Advances in Patellofemoral Arthroplasty

Sabrina M. Strickland¹ · Mackenzie L. Bird² · Alexander B. Christ³

Published online: 2 May 2018

© Springer Science+Business Media, LLC, part of Springer Nature 2018

Abstract

Purpose of Review To describe current indications, implants, economic benefits, comparison to TKA, and functional and patient-reported outcomes of patellofemoral arthroplasty.

Recent Findings Modern onlay implants and improved patient selection have allowed for recent improvements in short- and long-term outcomes after patellofemoral joint replacement surgery.

Summary Patellofemoral arthroplasty has become an increasingly utilized technique for the successful treatment of isolated patellofemoral arthritis. Advances in patient selection, implant design, and surgical technique have resulted in improved performance and longevity of these implants. Although short- and mid-term data for modern patellofemoral arthroplasties appear promising, further long-term clinical studies are needed to evaluate how new designs and technologies will affect patient outcomes and long-term implant performance.

Keywords Patellofemoral arthroplasty · PFA · Patellofemoral joint replacement · Isolated patellofemoral osteoarthritis

Introduction

Osteoarthritis (OA) of the knee is relatively common and epidemiologic studies have demonstrated that 10% of these patients over 40 years old have OA confined to the patellofemoral joint [1]. Isolated degeneration of the patellofemoral articulation has also been reported in 24% of women and 11% of men greater than 55 years who present with symptomatic knee arthritis [2]. These patients are typically younger and female, whose condition results from abnormal loading across the patellofemoral joint. Many patients attempt conservative treatments such as physical therapy, bracing, injections, weight loss, and activity modification. Failure to experience improvements through these measures

often results in the decision to seek surgical care [3]. Joint-preserving procedures include chondroplasty, microfracture, lateral release, autologous cartilage implantation, and tibial tubercle transfer (TTT), although these do not produce consistent results.

The surgical “gold standard” for knee OA has traditionally been total knee arthroplasty (TKA), which literature has demonstrated to provide good long-term outcomes. However, TKA surgery results in the loss of normal knee kinematics and markedly limits the types of activities and the activity level that patients can return to after surgery. Another alternative for patients with isolated patellofemoral OA is patellofemoral arthroplasty (PFA). This bone- and ligament-conserving partial knee replacement more accurately reproduces the natural knee movements compared to TKA.

This article is part of the Topical Collection on *Advances in Patellofemoral Surgery*

✉ Sabrina M. Strickland
StricklandS@HSS.edu

¹ The Patellofemoral Center, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA

² Tulane University School of Medicine, New Orleans, LA 70122, USA

³ Division of Adult Reconstruction and Joint Replacement, Hospital for Special Surgery, New York, NY 10021, USA

History and Implant Models

PFA dates back to the 1950s, when McKeever reported on 40 patients with a patellar resurfacing Vitallium prosthesis that screwed onto the back of the patella [4]. In the 1970s, first-generation resurfacing implants were introduced that replaced the worn cartilage of the femur without altering the shape of the subchondral bone, and thus were dependent on the anatomy of the native trochlea [5] (Fig. 1). Design

Fig. 1 Images of the first-generation Richards II prosthesis. **a** Anteroposterior radiograph. **b** Lateral radiograph. **c** Photograph. Adapted from “Long-Term Outcomes of Patellofemoral Arthroplasty,”

by H.P. van Jonbergen, 2010, *The Journal of Arthroplasty*, 25, p. 1066–1071. Copyright 2010 by Elsevier Inc. Adapted with permission

limitations, such as narrow anterior femoral flange width and suboptimal trochlear implant geometry, led to patellar tracking problems, instability, subluxation, and impingement. Failure rates were reported between 17.8–44%, 20–33%, 10–42%, and 16–78%, in the *Depuy's Autocentric™*, *Depuy's LCS™*, *Smith & Nephew's Richards™*, and *Waldemar's Lubinus™*, respectively [6–23].

These high failure rates necessitated the development of second-generation onlay implants that use the same anterior femoral cut as TKA, thus replacing the cartilage and subchondral bone of the anterior compartment of the knee (Fig. 2). These designs include a broad trochlear surface and valgus tracking angle to promote appropriate patellar tracking [3]. The surgeon could further optimize patellar tracking by controlling the amount of external rotation with which the anterior cut is made. Also, in cases of patellofemoral

instability and arthritis, second-generation PFA could be combined with medial patellofemoral ligament (MPFL) reconstruction to address both diagnoses simultaneously. Finally, if significant patellar subluxation or tilt without instability is present, the more forgiving trochlear design of the second-generation onlay implants could allow that to be addressed through medialization of the tibial tuberosity with or without lateral retinaculum release and/or lateral facetectomy during the same procedure.

One of the most studied second-generation implants is the Avon patellofemoral replacement, which accounts for 40% of all PFAs according to the National Joint Registry of England and Wales (*Stryker*, Howmedica Osteonics, Allendale, NJ, USA). The features of this implant are a 3 mm medially offset patellar dome and a broad, symmetrical femoral trochlear flange that narrows distally, which overall facilitates patellar

Fig. 2 The Hermes prosthesis, a second-generation PFA implant. Adapted from “Design, operative technique and ten-year results of the Hermes patellofemoral arthroplasty,” by H. Philippe, 2014, *Int Orthop*, 38, p. 437–442. Copyright 2013 by Springer-Verlag Berlin Heidelberg. Adapted with permission

tracking, stability, and engagement during flexion with minimal constraint during extension [24]. Survivorship for the Avon implant at 5 years ranges from 96.1–100%, and the documented revision rate at 5 years of 7.76% is lower than the 9.51% revision rate for all PFAs [24–32].

