Abstract

Patellofemoral arthroplasty has been described as an appropriate treatment for isolated patellofemoral arthritis. With the aging population and the increasing number of total joint arthroplasties, both patients and surgeons are on the lookout for alternatives to total joint arthroplasty. With appropriate patient selection, well-designed implants, and precise surgical technique, the outcomes of patellofemoral arthroplasty can be excellent. The main indication for patellofemoral arthroplasty is isolated patellofemoral arthritis.

Patellofemoral arthritis is defined as the loss of articular cartilage on the patella facets, the trochlear groove, or both. Chondral wear is most common on the lateral patellar facet, and in cases where both medial and lateral facets are involved, the lateral facet usually has worse disease (Fig. 1). The incidence of isolated patellofemoral arthritis has been reported in patients older than 55 as anywhere from 2% to 11% in men and 8% to 24% in women. Patients older than 40 have nearly a 10% incidence of isolated patellofemoral arthritis. Women account for 75% of patients with isolated patellofemoral arthritis. The higher incidence in women is likely related to mal-alignment and dysplasia, which are more common in women. The etiology of patellofemoral arthritis is multi-factorial. There is a clear correlation between increased body mass index and increased rates of patellofemoral arthritis. When performing activities, such as stair climbing or rising from a chair, the force across the patellofemoral joint increases exponentially with weight. Trauma has also been implicated as an etiology of patellofemoral arthritis with a study by Argenson and coworkers attributing 30% of patients with isolated patellofemoral disease to trauma. Patients who have sustained patella fractures, patella tendon or quad tendon ruptures, patella dislocations, or any injury that can lead to mal-alignment and altered patellofemoral tracking are all more susceptible to patellofemoral arthritis. Many congenital or developmental factors also play a role in the development of patellofemoral arthritis. Isolated patellofemoral arthritis can be attributed to abnormal patellofemoral mechanics in the absence of trauma, which can be caused by any combination of patella alta, trochlear dysplasia, increased Q angle, weak or hypoplastic vastus medialis oblique, a contracted lateral retinaculum, and absent or redundant medial patellofemoral ligament. These factors eventually result in secondary degenerative changes to articular surfaces.

The bony anatomy of the distal femur and trochlea play a significant role in the stability of the patella and act as a static restraint to medial and lateral translation. Alterations in the normal anatomy can rapidly lead to degenerative changes. The medial and lateral grooves of the trochlea act as a buttress to prevent instability. The lateral aspect of the patellofemoral joint is typically longer and more sloped than the medial articulation. The morphology of the patella also plays a role in its stability. The inferior pole is generally regarded as non-articular and is not covered by articular cartilage. The superior articular surface is generally divided by a central ridge into medial and lateral facets. An additional odd facet can also be found at the most medial edge of the patella. The surface of the patella that is in contact with the trochlea constantly changes throughout the arc of motion. Only a small portion of the patella is in contact with the trochlea at any given point of the flexion and extension arc. In a non-diseased joint, the patella and femur do not articulate in full extension; as the knee flexes, the contact...
area moves from the distal aspect of the articular surface to more proximally in deep flexion. In full flexion, the lateral and odd facets can both be found in contact with the femoral condyles. Normal function of the patellofemoral joint requires a smooth transition between the various points of articulation. Abnormalities in this process can be seen in diseases, such as patella alta, where abnormal cephalic tilt of the patella is noted in flexion. This process can also be abnormal in trochlear dysplasia where a decrease in the size of the lateral trochlear buttress or trochlear floor may increase the likelihood of patella instability, altered articulation, and subsequent arthritis. In addition to the bony anatomy, soft tissue structures play a large role in patellofemoral stability, and any abnormality may lead to instability or mal-alignment. Laterally, the superficial and deep transverse retinaculum, the patellofemoral ligament, and patellotibial band all play an important role. Medially, the medial patellofemoral ligament is the most important structure for maintaining patellar stability, although the medial patellotibial and patellomeniscal ligaments also play secondary stabilizing roles. Contracture of the lateral retinacular ligaments or absence of the medial patellofemoral ligament may, therefore, contribute to patella malalignment. The main dynamic stabilizer of the patella is the quadriceps muscle with each portion imparting a different force vector on the patella. A weakened or hypoplastic vastus medialis oblique may result in imbalance of force and lead to instability. An abnormal Q angle can also pre-dispose patients to patellofemoral instability and early onset patellofemoral arthritis. The Q angle is the angle formed by a line drawn from the center of the patella to the tibial tubercle and a line from the center of the patella to the anterior superior iliac spine. The Q angle is considered abnormal if it is greater than 20° in women or greater than 15° in men.

