The Clinical Outcome of Patellofemoral Arthroplasty

Jess H. Lonner, MD[a,*], Michael R. Bloomfield, MD[b]

KEYWORDS

• Patellofemoral arthroplasty (replacement) • Knee arthritis • Knee arthroplasty (replacement) results • Knee arthroplasty (replacement) design • Trochlea

KEY POINTS

- Patellofemoral arthroplasty (PFA) has a long record of use in the treatment of isolated patellofemoral arthritis, with outcomes influenced by patient selection, surgical technique, and trochlear implant design.
- The trochlear components have evolved from inlay-style to onlay-style designs, which have reduced the incidence of patellar instability.
- Inlay-design trochlear prostheses are inset within the native trochlea, flush with the surrounding articular cartilage. The component rotation is therefore influenced by the native trochlear inclination, which tends to be internally rotated relative to the anteroposterior and transepicondylar axes of the femur, accounting for the high incidence of patellar instability with inlay-design components.
- Onlay-design trochlear components are implanted perpendicular to the anteroposterior axis of the femur, resecting the anterior trochlear surface flush with the anterior femoral cortex and positioning the implant irrespective of the native trochlear inclination, which is the number one reason for the significant improvement in patellar tracking with onlay-style trochlear implants.
- Minimizing the risk of patellar instability with onlay-design PFAs has enhanced mid-term and long-term results and leaves progressive tibiofemoral arthritis as the primary failure mechanism beyond 10 to 15 years.
- Revision PFA to an onlay-design is reasonable to consider in the situation of a failed inlay-style trochlear prosthesis, if no tibiofemoral arthritis is present. Otherwise, revision to total knee arthroplasty can yield predictable results.

INTRODUCTION

Epidemiologic studies indicate that isolated patellofemoral arthritis affects nearly 10% of the population over 40 years of age.[1] In one study, women were more than twice as likely as men to have isolated anterior compartment degeneration (24% vs 11%),[2] likely related to subtle dysplasia and malalignment.[3] As the population ages and the burden of arthritis increases,[4] more patients will likely seek treatment for this condition in the upcoming years. In addition, as younger patients in their 30s through 50s continue to present with isolated patellofemoral arthritis, conservative operative treatments like patellofemoral arthroplasty (PFA) will remain important alternatives to total knee arthroplasty (TKA) when nonoperative interventions are ineffective.

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[a] Rothman Institute, Thomas Jefferson University, 925 Chestnut Street, 5th Floor, Philadelphia, PA 19107, USA; [b] Rothman Institute, Thomas Jefferson University Hospital, 925 Chestnut Street, 5th Floor, Philadelphia, PA 19107, USA
* Corresponding author.
E-mail addresses: Jess.lonner@rothmaninstitute.com; jesslonner@comcast.net

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Most patients with patellofemoral arthritis can be treated symptomatically and with nonoperative modalities (including anti-inflammatory medications, physical therapy, weight reduction, bracing, and injections). However, a small percentage of patients may require surgical intervention if these treatments fail. Surgical options include nonarthroplasty procedures (arthroscopic debridement, tibial tubercle unloading procedures, cartilage restoration, and patellectomy) and partial (patellofemoral) or TKA. Historically, nonarthroplasty surgical treatment has provided mixed and inconsistent results, with success rates of 60% to 70%, especially in patients with advanced arthritis.[5] Although TKA provides reproducible results in patients with isolated patellofemoral arthritis, it may be undesirable for those interested in a more conservative, kinematic-preserving approach, particularly in younger patients. Due to these limitations, PFA continues to emerge as a more mainstream option. This review focuses on the historical and contemporary results of PFA as influenced by advances in prosthetic (specifically trochlear component) design.