Another relatively new second-generation implant with a symmetrical trochlear component is the Femoro Patella Vialli (FPV) (Wright Medical Technology, Arlington, TN, USA), which is reported to have a 3-year survival rate between 85 and 97% [33–35]. Al-Hadity's FPV study demonstrated this implant to have comparable survivorship, 97% at 5 years, and improvements in Oxford Knee Score, which measures pain and function, compared to the Avon implant. A more recent study showed similarly encouraging results with no implant failures observed and only one revision to TKA due to post-operative rheumatoid arthritis diagnosis [36].

Several other second-generation implant designs exist; however, there is a paucity of outcomes reported in the literature. This includes *Depuy's* second-generation Sigma patellofemoral implant (Warsaw, IN, USA), which has been redesigned to decrease the overhang impingement commonly associated with postoperative anterior knee pain. Overall, this implant has shown significantly improved survivorship, 92% at 2 years, compared to *Depuy's* first-generation implants, the Autocentric and LCS [37, 38]. The Natural Knee II Patello-femoral Joint System (Zimmer, Warsaw, IN, USA) has demonstrated a 90% survivorship at 5-year follow-up. In their initial cohort of 40 knees in 34 patients, the designers reported that two patients underwent revision for traumatic injuries, one patient was revised for retained cement that eroded the patellar component, and a fourth patient was converted to TKA for an unknown reason at an outside institution [39].

Some companies have opted to create second-generation designs with an asymmetric trochlea, in which an elevated lateral flange resists the lateralizing forces exerted by the quadriceps [40]. These designs include the JourneyCompetitor, Vanguard, Hermes, Gender Solutions, and Leicester models.

In particular, the JourneyCompetitor (*Smith & Nephew*, Andover, MA, USA) was designed with a lateralized and deepened trochlear groove to improve patellar tracking throughout flexion and extension. This implant was shown to improve daily pain and clinical scores at 2 years postoperatively, and the greatest improvements were observed in patients being treated for concomitant patellofemoral instability [41].

The Vanguard prosthesis (*Biomet*, Warsaw, IN, USA) was designed with a trochlea that extends to the intercondylar notch and allows the convex patellar button to remain in contact from full extension to 100° of flexion, though there is the potential for ACL impingement. This prosthesis had a 94.3% survivorship at an average of 3.7 years; out of 53 patients evaluated, one revision was due to neuropathic pain and two

revisions were due to periprosthetic patellar fractures in patients after falling [42].

Similarly, the Hermes prosthesis (*Ceravor*, Roissy-en-France, France) was designed to reduce the loads on the lateral facet by allowing more external rotation and translocation of the femoral trochlear component by incorporating 7° of valgus into the trochlear groove. In a study of 85 implants at 10-year follow-up, three underwent conversion to TKA due to disease progression, and only four patients experienced slight lateral patellar subluxation and tilt. There were no failures for dislocation, fracture, wear, or maltracking [43].

Given that over 75% of PFAs are performed in women, the Gender Solutions (*Zimmer*, Warsaw, IN, USA) was designed and tailored to better fit female patients with a naturally increased trochlear groove angle [44, 45]. This implant demonstrated a survival rate of 95.6% at 3 years, with all failures being conversions to TKA due to progression of osteoarthritis [46•].

The implant with the best recorded survivorship in the literature is a custom patellofemoral implant design, the *KineMatch Custom PFR™* (Camarillo, CA, USA) [47, 48]. Twenty-five knees in 22 patients have demonstrated a survivorship of 100% at an average of 11.3 years, with no additional required surgeries or component loosening. Though all knees experienced some degree of pain, there were no reports of weakness or instability. Though this custom prosthesis is more expensive, the purported benefits include a patient-specific anatomic fit and appropriate patellofemoral alignment and medial-lateral constraint at the time of surgery.

Overall, improvements have been made in the understanding of patellar stability and tracking, and outcomes have improved due to advances in surgical indications, new implant designs, component positioning, and soft tissue balancing [49, 50]. Survivorship of both first- and second-generation PFA implants, calculated using a Kaplan-Meier estimation, is 91.7, 83.3, 74.9, and 66.6% at 5, 10, 15, and 20 years, respectively [51] (Fig. 3). Though the revision rates for second-generation PFA have improved dramatically, some patients are still not satisfied with their surgeries. Currently, there is scant literature on how the psychosocial aspects of undergoing PFA affect patient outcomes. One recent study determined that dissatisfied patients and those whose expectations were not met had significantly lower Mental Health scores (Short Form-36) after PFA, despite clinical and radiographic success of the PFA implant [52•]. These results imply that poor mental health may partially explain low patient satisfaction, though future studies are necessary to further explore the impact of mental health on knee arthroplasty outcomes.

Indications/Contraindications

In addition to improved implant design, careful patient selection has been recognized as a critical factor in

Fig. 3 Survivorship of patellofemoral arthroplasty (PFA) using the Kaplan-Meier method. Adapted from “Survivorship and Functional Outcomes of Patellofemoral Arthroplasty: A Systematic Review,” by J.P. van der List, 2017, *Knee Surg Sports Traumatol Arthrosc*, 25, p. 2622–2631. Copyright 2015 by European Society of Sports Traumatology, Knee Surgery, Arthroscopy (ESSKA). Adapted with permission

determining the success of PFA [5, 20, 53, 54]. The ideal candidate for PFA has primary or post-traumatic isolated patellofemoral OA or has developed patellofemoral arthritis associated with recurrent patellar subluxation or dysplasia of the trochlea [14, 55]. Patients with significant pain or evidence of OA in the medial or lateral tibiofemoral compartments should be excluded from PF arthroplasty, as well as those with tibiofemoral malalignment and inflammatory joint disease.