**Diagnosis of Patellofemoral Arthritis**

Patients with isolated patellofemoral arthritis will present differently than patients with disease involving multiple or tibiofemoral compartment arthritis. These patients will describe their pain as retropatellar or immediately peripatellar. Pain is associated with activities that load the patellofemoral joint, such as stair climbing or descent, squatting, sitting with flexed knees, or rising from a seated position. Pain is often less severe when walking on level ground, and patients are typically more comfortable with their knees in full extension than in any amount of flexion. Any history of recurrent patellar dislocations suggests the presence of patellofemoral misalignment or instability. Any history of pain in the medial or lateral compartment should raise suspicion for more diffuse disease.

On physical exam, crepitus and effusion may be present in patients with patellofemoral arthritis. One must evaluate patella tracking throughout the entire arc of motion. The presence of a J sign where there is lateral patella deviation during terminal extension should be noted, as this may be an indication of instability or quadriceps weakness. A patella compression test can also have a high correlation with patellofemoral arthritis. Range of motion should be evaluated, and the examiner should note the stage of flexion during which the patient experiences maximal pain as this may provide clues as to which aspects of the patellofemoral joint are involved. More distal lesions are painful early in the flexion arc with proximal lesions remaining asymptomatic until deeper flexion. The examiner should also rule out...
other potential causes of anterior knee pain, such as patellar ligament, quadriceps tendon, pes anserine, hip, or lumbar spine diseases. Tenderness over the medial or lateral joint line may be indicative of more diffuse disease or meniscal pathology.\(^9\)

Q angle can be assessed clinically but should also be measured on full leg length standing x-rays, as well as overall limb alignment. In addition to standing leg length x-rays, a routine series of radiographs should be obtained including standing AP, flexed weightbearing PA, lateral, and sunrise views. Lateral views can reveal patellofemoral osteophytes, joint space narrowing, and the presence of patella alta or baja. Sunrise views can also show a narrowed joint space, as well as the presence of trochlear dysplasia, patellar tilt, or subluxation. When mal-tracking is suspected on clinical exam, CT scan can be used to assess trochlear dysplasia and patella height, or calculate the tubial tubercle to trochlear groove (TTTG) distance, with values greater than 20 mm leading to patellar instability. MRI can be used to evaluate the quality of articular cartilage.\(^1\)

**Treatment**

Conservative treatment is usually attempted before surgery is considered for patellofemoral arthritis. Avoidance of activities that require deep knee flexion, bracing, use of assistive device, such as cane or walker, and physical therapy, often prove effective. Physical therapy should focus on quadriceps strengthening with isometric exercises, stretching of the lateral retinacular structures, and preservation of joint motion.\(^9\)

When conservative measures fail in patients with mild to moderate patellofemoral disease, there are a number of surgical options that exist, and each has its own set of indications. Arthroscopic debridement, tibial tubercle osteotomies, cartilage stimulation procedures, and cartilage transplant with autograft or allograft have all shown successes with appropriate indications.\(^2\) When patients fail to improve with these procedures or in the presence of severe patellofemoral osteoarthritis, arthroplasty is a viable option. Total knee arthroplasty is considered the gold standard by most investigators. In certain situations, such as younger patients where there is concern for bone conservation and possible need for future revision surgery, patellofemoral arthroplasty (PFA) is an attractive option that may maintain normal knee kinematics.\(^12,13\)