Indications for PFA

As with any surgical procedure, a prerequisite for good outcomes with PFA is proper patient selection. Therefore, results of any series of PFA should be interpreted in the context of appropriate indications. The ideal candidate for PFA has isolated, noninflammatory anterior compartment arthritis resulting in pain and functional limitations that are persistent despite reasonable attempts at nonoperative treatments. Patients should have only retropatellar and/or peri-patellar pain that is exacerbated by stairs, sitting with the knee flexed, and standing from a seated position. Symptoms should be reproducible during physical examination with squatting and patellar inhibition testing. An abnormal Q-angle or J-sign indicates significant maltracking and/or dysplasia, particularly with a previous history of patellar dislocations. The presence of these findings may necessitate concomitant realignment surgery with PFA. However, with newer prosthesis designs, moderate maltracking can be corrected with proper orientation of the prosthesis and occasionally a lateral release. Often, patients with patellofemoral arthritis will have significant quadriceps weakness, which should be corrected with preoperative physical therapy to prevent prolonged postoperative pain and functional limitations.

Radiographs should be consistent with isolated patellofemoral arthritis, indicated by joint space narrowing and osteophytes on the lateral and Merchant views (**Fig. 1**). Narrowing within the medial or lateral compartments on weight-bearing views may disqualify that patient from a PFA. The authors also prefer obtaining a preoperative magnetic resonance imaging scan to further evaluate the tibiofemoral compartments for evidence of chondral damage or reactive edema, to guide treatment between PFA and bicompartmental or total knee arthroplasty. Previous arthroscopy photographs are especially valuable in documenting the extent of anterior compartment cartilage loss and the presence or absence of degeneration elsewhere in the knee.

PFA DESIGN CONSIDERATIONS

PFA was first developed over 30 years ago, although it has remained somewhat controversial until recently because of high failure rates seen with early (and even some contemporary) inlay-style trochlear prosthesis designs (**Fig. 2**A). With contemporary onlay-style trochlear implants (see **Fig. 2**B) that replace the entire anterior trochlear surface and are more optimally positioned, high success rates and good functional outcomes are more easily achievable. **Table 1** summarizes key design differences between inlay-style and onlay-style trochlear components.

Inlay Style

Initial attempts at PFA used trochlear components inset into the native trochlea, attempting to position the prosthesis flush with the surrounding trochlear articular cartilage (**Fig. 3**). The resulting design characteristics have proved problematic when coupled with the inherent anatomic variations and inclination of the native trochlea, which make positioning of the component challenging relative to the articular surfaces and biases the component into internal rotation, predisposing to high rates of patellar maltracking, catching, and subluxation.

- The shapes of these components frequently do not match the shape of the trochlea, particularly in the situation of trochlear dysplasia, leading to malpositioning of the prosthesis as it will not sit flush against all surfaces. Several inlay prostheses have large radii of curvature. To avoid impingement of the implant on the anterior cruciate ligament or tibia by a proud inferior aspect of the prosthesis, flexion of these components may be necessary. Flexion of these components results in offset of the proximal aspect of the prosthesis from the anterior femoral cortex,

Fig. 1. Preoperative weight-bearing anteroposterior (*A*), lateral (*B*), and sunrise (*C*) radiographs demonstrating advanced patellofemoral arthritis.

causing catching and subluxation of the patella in the initial 15 to 30° of flexion.

- The rotation of the component is determined by the native trochlear orientation. A recent study by Kamath and colleagues[6] examined trochlear inclination angles in 329 patients with either normal or dysplastic patellofemoral anatomy. Based on magnetic