There is currently conflicting information regarding the effect of BMI on outcomes after PFA. While some studies demonstrate that obesity did not affect outcomes, a recent retrospective report indicates that a BMI $30 \geq \text{kg/m}^2$ resulted in lower patient satisfaction and no significant improvements in functional outcomes, as measured by the Melbourne Knee score and the Knee Society function score [38]. The same study, as well as another by Dahm et al., showed that the absence of trochlear dysplasia put patients at a higher risk of conversion surgery to TKA due to greater progression of tibiofemoral joint disease than patients with trochlear dysplasia [56].

Robotic PFA

As interest in robotic-assisted arthroplasty continues to increase, surgeons have applied these technologies to PFA [57]. Although several studies looking at the clinical and radiographic outcomes of bicompartamental arthroplasty have been published, no studies on robotic PFA are available [58–60]. One study has reported that there were no complications related to the pin sites following robotic joint replacement, demonstrating the low morbidity associated with this arthroplasty technique [61]. Although there are numerous studies demonstrating that robotic-assisted arthroplasty improves component positioning and alignment [62], it remains to be seen how new technologies will affect outcomes and survivorship of PFA.

PFA versus TKA

Complication, revision, and conversion rates after PFA surgery have led to controversy over the surgical treatment for isolated patellofemoral OA. The most recent research seeks to compare outcomes of PFA compared to the “gold standard,” TKA.

An early retrospective comparison study of PFA versus TKA described benefits of improved function, return to higher activity, and less morbidity in the PFA patients using the AVON implant [63]. There were no revisions nor further surgery needed after PFA, compared to the TKA group, in which one patient required manipulation for stiffness and one patient developed deep vein thrombosis after surgery. While both groups experienced similar pain relief results and satisfaction, PFA patients had shorter hospital stays after surgery, less blood loss, and fewer complications.

A 2011 meta-analysis of 28 studies showed no significant differences in reoperation, revision, pain, or mechanical complications between second-generation PFA and TKA [64]. However, first-generation PFA did have higher complication and reoperation rates when compared to second-generation PFA [64] (Table 1). Similarly, second-generation PFA revision and reoperation rates (0.4 and 2.7%) were found to be comparable to the revision and reoperation rates in primary TKA (0.5 and 2.0%) from early and mid-term follow-up studies [65]. However, this study also demonstrated that survivorship was significantly lower in second-generation PFA than TKA.

A 2017 randomized clinical trial found that TKA patients lost almost 3 months of knee function in the first 2 years and had longer recoveries compared to PFA patients [66]. PFA patients in the study also demonstrated a greater range of motion, better physical function scores, less pain, and significantly better results for all of the “symptoms” dimensions of the KOOS and OKS.

Table 1 Rates and reasons for postoperative complications, reoperation, and revision surgeries for PFA or TKA. Adapted from “Complications after patello-femoral versus total knee replacement in the treatment of isolated patello-femoral osteoarthritis. A meta-analysis,” by C.J. Dy, 2012, *Knee Surg Sports Traumatol Arthrosc*, 20, p. 2174–2190. Copyright 2011 by Springer-Verlag. Adapted with permission

Variable	All PFA	1G PFA	2G PFA	TKA
Weighted pooled-proportion (95% CI)				
All complications	0.30 (0.22, 0.38)	0.39 (0.31, 0.47)	0.14 (0.07, 0.22)	0.07 (0.03, 0.12)
Mechanical	0.10 (0.05, 0.16)	0.14 (0.07, 0.23)	0.03 (0.01, 0.06)	0.01 (0.002, 0.03)
Pain or stiffness	0.07 (0.03, all)	0.08 (0.03, 0.14)	0.04 (0.01, 0.09)	0.05 (0.02, 0.08)
Progression of OA	0.08 (0.04, 0.11)	0.09 (0.05, 0.15)	0.04 (0.01, 0.10)	NA
Other complications	0.03 (0.02, 0.05)	0.04 (0.02, 0.06)	0.02 (0.004, 0.04)	0.02 (0.004, 0.04)
Reoperation (any reason)	0.21 (0.15, 0.29)	0.30 (0.22, 0.38)	0.07 (0.04, 0.11)	0.02 (0.003, 0.05)
Reason for reoperation				
Mechanical	0.07 (0.04, 0.12)	0.11 (0.06, 0.17)	0.02 (0.01, 0.03)	0.01 (0.002, 0.03)
Pain or stiffness	0.05 (0.02, 0.09)	0.06 (0.02, 0.13)	0.03 (0.004, 0.07)	0.01 (0.001, 0.03)
Progression of OA	0.06 (0.04, 0.09)	0.09 (0.05, 0.13)	0.03 (0.02, 0.05)	NA
Other reasons	0.01 (0.006, 0.02)	0.01 (0.005, 0.02)	0.01 (0.002, 0.02)	0.01 (0.001, 0.03)
Revision arthroplasty (revision PFA/TKA or conversion to TKA)	0.11 (0.07, 0.16)	0.16 (0.11, 0.23)	0.04 (0.02, 0.06)	0.01 (0.0003, 0.02)
Revision PFA	0.04 (0.02, 0.06)	0.06 (0.03, 0.09)	0.006 (0.001, 0.02)	NA
Conversion to TKA	0.07 (0.04, 0.11)	0.10 (0.05, 0.16)	0.03 (0.01, 0.05)	NA

1G PFA first-generation patellofemoral arthroplasty, 2G PFA second-generation patellofemoral arthroplasty, NA not applicable

TKA Conversion

PFA is sometimes viewed as a bridging surgery for younger patients until they require conversion to TKA [67]. However, this concept has been met with some skepticism as it was unclear whether the functional outcomes of conversion of PFA to TKA would be more consistent with primary or revision TKA.

A recent 2017 systematic review of 39 cohort studies and three registries assessed the causes of 938 PFA failures from 1996 to 2015. Overall, PFA failure was due to OA progression (38%), pain (16%), aseptic loosening (14%), and patellar maltracking (14%) [68•]. On closer inspection, early failures in more recent studies were mostly attributed to pain (31%), while late failures in older studies were a result of OA progression (46%) [26, 69] (Table 2).