**Indications and Contraindications**

The most common indication cited for patellofemoral arthroplasty is advanced primary isolated patellofemoral arthritis that has severely affected activities of daily living with no relief from non-operative interventions. Isolated trochlear dysplasia is another common indication for PFA and often results in the best outcomes.\(^7\) Post-traumatic arthritis of the PF joint is also a common indication for PFA. Failure of previous PF joint unloading procedures, such as Maquet or Fulkerson osteotomy, is also an indication to perform a PFA. While PFA can be effective when performed in the right patient, there are many contra-indications to the procedure. Disease involving the tibiofemoral joint is a contraindication with investigators citing Outerbridge lesions greater than grade one in these compartments as the threshold for not proceeding with PFA.\(^3\) Other contra-indications include medial or lateral joint pain, systemic inflammatory arthropathy, patella baja, uncorrected patellofemoral mal-alignment, fixed loss of knee range of motion, or evidence of psychogenic pain or complex regional pain syndrome. Another absolute contra-indication to PFA is uncorrected tibiofemoral mal-alignment, with patients who have varus or valgus greater than 3° from normal having poor outcomes.\(^14\) Although not contra-indications, some conditions cited as possibly leading to poorer outcomes after PFA are quadriceps atrophy, ligamentous instability, prior meniscectomy, chondrocalcinosis, higher patient activity, male gender, and lack of surgeon experience. The ideal patient age for PFA has yet to be determined, but most investigators agree that it is best restricted to patients 40 to 60 years of age.\(^15,16\) DeCloedt reported significantly better outcomes in patients who underwent PFA for trochlear dysplasia than patients who had a diagnosis of primary PF arthritis. In this study, 83% of patients who were treated with PFA for a diagnosis of trochlear dysplasia had good to excellent results compared to 43% of patients with a diagnosis of PF osteoarthritis. The thought was that osteoarthritis progressed to affect all compartments, while isolated trochlear dysplasia is a non-progressive disorder.\(^17\)

**History and Implant Design**

In 1955, McKeever performed the first PFA. He only resurfaced the patella and used a screw-on Vitallium patellar shell. These cases failed mostly due to rapid trochlear wear.\(^17\) In 1974, Richards Medical introduced the concept of resurfacing both the patella and trochlea. The early implant designs were successful in providing early pain relief, but satisfactory results were not maintained. More than 50% of the first generation devices failed for many reasons such as mal-tracking, polyethylene wear, component mal-positioning, poor patient selection, and poor implant design.\(^18\) In response to these results, second generation implants were introduced in the 1990s and showed improved outcomes. The four second generation off-the-shelf implants currently available for use in the USA are Avon by Stryker, Vanguard by Biomet, Low Contact Stress by Depuy, and The Natural Knee II by Zimmer. KineMatch is the only CT guided option available in the USA and usually is more expensive than the off-the-shelf designs.\(^19,20\)

The crucial elements of implant design are mostly related to the shape of the trochlear component. The four most important factors are the sagittal radius of curvature, the proximal extension of the anterior flange, the medial to lateral breadth of the implants, and the level of constraint.\(^21\) An implant with a radius of curvature that is too obtuse will
not fit the anterior femoral shaft and make the design vulnerable to catching and snapping as the patella transitions from the femur to the trochlear prosthesis. Prostheses with shorter proximal extension will allow the patella to articulate with the femur in full extension before engaging the trochlear component in flexion. A narrower implant will provide less freedom for patellar excursion and make the implant prone to subluxation. Finally, the less constrained the implant is in the axial plane, the better its patellofemoral tracking. The goals of implant design are to most closely resemble the patient’s normal anatomy allowing smooth patellar tracking and minimizing the chance of subluxation or dislocation.21-23