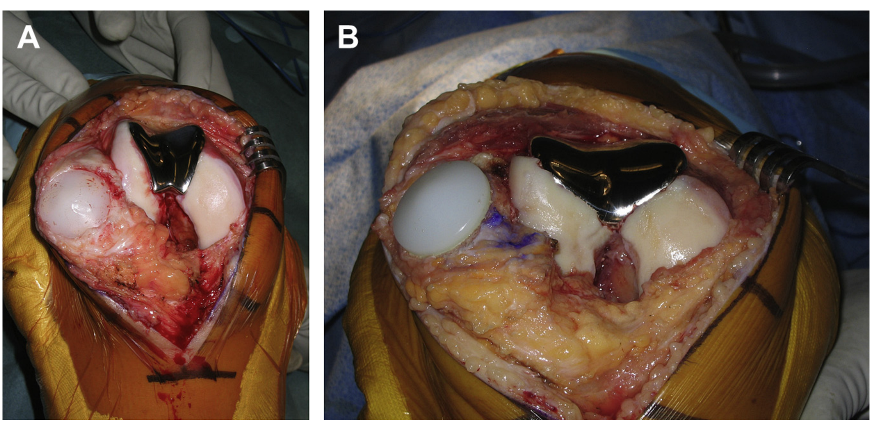

Fig. 2. Intraoperative photos showing components positioned after inlay (*A*) and onlay (*B*) methods of bone preparation.

Table 1
Generalized design characteristics of inlay and onlay designed patellofemoral prostheses

	Inlay	Onlay
Positioning	Inset flush with native trochlea	Replaces entire trochlea, perpendicular to AP axis
Rotation	Determined by native trochlea	Set by surgeon, perpendicular to AP axis
Width	Narrower	Wider
Proximal extension	No further than native trochlear surface	Extends further proximal than native trochlea

resonance imaging scans, both groups had trochlear inclination angles averaging 11.4° and 9.4° of internal rotation, respectively, relative to the anatomic landmarks (anteroposterior and transepicondylar axes). This finding explains the propensity to internally malrotate inlay-style trochlear components, which predisposes to patellar maltracking and subluxation. Like internally rotated femoral components in TKA, internal rotation of the trochlear component in PFA effectively medializes the trochlear groove, increases the Q-angle, and puts tension on the lateral retinaculum, all of which predispose to patellar maltracking and instability.

- The narrow width and often deep constraining sulcus of some inlay-style trochlear