A 2006 study on the conversion of 12 PFA to TKA in ten patients demonstrated significantly improved Knee Society clinical and functional scores at a mean follow-up of 3.1 years. There was neither clinical nor radiographic evidence of patellofemoral maltracking, loosening, or wear. Despite short-term follow-up, the results of the TKA did not appear to be compromised after conversion of failed PFA [70]. In two other small studies, it was also suggested that conversion of PFA to TKA has postoperative patient outcomes and surgical characteristics comparable to primary TKA and superior to revision TKA [71•, 72]. Although there were higher complication rates and less satisfaction for PFA conversion to TKA

than primary TKA, conversion surgeries used a standard TKA implant and rarely had to revise the patellar button, making them relatively straightforward [71•, 73].

Economic Benefits

While the attractiveness of PFA has been driven by its more conservative nature in terms of bony resection and knee kinematics, particularly in younger patients, many have contended that it lacks long-term economic advantages when compared to TKA because of higher revision rates. Currently, there are no randomized clinical trials (RCT) that compare the quality of life outcome assessments, functional knee scores, and complication rates between the two arthroplasty techniques [32]. However, the cost-effectiveness of PFA versus TKA has been assessed using a Markov transition state model and revision rates derived from the National Joint Registry for England, Wales, Northern Ireland, and the Isle of Man [74•]. This study assessed lifetime costs, quality-adjusted life year (QALY) gains, and incremental cost-effectiveness ratio (ICER) from a healthcare payer perspective and determined that PFA was more expensive than TKA (\$49,811 versus \$46,632, respectively), but also more effective (14.3 QALYs versus 13.3 QALYs, respectively). When accounting for the functional advantages and implant survivorship of PFA, the model's results suggest that a 24.5% decrease in annual rates of PFA revision would make it both less expensive and more effective than

Table 2 Reported modes of patellofemoral arthroplasty failure in cohort studies and registries published from 1996 to 2015. Adapted from “Why do patellofemoral arthroplasties fail today? A systematic review,” by J.P. van der List, 2017, *The Knee*, 24, p. 2–8. Copyright 2015 by Elsevier B.V. Adapted with permission

Study characteristics				Failure modes												
Author	Year	Start	End	Prosthesis design	No. of PFA	No. failures	OA prog.	Pain	Asep. loos.	Maltrack.	Malpos.	Wear	Infection	Stiffness	Fracture	Other
Cohort studies																
Krajca [63]	1996	1975	1991	Bechtol I & II	16	1				1						
Mertl [48]	1997	1988	1994	Unknown	51	3	3									
De Cloedt [64]	1999	1986	1995	Autocentric	45	8			3	4	1					
De Winter [70]	2001	1978	1995	Richards II	26	5	1	1		3						
Tauro [68]	2001	1989	1995	Lubinus	27	21	5			15					1	
Smith [56]	2002	1992	1998	Lubinus	45	7	3	1		3						
Kooijman [73]	2003	1977	1983	Richards II	45	19	12		1	1	2		1	1		3
Board [51]	2004	1994	1999	Lubinus	17	4	2									
Ackroyd [27]	2005	1997	2004	Avon	170	11	11									
Argenson [11]	2005	1972	1990	Autocentric	66	29	14		8				3	4		
Cartier [44]	2005	1975	1991	Richards II & III	79	8	8									
Lonner [74]	2006	1997	2003	Multiple		12	6			3						3
Nicol [67]	2006	1996	1999	Avon	103	14	12			1						
Jorgensen [69]	2007	1996	1999	Richards II	31	3	2					1				
Gadeyne [65]	2008	1986	2007	Multiple	45	11	5									6
Hendrix [75]	2008	1996	2002	Lubinus		14				8	1					5
Mohammed [54]	2008	1997	2006	Multiple	101	4	3						1			
Butler [60]	2009	1994	2002	Patient-specific	22	1				1						
Leadbetter [49]	2009	2001	2007	Avon	79	5	4			1						
Starks [45]	2009	2002	2007	Avon	37	2				1					1	
Odumenya [62]	2010	1998	2007	Avon	50	2	2									
van Jongbergen [72]	2010	1976	2005	Richards II	181	41	23		4		10	4				
Charalambous [33]	2011	2004	2008	LCS	51	17		12		3	2					
Sarda [58]	2011	2002	2007	Avon	44	2	1	1								
Mont [66]	2012	2001	2006	Avon	43	5	4							1		
Yadav [34]	2012	2003	2008	LCS	51	10	2			8						
Hutt [76]	2013			Multiple		21	12	2	1		5					1
Davies [52]	2013	2007	2010	FPV	52	7	1	6								
Hofmann [30]	2013	2010	2011	Natural Knee II	40	4			1	1					1	1
Morris [47]	2013	2006	2011	Various	31	1				1						
Williams [46]	2013	2007	2011	FPV	48	7	5								1	1

Table 2 (continued)

Study characteristics				Failure modes												
Author	Year	Start	End	Prosthesis design	No. of PFA	No. failures	OA prog.	Pain	Asep. loos.	Maltrack.	Malpos.	Wear	Infection	Stiffness	Fracture	Other
Al-Hadidy [50]	2014	2006	2012	FPV	53	2	2								1	1
Benazzo [59]	2014	2007	2012	Multiple	25	3	2		1							
Dahm [55]	2014	2003	2009	Avon	59	2	2									
Fink [53]	2014	2005	2012	Vanguard	53	3		1							2	
Hernigou [71]	2014	1997	2003	Hermes	85	3	3									
Akhbari [61]	2015	2001	2011	Avon	61	4	3			1						
Hoogervorst [35]	2015	1998	2007	Richards II	33	7	5		1	1						
Liow [57]	2015	2008	2012	Sigma	51	4	3			1						
Registries studies																
UK [77]	2012	2003	2010	Multiple	2495	195	22	72	25	27		12	6	7	6	18
New Zealand [78]	2014	1999	2013	Multiple	243	20		9	2							9
Australia [10]	2014	1999	2013	Multiple	4634	396	173	53	81	11	16	15	11			36
Total cohort studies (%)					2065	327	49%	6%	7%	17%	7%	2%	2%	2%	2%	6%
Total registries (%)					7372	611	32%	22%	18%	6%	3%	4%	3%	1%	1%	10%
Cohort studies versus registries							<0.001	<0.001	<0.001	<0.001	<0.001	0.075	0.227	0.390	0.269	9.047
Total (%)					9437	938	38%	16%	14%	10%	4%	4%	2%	1%	1%	9%