Surgical Technique
A standard midline incision is carried down from 1 cm proximal to the patella to just proximal to the tibial tubercle. An arthrotomy can be performed using the surgeon’s choice of medial parapatellar, midvastus, or subvastus approaches. During the arthrotomy, the surgeon must be careful not to cut the menisci, intermeniscal ligaments, or the articular cartilage. After excising some of the infrapatella and supratrochlear fat pad, the patella can be subluxed or everted. At this point, the surgeon should confirm that disease is isolated to the PF compartment and that the cruciate ligaments are intact and there are no significant osteophytes in the intercondylar notch. The anterior femoral cut should be made perpendicular to Whiteside’s line or parallel to the transepicondylar axis. Using the starting point of 10 mm anterior to the PCL insertion, the intra-medullary canal is accessed with a drill, and the anterior femoral guide is introduced. The surgeon should adjust the external rotation of the guide as needed. The appropriate amount of resection is determined using a stylus on the anterior cortex of distal femur. The surgeon should see the classic baby grand piano sign after the cut is made. The next step is to choose the appropriate size of the component. Here the surgeon must make sure that the superior part of the guide is flush with the anterior cortex, and that the medial and lateral borders of the guide do not overhang. The guide should be centered or slightly lateral to prevent patella mal-tracking. The trochlear surface is then prepared using a special milling burr or an alternative system. A template is placed and secured on the prepared surface and lugholes are drilled. The trial component is then impacted onto the surface making sure that the lugholes are appropriately aligned. It is important that the component is flush with the anterior femur superiorly and the articular cartilage inferiorly. Patella preparation is performed in standard fashion as done in a total knee replacement. The patellar component is medialized to prevent patella mal-tracking, and lateral osteophytes are removed to prevent bony impingement. Patella tracking is then assessed. A lateral release may be needed to achieve normal patellar tracking. There should be no tilt or subluxation as the knee is put through a full range of motion. Trial components are then removed, and the final implants are cemented into place. Care must be taken to remove the cement quickly from the margins of the implant to minimize the potential thermal damage to the adjacent articular cartilage. Component position and patella tracking are re-checked prior to closure.24-26

Postoperative management is similar to that of total knee arthroplasty. Patients are allowed to be weightbearing as tolerated. Physical and occupational therapy focus on active and passive range of motion along with gait training. Continuous passive motion (CPM) can be used at the surgeon’s discretion.

Complications
Patellofemoral arthroplasty has some similar complications to total knee arthroplasty, such as poly wear, arthrofibrosis, and persistent pain. However, patellofemoral mal-alignment is the most common cause of poor outcome following PFA. Loosening and infection occur at lower rates than reported in TKA, although they must always be considered in a patient with persistent pain.27,28 Unlike TKA, patients who undergo PFA have a risk for progression of the disease to the non-resurfaced compartments.27-29

Outcomes with First Generation Implants
In 2002, Tauro and coworkers retrospectively reviewed 76 cases of PFA, all performed with the Lubinus implant in patients 50 to 87 years of age, finding a 65% survivorship at 5-year follow-up. Fifteen of 21 failures were due to PF mal-tracking, and the remaining six failed due to progression of tibiofemoral arthritis. These results led the investigators to abandon the use of this implant.30 The survival of other first generation implants was reported by other investigators to be slightly better than Lubinus but still not optimal.5 Argenson and associates reported 58% survival for acocentric implants at an average of 16 years, and Van Jonbergen and colleagues reported 69% survival at the 20-year follow up of the Richards II implant. The most common causes of postoperative problems in these implants were residual mal-alignment of the patella and wear which were found in up to 30% of cases. Progression of the arthritic disease in either the medial or lateral compartment was also regularly reported.5,31

Outcomes with Second Generation Implants
The second generation implants, better patient selection, and better indications have significantly improved short to mid-term outcomes. In contrast to the prosthesis-related failures of first-generation implants, the most commonly reported complication seen in all second-generation designs is progression of tibiofemoral arthritis. Butler and Shannon reported a 91% 5-year survivorship in 22 patients with second generation PFA.32 Leadbetter and coworkers reported a series of 79 PFAs noting 94% survival of the Avon implant at an average 3-year follow-up with 84% achieving knee society scores greater than 80. Five patients eventually underwent conversion to total knee arthroplasty.
for progression of disease. Other studies have reported similar results at 5-year follow-up despite a reported 26% re-operation rate for arthroscopic assessment, debridement, lateral release, and tibial tubercle osteotomy; only three cases needed to be revised to total knee arthroplasty for progression of disease. In 2007, Ackroyd reported a 96% 5-year survivorship of the Avon prosthesis. Sisto and Sarin followed 25 Kinamed implants for an average of 6 years and reported implant survivorship of 100% with 18 excellent and 7 good results. Nicol and coworkers in their series of 103 Avon implants reported implant survivorship of 86% at average of 7 years. Of the 14 cases that were revised, 12 were for arthritis progression, one for condyle necrosis, and one for patellar subluxation with pain. In 2012, Mont and associates in their series of Avon implants reported implant survivorship of 88% at an average of 7 years. Four knees were revised to TKA for tibiofemoral progression. Revision PFA remains a viable option for failed PFA with an 86% 5-year survival reported for revision PFA when a failed first generation implant was replaced with a second generation implant. Not all second generation implants have done well. The low contact stress patellofemoral prosthesis is an example. This implant consists of a trochlear component and a modular patellar component that has a metal-backed mobile polyethylene bearing, with a high degree of conformity between the patellar and trochlear components. A 2011 study by Charalambous and colleagues followed 51 LCS implants for an average of 2 years and found an unacceptably high revision rate of 33%. Other studies also reported high complication rates with this implant. At this point, long-term results for second-generation implants are not available, but with high early and mid-term survival, the hope is that these will out-perform their first generation counterparts.