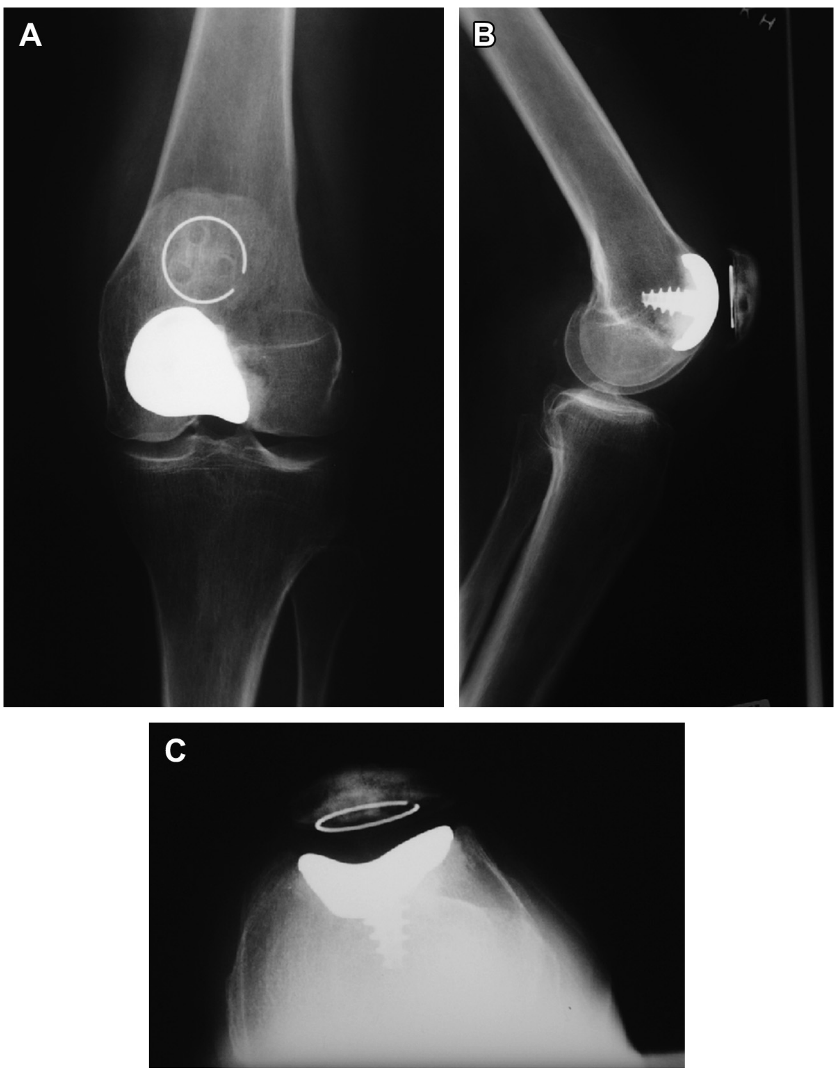

Fig. 3. Inlay design patellofemoral arthroplasty prosthesis. Weight-bearing anteroposterior (*A*), lateral (*B*), and sunrise (*C*) radiographs.

components are more constraining to the patella with little accommodation for patellar tracking, which also increases the potential for patellar maltracking.

- The proximal aspect of the inlay-style trochlear component does not extend proximal to the trochlear articular margin. This proximal aspect often results in the patella not being engaged in the trochlear component when the knee is in full extension, particularly in patients with patella alta. As the knee flexes, the patella transitions onto the trochlear component, which may cause catching and subluxation, particularly if the trochlear component is flexed, offset proximally, and internally rotated.

Onlay Style

Onlay-style trochlear prostheses (**Fig. 4**) replace the entire anterior trochlear surface, alleviating many of the issues described above when having to accept the constraints of native anatomic aberrations common in this population. This design can be applied to all patients, regardless of anatomic variations, and is therefore more versatile and suitable for general use.

- Most onlay prostheses have anatomic radii of curvature, ensuring the prosthesis sits flush with the anterior femoral cortex proximally and the articular cartilage above the intercondylar notch distally.
- The rotation of the trochlear component is determined by the surgeon intraoperatively based on anatomic landmarks, similar to TKA. The component is positioned perpendicular to the anteroposterior axis (Whiteside's line) and parallel to the transepicondylar axis, facilitating patellar tracking and eliminating the effect of native