PFA, patellofemoral arthroplasty; OA prog, progression of osteoarthritis; Asep. loos., Aseptic loosening; Maltrack., Maltracking of the patella; Malpos., Malpositioning of components

TKA. Though PFA is considered cost-effective when it provides at least a 1.0% greater utility than TKA, further data is necessary to quantify health-related quality of life between the two arthroplasty techniques.

Conclusions

Patellofemoral arthroplasty is a bone-conserving arthroplasty technique used to successfully treat isolated patellofemoral arthritis. From its inception as a patellar resurfacing prosthesis in the 1950s, the procedure has greatly advanced through new implant designs, better patient selection, and improved surgical techniques. While the revision and reoperation rates of second-generation PFA implants are now approaching other partial knee replacements, the survivorship of second-generation PFA implants is still significantly lower than TKA. However, in general, PFA patients experience a shorter recovery, less blood loss, less pain, better physical function, and a greater range of motion than TKA patients. Progression of tibiofemoral arthritis represents up to one-third of PFA conversions and thus more stringent patient selection for isolated patellofemoral arthritis may optimize outcomes. Encouragingly, PFA conversion to TKA has similar postoperative patient outcomes and surgical characteristics to primary TKA, although conversion TKA does have higher complication rates. Recent improvements in PFA implant design and more meticulous patient selection have improved survivorship, making PFA an economically beneficial joint-preserving procedure in younger patients. Future studies assessing the long-term results of new designs and technologies of PFA as well as comparison studies to TKA are necessary to evaluate patient outcomes and implant performance.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent No human or animal studies were performed by the authors. This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance

1. Davies AP, Vince AS, Shepstone L, Donell ST, Glasgow MM. The radiologic prevalence of patellofemoral osteoarthritis. *Clin Orthop Relat Res.* 2002;402:206–12. <http://www.ncbi.nlm.nih.gov/pubmed/12218486>.
2. McAlindon TE, Snow S, Cooper C, Dieppe PA. Radiographic patterns of osteoarthritis of the knee joint in the community: the importance of the patellofemoral joint. *Ann Rheum Dis.* 1992;51(7):844–9. <https://doi.org/10.1136/ard.51.7.844>.
3. Walker T, Perkinson B, Mihalko WM. Patellofemoral arthroplasty: the other unicompartmental knee replacement. *Instr Course Lect.* 2013;62:363–71.
4. McKeever DC, Sherk HH. THE CLASSIC: patellar prosthesis. *Clin Orthop Relat Res.* 2005;440:13–21. <https://doi.org/10.1097/01.blo.0000187334.15841.05>.
5. Blazina ME, Fox JM, Del Pizzo W, Broukhim B, Ivey FM. Patellofemoral replacement. *Clin Orthop Relat Res.* 1979;144:98–102. <https://doi.org/10.1097/01.blo.0000172301.66790.62>.
6. De Cloedt P, Legaye J, Lokietek W. Femoro-patellar prosthesis. A retrospective study of 45 consecutive cases with a follow-up of 3–12 years. *Acta Orthop Belg.* 1999;65(2):170–5. <http://www.ncbi.nlm.nih.gov/pubmed/10427798>.
7. Argenson J-NA, Flecher X, Parratte S, Aubaniac J-M. Patellofemoral arthroplasty: an update. *Clin Orthop Relat Res.* 2005;440(440):50–3. <https://doi.org/10.1097/01.blo.0000187061.27573.70>.
8. Charalambous CP, Abiddin Z, Mills SP, Rogers S, Sutton P, Parkinson R. The low contact stress patellofemoral replacement: high early failure rate. *J Bone Joint Surg Br.* 2011;93(4):484–9. <https://doi.org/10.1302/0301-620X.93B4.25899>.
9. Yadav B, Shaw D, Radcliffe G, Dacheppalli S, Kluge W. Mobile-bearing, congruent patellofemoral prosthesis: short-term results. *J Orthop Surg (Hong Kong).* 2012;20(3):348–52.
10. de Winter WE, Feith R, van Loon CJ. The Richards type II patellofemoral arthroplasty: 26 cases followed for 1–20 years. *Acta Orthop Scand.* 2001;72(5):487–90. <https://doi.org/10.1080/000164701753532826>.
11. Kooijman HJ, Driessen AP, van Horn JR. Long-term results of patellofemoral arthroplasty. A report of 56 arthroplasties with 17 years of follow-up. *J Bone Joint Surg Br.* 2003;85(6):836–40.
12. Cartier P, Sanouiller JL, Khefacha A. Long-term results with the first patellofemoral prosthesis. *Clin Orthop Relat Res.* 2005;436(436):47–54.
13. Jørgensen PS, Konradsen LA, Mati WB, Tørholm C. Treatment of patellofemoral arthritis with patello-femoral arthroplasties. *Ugeskr Laeger.* 2007;169(23):2201–4.
14. van Jonbergen HP, Werkman DM, Barnaart LF, van Kampen A. Long-term outcomes of patellofemoral arthroplasty. *J Arthroplast.* 2010;25(7):1066–71. <https://doi.org/10.1016/j.arth.2009.08.023>.
15. Hoogervorst P, de Jong RJ, Hannink G, van Kampen A. A 21% conversion rate to total knee arthroplasty of a first-generation patellofemoral prosthesis at a mean follow-up of 9.7 years. *Int Orthop.* 2015;39:1857–64. <https://doi.org/10.1007/s00264-015-2941-1>.
16. Tauro B, Ackroyd CE, Newman JH, Shah NA. The Lubinus patellofemoral arthroplasty. A five- to ten-year prospective study. *J Bone Joint Surg Br.* 2001;83(5):696–701.
17. Smith AM, Peckett WRC, Butler-Manuel PA, Venu KM, D'Arcy JC. Treatment of patello-femoral arthritis using the Lubinus patellofemoral arthroplasty: a retrospective review. *Knee.* 2002;9(1):27–30. [https://doi.org/10.1016/S0968-0160\(01\)00127-2](https://doi.org/10.1016/S0968-0160(01)00127-2).
18. Board TN, Mahmood A, Ryan WG, Banks AJ. The Lubinus patellofemoral arthroplasty: a series of 17 cases. *Arch Orthop Trauma Surg.* 2004;124(5):285–7. <https://doi.org/10.1007/s00402-004-0645-x>.
19. Hendrix MR, Ackroyd CE, Lonner JH. Revision patellofemoral arthroplasty: three- to seven-year follow-up. *J Arthroplast.* 2008;23(7):977–83. <https://doi.org/10.1016/j.arth.2007.10.019>.
20. Arciero RA, Toomey HE. Patellofemoral arthroplasty. A three- to nine-year follow-up study. *Clin Orthop Relat Res.* 1988;236:60–71. <http://www.ncbi.nlm.nih.gov/pubmed/3180587>.