**PFA Compared to TKA**

Total knee arthroplasty remains the gold standard for treatment of knee arthritis. In addition to providing advantages of maintaining knee kinematics and preserving bone, PFA must provide similar outcomes to be considered an alternative to TKA. This 2011 meta-analysis by Dy and associates reviewed 22 observational studies and compared the mid-term outcomes of first and second generation PFA versus total knee arthroplasty. They found that there was a higher likelihood of re-operations and revisions when comparing all PFA to TKA. However, re-operations and revisions were much more likely in first generation implants than in second generation implants. The most important finding of the study was that when they compared second generation implants to total knee replacements there was no significant difference in re-operation rate, revision, pain, or mechanical complications. In a retrospective study, Dahm and colleagues compared the short-term outcomes of PFA and TKA. They showed that patients treated with PFA demonstrated similar results with respect to pain relief but showed improved function and return to activity when compared with the patients treated with TKA. There was a trend toward better postoperative flexion in PFA group (127°) compared to TKA (118°). Patients treated with PFA also experienced less blood loss, fewer complications, and shorter hospital stay following surgery. This is the only paper that compared return to sporting activities after PFA and TKA, and it appears that patients in the patellofemoral group are generally able to return to more high impact activities compared to their total knee counterparts. In a case control study, Van Jonbergen and coworkers followed 14 patients who had PFA converted to TKA and compared them to 14 primary TKAs. Outcomes were similar in the two groups. However, within 6 months after conversion, three knees from the conversion group had to be manipulated for limited motion. The investigators reported that they did not experience any significant technical problems during the conversions. This has been confirmed by other investigators. They, therefore, concluded that patellofemoral arthroplasty does not appear to have a negative effect on the outcome of later total knee arthroplasty.

**Discussion**

Total knee arthroplasty may provide relief at least equal to PFA for advanced patellofemoral arthritic disease in patients younger than 60, but this comes at a cost. Patients who suffer from symptomatic patellofemoral arthritis at an age where the survivorship of their total knee would have to extend well over 30 years must be given a practical alternative, especially when they have failed other early surgical interventions. Patellofemoral arthroplasty appears to be a useful and versatile option for these patients; it preserves physiologic tibiofemoral joint mechanics and patients enjoy quicker recovery and have better satisfaction than TKA.

The second-generation implants have shown significantly lower failure rates and can potentially delay TKA by 10 to 15 years in 75% to 80% of cases. In addition, revision to TKA has been performed without difficulty. Gait analysis in PFA has revealed correction of preoperative pathologic patterns that approach normal knee kinematics as well as improvement that is slightly better than that seen in TKA. Second generation implants compare well with total knees at short-term and mid-term follow up, and more research is needed to evaluate the long-term outcomes of these newer generation implants. At this point, there are no published randomized trials comparing total knee arthroplasty with PFA for isolated PF disease, although Odumena and colleagues have published a protocol for an ongoing randomized trial.

**Conclusion**

The ideal patient for isolated PFA is a non-obese patient less than age 60 that has severe isolated and refractory PF arthritis secondary to trochlear dysplasia, trauma, or correctible mal-alignment. The patient must understand the high likelihood of TKA in the near future. Newer second-
generation implants have results that are comparable to TKA in the early and mid-term follow-up studies. More follow-up is needed to provide long-term outcomes for the second generation implants.

**Disclosure Statement**

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

**References**