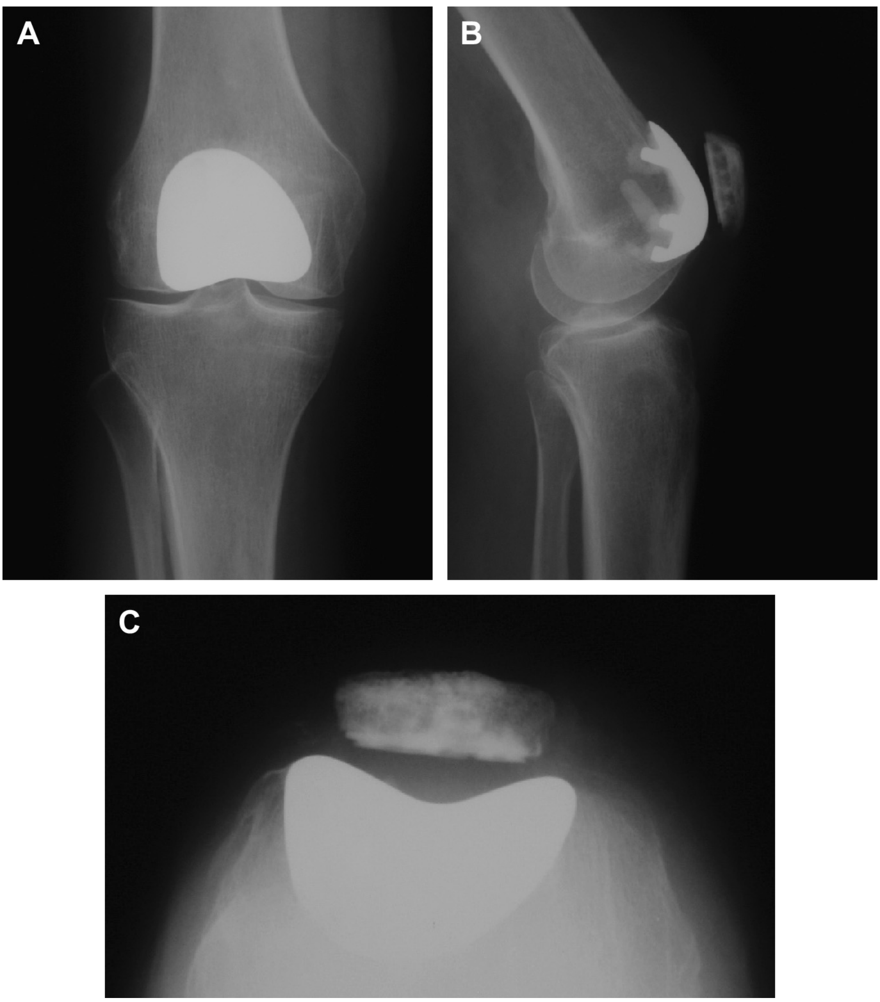

Fig. 4. Onlay design patellofemoral arthroplasty prosthesis. Weight-bearing anteroposterior (*A*), lateral (*B*), and sunrise (*C*) radiographs.

trochlear rotation seen with inlay prostheses (**Fig. 5**).

- Onlay prostheses are wider and less constraining than inlay designs, thus allowing greater excursion of the patella throughout the arc of motion.
- Onlay prostheses often extend further proximal than the native trochlear cartilage and are positioned flush against the anterior femoral cortex, eliminating the catching common to inlay designs and also keeping the patella engaged in the trochlea even in full extension.

RESULTS OF PFA

Primary PFA

Although patient selection and sound surgical technique are important drivers of success in PFA, the results of PFA have shown a disparity in the early and mid-term failures that occur as a result of patellar instability and maltracking, depending on whether an inlay-style or onlay-style component is used.[5] **Tables 2** and **3** contain the cumulative results of published series of inlay-style and onlay-style trochlear prosthesis designs, respectively. Although no studies have directly compared inlay-style and onlay-style trochlear prostheses, the preponderance of the evidence shows lower revision rates and need for secondary surgery to address patellar maltracking, and higher functional success rates and durability with the latter. Although initially poorly understood, high reoperation and revision rates with inlay-style trochlear designs were often attributed to poor patient selection, soft tissue imbalance, and component malposition. In those series, the components were likely positioned flush with some, but not all, articular surfaces (due to morphologic mismatches between surface anatomy and trochlear implant) and internally rotated due to the native trochlear inclination. Again, although poorly defined in the published series, the disproportionately low rates of satisfactory outcomes can likely be attributed at some level to trochlear component design features, which helps explain the data published in the Australian National Joint Registry, showing that the 5-year cumulative revision rate was greater than 20% for inlay prostheses and less than 10% for onlay designs.[7] Series reviewing the results of inlay-style implants have reported an incidence of patellar maltracking ranging between 17% and 36%.[5,8–10] Other studies that have reviewed the experience with different onlay-style trochlear designs in PFA have found a considerably lower incidence of patellar maltracking, typically less than 1%.[11–14] Several of the older and contemporary inlay-style PFA systems are no longer in use today. If patella tracking is satisfactory after PFA, the primary mode of failure will be progressive tibiofemoral arthritis, irrespective of the type of trochlear prosthesis used.

Late complications of PFA

As opposed to the short-term complications related most frequently to patellar catching and maltracking, late complications requiring revision may occur in the setting of a well-functioning PFA. Revision rates have been shown to be higher in obese patients,[15] likely due to a combination of the factors discussed below.