21. Gadeyne S, Besse JL, Galand-Desme S, Lerat JL, Moya B. Results of self-centering patellofemoral prosthesis: a retrospective study of 57 implants. *Rev Chir Orthop Reparatrice Appar Mot.* 2008;94(3):228–40. <https://doi.org/10.1016/j.rco.2007.06.001>.
22. van Wagenberg JM, Speigner B, Gosens T, de Waal Malefijt J. Midterm clinical results of the Autocentric II patellofemoral prosthesis. *Int Orthop.* 2009;33(6):1603–8. <https://doi.org/10.1007/s00264-009-0719-z>.
23. Lonner JH, Mehta S, Booth RE. Ipsilateral patellofemoral arthroplasty and autogenous osteochondral femoral condylar transplantation. *J Arthroplast.* 2007;22(8):1130–6. <https://doi.org/10.1016/j.arth.2005.08.012>.
24. Akhbari P, Malak T, Dawson-Bowling S, East D, Miles K, Butler-Manuel PA. The Avon patellofemoral joint replacement: mid-term prospective results from an independent Centre. *Clin Orthop Surg.* 2015;7(2):171–6. <https://doi.org/10.4055/cios.2015.7.2.171>.
25. Ackroyd CE, Chir B. Development and early results of a new patellofemoral arthroplasty. *Clin Orthop Relat Res.* 2005;436(436):7–13.
26. Nicol SG, Loveridge JM, Weale AE, Ackroyd CE, Newman JH. Arthritis progression after patellofemoral joint replacement. *Knee.* 2006;13(4):290–5. <https://doi.org/10.1016/j.knee.2006.04.005>.
27. Leadbetter WB, Kolisek FR, Levitt RL, Brooker AF, Zietz P, Marker DR, et al. Patellofemoral arthroplasty: a multi-centre study with minimum 2-year follow-up. *Int Orthop.* 2009;33(6):1597–601. <https://doi.org/10.1007/s00264-008-0692-y>.
28. Starks I, Roberts S, White SH. The Avon patellofemoral joint replacement: independent assessment of early functional outcomes. *J Bone Joint Surg Br.* 2009;91(12):1579–82. <https://doi.org/10.1302/0301-620X.91B12.23018>.
29. Sarda PK, Shetty A, Maheswaran SS. Medium term results of Avon patellofemoral joint replacement. *Indian J Orthop.* 2011;45(5):439–44. <https://doi.org/10.4103/0019-5413.83761>.
30. Mont MA, Johnson AJ, Naziri Q, Kolisek FR, Leadbetter WB. Patellofemoral arthroplasty: 7-year mean follow-up. *J Arthroplast.* 2012;27(3):358–61. <https://doi.org/10.1016/j.arth.2011.07.010>.
31. Farr J, Arendt E, Dahm D, Daynes J. Patellofemoral arthroplasty in the athlete. *Clin Sports Med.* 2014;33(3):547–52. <https://doi.org/10.1016/j.csm.2014.03.003>.
32. Odumanya M, Costa ML, Parsons N, Achten J, Dhillon M, Krikler SJ. The Avon patellofemoral joint replacement: five-year results from an independent centre. *J Bone Joint Surg Br.* 2010;92(1):56–60. <https://doi.org/10.1302/0301-620X.92B1.23135>.
33. Al-Hadithy N, Patel R, Navadgi B, Deo S, Hollinghurst D, Satish V. Mid-term results of the FPV patellofemoral joint replacement. *Knee.* 2014;21(1):138–41.
34. Davies AP. High early revision rate with the FPV patello-femoral unicompartmental arthroplasty. *Knee.* 2013;20(6):482–4. <https://doi.org/10.1016/j.knee.2013.07.005>.
35. Williams DP, Pandit HG, Athanasou NA, Murray DW, Gibbons CL. Early revisions of the Femoro-Patella Vialla joint replacement. *Bone Joint J.* 2013;95-B(6):793–7. <https://doi.org/10.1302/0301-620X.95B6.31355>.
36. Halai M, Ker A, Anthony I, Holt G, Jones B, Blyth M. Femoro Patella Vialla patellofemoral arthroplasty: an independent assessment of outcomes at minimum 2-year follow-up. *World J Orthop.* 2016;7(8):487–93. <https://doi.org/10.5312/wjo.v7.i8.487>.
37. Goh GS, Liow MH, Tay DK, Lo NN, Yeo SJ. Four-year follow up outcome study of patellofemoral arthroplasty at a single institution. *J Arthroplast.* 2015;30(6):959–63. <https://doi.org/10.1016/j.arth.2015.01.020>.
38. Liow MH, Goh GS, Tay DK, Chia SL, Lo NN, Yeo SJ. Obesity and the absence of trochlear dysplasia increase the risk of revision in patellofemoral arthroplasty. *Knee.* 2016;23(2):331–7. <https://doi.org/10.1016/j.knee.2015.05.009>.
