bone ingrowth. Because of the high shear forces at the patella, especially at extremes of flexion, disruption of bone ingrowth of the patellar component is a risk. When ingrowth occurs, it is usually at the fixation pegs, not at the base plate. Incomplete fixation, combined with the high and repetitive shear forces, can cause a stress fracture at the peg-plate junction, resulting in loosening of the patellar component. Rosenberg et al[31] have reported that this usually occurs about 2 years after implantation.

In a continued effort to improve fixation of implants designed for cementless arthroplasty, several manufacturers have introduced recessed metal-backed patellar components. Theoretically, this design should protect the thin polyethylene margin from the high peripheral forces. However, there is a trade-off, because the smaller contact area between the bone and the implant increases the risk of fracture at the patellar margins. This would result if unresurfaced bone articulated with the femoral condyles at extremes of flexion. Also, in patients with inflammatory arthritis, articular cartilage may serve as a nidus for continued inflammation. Therefore, the long-term effectiveness of this design has yet to be determined.

Rupture of the Extensor Mechanism

Disruption of the extensor mechanism (Fig. 4) is a devastating complication of total knee arthroplasty, and the treatment outcome is generally poor.[33] The best way to avoid this problem is to use meticulous surgical technique. The extensor mechanism is placed at risk during medial parapatellar arthrotomy if the patellar tendon is split and the medial border of the tendon is elevated with the medial capsule. If there is difficulty in everting the patella, a proximal quadriceps release or distal tubercle osteotomy should be performed for exposure.

Struggling for adequate exposure may lead to avulsion of the patellar tendon. Reconstruction for an avulsed patellar tendon is, at best, troublesome. In our experience, simple reattachment is thoroughly ineffective. Elevating periosteal flaps and burrowing the tendon has an anecdotal record of resulting in very limited flexion (less than 70 degrees). Extensor-mechanism allografting might be an acceptable alternative, but at this time there is no confirmatory data.

Fig. 4 Rupture of the quadriceps tendon.

Midsubstance tears of the patellar tendon or quadriceps tendon are rare but have been associated with loose patellar components that lie against and erode the tendon. Such ruptures should be addressed by methods similar to those normally used in the repair or reconstruction of quadriceps and patellar tendon rupture.

Summary

Patellar resurfacing in total knee arthroplasty is still undergoing scrutiny. In general, it is recommended that patellar replacement be routinely performed in patients with inflammatory arthritis. It is less certain which patients with osteoarthritis can be effectively treated without patellar resurfacing. The ideal patient is a thin osteoarthritic person with a relatively normal-appearing patella. The ideal prosthetic design has not been established, although the all-polyethylene dome, with its nonconforming design, has the longest successful follow-up. Design considerations on the horizon are inset components and recession of the anterior or trochlear aspects of the femur. Clinical results that should be forthcoming within the next few years will allow assessment of the efficacy of these design characteristics. Recreation of patellofemoral mechanics is greatly influenced by the rotational position of the femoral and tibial components, as well as by restoration of patellar thickness and alignment. Many complications are preventable with the use of meticulous surgical technique.

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