- Progression of tibiofemoral arthritis is the most common reason for long-term “failure” after successful PFA. In one series, 25% of patients at 15 years required additional surgery for progressive arthritis.[16] Two other series also found radiographic evidence of progressive degeneration in greater than 20% of knees.[11,17] Similarly, Nicol and colleagues[18] found a 12% revision rate for symptomatic tibiofemoral arthritis at a mean of 55 months. These authors also observed that the

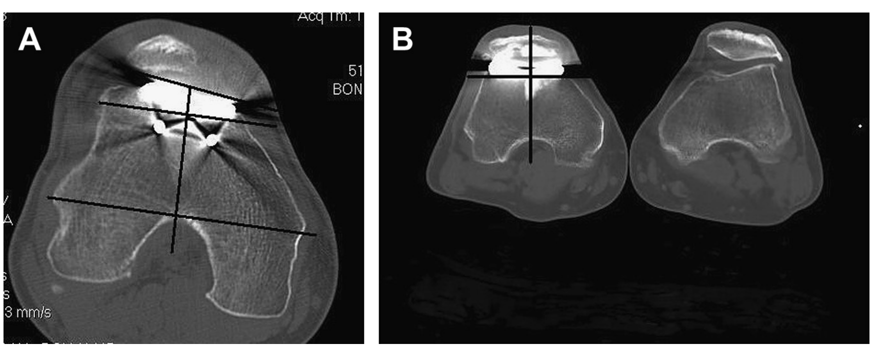

Fig. 5. (*A*) Axial CT scan of an inlay-style implant demonstrating internal rotation relative to the anteroposterior axis of the distal femur, resulting in lateral patellar catching and subluxation. (*B*) Axial CT scan of an onlay style trochlear prosthesis showing rotation perpendicular to the AP axis of the femur.

Table 2
Published results of inlay-style patellofemoral arthroplasty prostheses

Series (y)	Implant	No. of PFAs	Age in Years (Range)	Duration of Follow-up in Years (Range)	% of Good/ Excellent Results	% Revised
Blazina et al,[8] 1979	Richards Types I & II	57	39 (19–81)	2 (0.6–3.5)	NA	35
Krajca & Coker,[36] 1996	Richards Types I & II	16	64 (42–84)	5.8 (2–18)	88	6
Arciero & Toomey,[37] 1988	Richards Type II (14); CFS-Wright (11)	25	62 (33–86)	5.3 (3–9)	85	28
De Winter et al,[9] 2001	Richards Type II	26	59 (22–90)	11 (1–20)	76	19
Kooijman et al,[16] 2003	Richards Type II	45	50 (20–77)	17 (15–21)	86	22
van Jonbergen et al,[38] 2010	Richards Type II	185	52 (NA)	13.3 (2–30.6)	NA	25
Cartier et al,[39] 1990	Richards Types II & III	72	65 (23–89)	4 (2–12)	85	7
Cartier et al,[40] 2005	Richards Types II & III	79	60 (36–81)	10 (6–16)	77	25
Argenson et al,[21] 1995	Autocentric	66	57 (19–82)	5.5 (2–10)	84	15
Argenson et al,[19] 2005	Autocentric	66	57 (21–82)	16 y (12–20)	NA	42
van Wagenberg et al,[15] 2009	Autocentric	24	63 (31–81)	4.8 (2–11)	30	29
Tauro et al,[10] 2001	Lubinus	62	66 (50–87)	7.5 (5–10)	45	28
Smith et al,[41] 2002	Lubinus	45	72 (42–86)	4 (0.5–7.5)	69	19
Lonner,[5] 2004	Lubinus	30	38 (34–51)	4 (2–6)	84	33
Merchant,[42] 2004	Low contact stress	15	49 (30–81)	3.8 (2.3–5.5)	93	0
Charalambous et al,[43] 2011	Low contact stress	51	64 (47–84)	2.1 (0.4–5)	33	33
Sisto & Sarin,[44] 2006	Kinematch	25	45 (23–51)	6 (2.6–10)	100	0