39. Hofmann AA, McCandless JB, Shaeffer JF, Magee TH. Patellofemoral replacement: the third compartment. *Bone Joint J.* 2013;95-B(11 Suppl A):124–8. <https://doi.org/10.1302/0301-620X.95B11.32985>.
40. Lustig S. Patellofemoral arthroplasty. *Orthop Traumatol Surg Res.* 2014;100(1 Suppl):S35–43. <https://doi.org/10.1016/j.otsr.2013.06.013>.
41. Beitzel K, Schottle PB, Cotic M, et al. Prospective clinical and radiological two-year results after patellofemoral arthroplasty using an implant with an asymmetric trochlea design. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(2):332–9. <https://doi.org/10.1007/s00167-012-2022-6>.
42. Fink B, Schwenninger C. Arthroplasty of the Femoropatellar joint—what data are available? *Zeitschrift fur Orthopadie Unfallchirurgie.* 2014;152(2):182–7. <https://doi.org/10.1055/s-0033-1360353>.
43. Philippe H, Caton J. Design, operative technique and ten-year results of the Hermes™ patellofemoral arthroplasty. *Int Orthop.* 2014;38(2):437–42. <https://doi.org/10.1007/s00264-013-2158-0>.
44. Lonner JH. Patellofemoral arthroplasty: the impact of design on outcomes. *Orthop Clin North Am.* 2008;39(3):347–54, vi. <https://doi.org/10.1016/j.ocl.2008.02.002>.
45. Guy SP, Fardon MA, Conroy JL, Bennett C, Grainger AJ, London NJ. A prospective randomised study of minimally invasive midvastus total knee arthroplasty compared with standard total knee arthroplasty. *Knee.* 2012;19(6):866–71. <https://doi.org/10.1016/j.knee.2012.04.009>.
46. Osarumwense D, Syed F, Nzeako O, Akilapa S, Zubair O, Waite J. Patellofemoral joint arthroplasty: early results and functional outcome of the Zimmer gender solutions patello-femoral joint system. *Clin Orthop Surg.* 2017;9(3):295–302. <https://doi.org/10.4055/cios.2017.9.3.295>. **Describes outcomes of one of the newest, gender-specific implant designs.**
47. Sisto DJ, Sarin VK. Custom patellofemoral arthroplasty of the knee: surgical technique. *JBJS Essent Surg Tech.* 2007;os-89(2_suppl_2):214–25. <https://doi.org/10.2106/JBJS.G.00186>.
48. Sisto DJ, Henry J, Sisto M, Sarin VK. Patient-specific patellofemoral arthroplasty. *Tech Knee Surg.* 2010;9(3):188–92. <https://doi.org/10.1097/BTK.0b013e3181e0e3ef>.
49. Lonner JH. Patellofemoral arthroplasty: an evolving science. *Instr Course Lect.* 2017;66:211–21.
50. Borus T, Brilhault J, Confalonieri N, Johnson D, Thienpont E. Patellofemoral joint replacement, an evolving concept. *Knee.* 2014;21(Suppl 1):S47–50. [https://doi.org/10.1016/S0968-0160\(14\)50010-5](https://doi.org/10.1016/S0968-0160(14)50010-5).
51. van der List JP, Chawla H, Zuiderbaan HA, Pearle AD. Survivorship and functional outcomes of patellofemoral arthroplasty: a systematic review. *Knee Surg Sports Traumatol Arthrosc.* 2015;25:2622–31. <https://doi.org/10.1007/s00167-015-3878-z>.
52. Kazarian GS, Tarity TD, Hansen EN, Cai J, Lonner JH. Significant functional improvement at 2 years after isolated patellofemoral arthroplasty with an onlay trochlear implant, but low mental health scores predispose to dissatisfaction. *J Arthroplast.* 2016;31(2):389–94. <https://doi.org/10.1016/j.arth.2015.08.033>. **Addresses the psychosocial component of patient outcomes after arthroplasty. Mental health may influence perceptions of satisfaction.**
53. Lonner JH. 101. Patellofemoral Arthroplasty. Vol 33.; 2010. <https://doi.org/10.3928/01477447-20100722-39>.
54. Leadbetter WB, Seyler TM, Ragland PS, Mont MA. Indications, contraindications, and pitfalls of patellofemoral arthroplasty. *J Bone Joint Surg Am.* 2006;88(Suppl 4):122–37.
55. Dejour D, Ferrua P, Ntgiopoulos PG, et al. The introduction of a new MRI index to evaluate sagittal patellofemoral engagement.

- Orthop Traumatol Surg Res. 2013;99(8 S). <https://doi.org/10.1016/j.otsr.2013.10.008>.
56. Dahm DL, Kalisvaart MM, Stuart MJ, Slettedahl SW. Patellofemoral arthroplasty: outcomes and factors associated with early progression of tibiofemoral arthritis. *Knee Surg Sports Traumatol Arthrosc.* 2014;22(10):2554–9. <https://doi.org/10.1007/s00167-014-3202-3>.
 57. Carroll KM, Mayman DJ. Robotic patellofemoral replacement. *Oper Tech Orthop.* 2015;25(2):120–6. <https://doi.org/10.1053/j.oto.2015.02.001>. **Discusses the role and technological improvements that robotics can have in patellofemoral arthroplasty.**
 58. Tamam C, Plate JF, Augart M, Poehling GG, Jinnah RH. Retrospective clinical and radiological outcomes after robotic assisted bicompartamental knee arthroplasty. *Adv Orthop.* 2015;2015:1–7. <https://doi.org/10.1155/2015/747309>.
 59. Watanabe T, Abbasi AZ, Conditt MA, Christopher J, Kreuzer S, Otto JK, et al. In vivo kinematics of a robot-assisted uni- and multi-compartmental knee arthroplasty. *J Orthop Sci.* 2014;19(4):552–7. <https://doi.org/10.1007/s00776-014-0578-3>.
 60. Lonner JH. Indications for unicompartmental knee arthroplasty and rationale for robotic arm-assisted technology. *Am J Orthop (Belle Mead NJ).* 2009;38(2 Suppl):3–6. <http://www.ncbi.nlm.nih.gov/pubmed/19340375>.
 61. Kamara E, Berliner ZP, Hepinstall MS, Cooper HJ. Pin site complications associated with computer-assisted navigation in hip and knee arthroplasty. *J Arthroplast.* 2017;32(9):2842–6. <https://doi.org/10.1016/j.arth.2017.03.073>.
 62. van der List JP, Chawla H, Joskowicz L, Pearle AD. Current state of computer navigation and robotics in unicompartmental and total knee arthroplasty: a systematic review with meta-analysis. *Knee Surg Sport Traumatol Arthrosc.* 2016;24(11):3482–95. <https://doi.org/10.1007/s00167-016-4305-9>.
 63. Dahm DL, Al-Rayashi W, Dajani K, Shah JP, Levy BA, Stuart MJ. Patellofemoral arthroplasty versus total knee arthroplasty in patients with isolated patellofemoral osteoarthritis. *Am J Orthop (Belle Mead NJ).* 2010;39(10):487–91.
 64. Dy CJ, Franco N, Ma Y, Mazumdar M, McCarthy MM, Gonzalez Della Valle A. Complications after patello-femoral versus total knee replacement in the treatment of isolated patello-femoral osteoarthritis. A meta-analysis. *Knee Surg Sport Traumatol Arthrosc.* 2012;20(11):2174–90. <https://doi.org/10.1007/s00167-011-1677-8>.
 65. Vasta S, Papalia R, Zampogna B, Espregueira-Mendes J, Amendola A. Current design (onlay) PFA implants have similar complication and reoperation rates compared to those of TKA for isolated PF osteoarthritis: a systematic review with quantitative analysis. *J ISAKOS Jt Disord Orthop Sport Med.* 2016;1(5):257–68. <https://doi.org/10.1136/jisakos-2015-000044>. **Reviews the types of complications, as well as the causes and rates of reoperation and revision for PFA or TKA.**
 66. Odgaard A, Madsen F, Kristensen PW, Kappel A, Fabrin J. Double-blinded randomized controlled trial of patellofemoral vs. total knee arthroplasty for patellofemoral osteoarthritis: two-year results. 2014. **This is the first blinded randomized trial that compares clinical and patient-reported outcomes of PFA versus TKA. The PFA group had superior outcomes to TKA in recovery time, range of motion, and function, contradictory to registry-based results.**
 67. Hollinghurst D, Stoney J, Ward T, Pandit H, Beard D, Murray DW. In vivo sagittal plane kinematics of the Avon patellofemoral arthroplasty. *J Arthroplast.* 2007;22(1):117–23.
 68. van der List JP, Chawla H, Villa JC, Pearle AD. Why do patellofemoral arthroplasties fail today? A systematic review. *Knee.* 2017;24(1):2–8. **Analyzes the causes of PFA failure according to prosthesis design, follow-up period, and cohort studies versus registries over a long-follow up period.**
 69. Christ AB, Baral E, Koch C, Shubin Stein BE, Gonzalez Della Valle A, Strickland SM. Patellofemoral arthroplasty conversion to total knee arthroplasty: retrieval analysis and clinical correlation. *Knee.* 2017.
 70. Lonner JH, Jasko JG, Booth RE Jr. Revision of a failed patellofemoral arthroplasty to a total knee arthroplasty. *J Bone Joint Surg Am.* 2006;88(11):2337–42.
 71. Parratte S, Lunebourg A, Ollivier M, Abdel MP, Argenson JN. Are revisions of patellofemoral arthroplasties more like primary or revision TKAs. *Clin Orthop Relat Res.* 2015;473(1):213–9. <https://doi.org/10.1007/s11999-014-3756-x>. **Determined that PFA to TKA conversion surgery shares similar surgical characteristics and postoperative outcomes as primary TKA.**
 72. van Jonbergen HP, Werkman DM, van Kampen A. Conversion of patellofemoral arthroplasty to total knee arthroplasty: a matched case-control study of 13 patients. *Acta Orthop.* 2009;80(1):62–6. <https://doi.org/10.1080/17453670902805031>.
 73. Hutt J, Dodd M, Bourke H, Bell J. Outcomes of total knee replacement after patellofemoral arthroplasty. *J Knee Surg.* 2013;26(4):219–23. <https://doi.org/10.1055/s-0032-1329233>.
 74. Chawla H, Nwachukwu BU, Van Der List JP, Eggman AA, Pearle AD, Ghomrawi HM. Cost effectiveness of patellofemoral versus total knee arthroplasty in younger patients. *Bone Joint J.* 2017;99B(8) <https://doi.org/10.1302/0301620X.99B8.BJJ20161032.R1>. **Describes the economical and lifetime benefits of PFA versus TKA.**