Table 3
Published results of onlay-style patellofemoral arthroplasty prostheses

Series (y)	Implant	No. of PFAs	Age in Years (Range)	Duration of Follow-up in Years (Range)	% of Good/ Excellent Results	% Revised
Lonner,[5] 2004	Avon trochlea; Nexgen patella	25	44 (28–59)	0.5 (0.1–1)	96	0
Ackroyd et al,[11] 2007	Avon	109	68 (46–86)	5.2 (5–8)	80	3.6
Starks et al,[12] 2009	Avon	37	66 (30–82)	2 (NA)	86	0
Leadbetter et al,[13] 2009	Avon	79	58 (34–77)	3 (2–6)	84	6.3
Gao et al,[45] 2010	Avon	11	54 (46–74)	2 (0.5–4)	100	0
Odumenya et al,[17] 2010	Avon	50	66 (42–88)	5.3 (2.1–10.2)	NA	4
Mont et al,[14] 2012	Avon	43	29 (27–67)	7 (4–8)	NA	12
Beitzel et al,[46] 2012	Journey PFJ	22	46 (26–67)	2 (NA)	NA	4.5

indication for primary PFA was osteoarthritis in all of the revised patients, whereas none of the patients with trochlear dysplasia as the primary cause were revised. Other authors have also found that patients with primary trochlear dysplasia tend to have better long-term outcomes than those with primary osteoarthritis.[13,19]

- Loosening is an infrequent cause of late revision in most series.[11,20] Kooijman and coworkers found a loosening rate of 2% of prostheses at a mean of 15 years.[16]
- Despite relatively good mid-term clinical results,[21] Argenson and coworkers found in a subsequent follow-up study using the same patient series that the extended survivorship declined significantly, with 58% survivorship at mean 16 years postoperatively.[19] Most of these patients were revised for progression of arthritis (25%) or loosening (14%). In that series, most trochlear components that were revised for aseptic loosening were cementless designs. Cemented components fared substantially better.

PFA with Concomitant Procedures for Tibiofemoral Arthritis

One study has reported results of combined PFA and biologic reconstruction of isolated articular cartilage lesions of the tibiofemoral compartments. Lonner and colleagues[22] performed PFA with simultaneous autologous osteochondral transplantation in 4 knees with isolated full-thickness femoral condylar lesions. Lesion sizes ranged from 10 × 9 mm and 24 × 7 mm, which were reconstructed with up to 3 plugs taken from uninvolved areas of the trochlea that would be resurfaced by the prosthesis. At an average 2.7-year follow-up (range 2–4 years), good clinical results and improved Knee Society scores were reported. No reoperations or complications occurred, and no radiographic evidence of tibiofemoral arthritis was seen. These results are limited by the small sample size and short duration of follow-up.

Modular bicompartmental knee arthroplasty, consisting of both PFA and medial or lateral unicompartmental knee arthroplasty (UKA), has been proposed for the treatment of knee arthritis whereby one of the tibiofemoral compartments is spared and the ligaments are intact.[23,24] Although complications with a monolithic bicompartmental knee arthroplasty have been reported arising from potential femoral component malpositioning/malrotation,[25,26] use of a separate UKA and PFA (modular approach) allows independent placement of the prostheses and optimized sizing and orientation with superior results. Heyse and colleagues[27] reported on 9 knees in 9 patients treated with medial UKA and PFA. Three procedures were performed in a staged fashion, with a mean of 5 years between UKA and PFA. At a mean follow-up of 12 years (range, 4–17 years), no revision surgeries were necessary, although one asymptomatic patient had substantial progression of lateral arthritis. Knee Society scores increased significantly, as did the range of motion. Mahoney and colleagues[24] reported on their short-term experience with 17 unlinked UKA and PFA, observing mild or no pain and >120° of flexion in all patients. In that series all patients were able to rise unassisted and ascend stairs in a reciprocal manner. There were no cases of incompatibility between the UKA or PFA components. Lonner and colleagues[28] reviewed the initial 28 consecutive modular unlinked bicompartmental UKA/PFAs performed by the authors and found that at a minimum 2-year follow-up (range, 2–4 years), WOMAC, and Knee Society subscores all improved significantly. There were no perioperative complications and no radiographic evidence of loosening, polyethylene wear, or progressive arthritis of the lateral tibiofemoral compartment.

Revision Patellofemoral Arthroplasty

One study investigated the use of the role of revision PFA. Hendrix and colleagues[20] reported 14 failed first-generation inlay-style prostheses that were revised to a second-generation onlay-style PFA implant. The primary failure modes were component malposition, patellar subluxation/catching, polyethylene wear, and overstuffing; no loosening was reported. At a mean 5-year follow-up (range 3–7 years), significant improvements were noted in the Bristol Knee Scores, as well as its pain and function subscores. Five patients had evidence of mild tibiofemoral arthritis at reoperation, which predicted poorer outcome. Two of these 5 patients were revised to TKA by final follow-up. No malposition, loosening, wear, or subluxation was noted in any of the revision PFA prostheses. The authors concluded that revision PFA using an onlay-style trochlear component is a viable option when faced with a failed inlay-style PFA, provided there is no evidence of degeneration elsewhere within the joint. In addition, although the design characteristics of the inlay prosthesis likely contributed to its clinical failure, it also facilitated a relatively easy revision due to the bone-preserving nature of the early design.

As opposed to conversion of UKA to TKA, little has been written about revision of PFA to TKA. Lonner and colleagues[29] reported the results of a series of failed PFAs revised to TKA. Twelve PFA in 10 patients failed at a mean of 4 years postoperatively due to progression of arthritis alone or in combination with patellar maltracking and catching. Significant improvements in the clinical and functional Knee Society scores after revision were noted, with no evidence of wear, maltracking, or failure of the resultant reconstruction at a mean of 3 years. In that series, outcomes of conversion to TKA were similar to those after primary TKA; however, only the trochlear components were revised. Outcomes may not have been as optimal if the patellar components required revision as well.

PFA Versus TKA for Isolated Patellofemoral Arthritis

Several studies have reported successful results of TKA for isolated anterior compartment arthritis, with good midterm results in up to 90% of patients.[30–32] One retrospective study compared outcomes in 45 patients undergoing PFA or TKA at mean of 2.5 years of follow-up.[33] They found similar Knee Society and pain scores, but the PFA group had significantly higher activity scores. However, high-quality comparisons of PFA to other treatments, including TKA, for isolated patellofemoral arthritis have not been reported to date. One ongoing randomized controlled trial is currently evaluating PFA compared with TKA in this scenario and is expected to report results in 2013.[34]

A recent meta-analysis of 28 studies compared complications with PFA and TKA performed for isolated patellofemoral arthritis.[35] The authors found an eightfold higher likelihood of reoperation and revision for all PFA compared with TKA. However, when comparing second-generation onlay prostheses only, no significant differences in reoperation, revision, pain, or mechanical complications were found, indicating a significant effect of implant design. On subgroup analysis, first-generation inlay-style prostheses had over fourfold higher rates of significant complications than second-generation prostheses, likely biasing the overall results. These data indicate that modern onlay-style PFA and TKA likely have similar rates of complications in this patient population.

In conclusion, the significant failure rates and patellar tracking complications that plagued early inlay PFA designs have now been minimized with the modern generation of onlay-style prostheses. PFA outcomes can be optimized with proper patient selection, meticulous surgical technique, and selection of an onlay-style implant that can be positioned perpendicular to the AP axis of the femur. These factors have contributed to a renewed enthusiasm for PFA as a successful treatment option for this challenging clinical problem.

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