Journal of Clinical Orthopaedics and Trauma 9 (2018) 24–28

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

journal homepage: www.elsevier.com/locate/jcot

Review article

Patellofemoral arthroplasty: Current concepts

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ARTICLE INFO

Article history:
Received 6 September 2017
Accepted 20 November 2017
Available online 22 November 2017

Keywords:
Patellofemoral arthroplasty
Patellofemoral arthritis
Knee arthroplasty
Knee arthritis
Unicompartmental arthroplasty

ABSTRACT

Isolated patellofemoral arthritis (IPA) is a debilitating condition characterised by a loss of articular cartilage on the patella facets, the trochlear groove or both. By definition, patients with IPA must have normal cartilage in the tibiofemoral compartments of their knee. It is therefore logical to pursue arthroplasty which corrects the abnormality while sparing healthy bone and preserving the knee's native kinematics, which is the premise underpinning patellofemoral arthroplasty (PFA). However, its use remains controversial, with many surgeons still favouring total knee replacement (TKR) in these patients. This paper provides a comprehensive review of PFA in the literature to date and concludes, in carefully selected patients, PFA is worthy of consideration as a functionally superior and economically beneficial joint-preserving procedure – delaying TKR until implant failure or tibiofemoral osteoarthritis progression.

1. Introduction

Isolated patellofemoral arthritis (IPA) is a debilitating condition characterised by a loss of articular cartilage on the patella facets, the trochlear groove or both. IPA affects 9% of the population over 40 years of age and between 11 and 24% of patients with knee pain,[1,2] however registry data shows that patellofemoral arthroplasty (PFA) only accounts for 1.3% of all knee arthroplasty in the United Kingdom.[3] As forecasters continue to predict an ageing population with an increased burden of arthritis, it is inevitable more patients will require treatment for this condition in the future.

Many patients with IPA can be managed with non-operative measures. If these are unsuccessful, arthroscopic debridement or soft tissue realignment procedures may be attempted. However, these interventions have provided inconsistent results – with success rates reported at 60–70%.[4] Therefore, particularly when IPA is at an advanced stage, the principal surgical intervention is arthroplasty.[4,5]

IPA often occurs in younger, active patients who, by definition, must have normal cartilage in the tibiofemoral compartments of their knee. It is therefore logical to pursue arthroplasty which corrects the abnormality while sparing healthy bone and preserving the knee's native kinematics, which is the premise underpinning patellofemoral arthroplasty (PFA). However, its use remains controversial, with many surgeons still favouring total knee replacement (TKR) in these patients.[6–8]

This paper provides a comprehensive review of PFA in the literature to date. We discuss first and second generation patellofemoral implants, outline criteria for patient selection, and compare PFA with TKR in the treatment of IPA. Finally, we describe ongoing research, and explore what the future may hold.

2. Patellofemoral implant design

2.1. Historical overview

The first "replacement" of the patellofemoral joint was reported by McKeever in 1955, who used a vitallium shell to resurface the arthritic patellar surface in 5 patients, leaving an untouched native trochlea.[9] Early results were promising, but the design was ultimately discontinued due to excessive trochlear wear. The first total PFA did not occur until 1979 following introduction of the Richards and Lubinus prostheses.[10] These were inlay designs, and are commonly referred to as first generation patellofemoral implants.

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https://doi.org/10.1016/j.jcot.2017.11.006

2.2. First generation patellofemoral arthroplasty

First generation implants used trochlear prostheses inset within the native trochlea and flush with the surrounding articular cartilage. This effectively replaced worn cartilage without altering the shape of the subchondral bone – meaning rotational alignment was determined by the native trochlear orientation. Outcomes were poor. In a short-term follow-up of the Lubinus implant, Board demonstrated only 53% of knees were classified as satisfactory by patients, with 24% requiring revision to total knee arthroplasty and 18% exhibiting an extension block.[11] Similarly, in long-term studies, the highest documented survivorship was 75% at 10 years with large scale studies by Tauro and Van Jonbergen reporting 65% survival of the Lubinus implant at 5 years and 69% survival of the Richards implant at 20 years respectively.[12,13]

Initially, high failure rates were attributed to poor patient selection. However, the comparative success of second generation patellofemoral implants suggests it was the first generation implants' reliance on orientation of the native trochlea which is culpable for high rates of patellar instability. Using magnetic resonance imaging, Kamath analysed trochlear inclination angles in 329 patients with either normal or dysplastic patellofemoral anatomy.[14] Both groups had trochlear inclination angles averaging 11.4° and 9.4° respectively relative to the anteroposterior and transepicondylar axes of the femur. This explains the propensity to bias the inlay-design trochlear prosthesis into internal malrotation – increasing the Q-angle and predisposing to high rates of patellar maltracking, impingement, subluxation and ultimately failure.

2.3. Second generation patellofemoral arthroplasty

Onlay trochlear prostheses were introduced in the 1990s. These second generation patellofemoral implants completely replace the anterior compartment of the knee – providing a design that can be universally applied to all patients irrespective of innate anatomical variation.

The trochlear component is implanted perpendicular to the anteroposterior axis of the femur and parallel to the trans-epicondylar axis – allowing the surgeon to determine the rotation of the prosthesis irrespective of the native trochlear inclination. Further, onlay prostheses are typically wider and less constraining, allowing increased movement of the patella through the arc of motion and facilitating smoother patellar tracking. Finally, by extending the prosthesis more proximally than the native trochlear cartilage and ensuring it is seated flush against the anterior femoral cortex, the risk of impingement is minimised whilst the patellar component remains engaged even when in maximally extension.

The improvement in the design of second generation prostheses has been reflected in both short and medium term results. In a multi-centre trial of 79 patients at 3 year follow-up, Leadbetter reported a 94% survival rate of the Avon prosthesis with a Knee Society Score greater than 80 achieved in 84% of patients.[15] Similarly, in a study of 109 patients at 5 year follow-up, Ackroyd documented a 96% survival rate of the Avon prosthesis with an 80% success rate based on Bristol knee scores.[16] Goh established a 92% survival rate with 76% of patients reporting "good satisfaction" with their symptomatic improvement.[17]

Longer term studies are also promising. In a study of 51 prostheses with 7 year follow-up, Konan described a 96% probability for survival (Kaplan-Meyer analysis) with revision as the end-point.[18] Equally, in a study of 71 Hermes™ prostheses at 10 year follow-up, Hernigou found no late complications attributable to the arthroplasty.[19]

Analysis of cohort studies illustrates the contrast between survivorship in first and second generation PFA. Older studies (before 2010) report an annual revision rate of 2.33% whereas more recent studies (after 2010) exhibit an annual revision rate of 1.93% with heterogeneity mainly seen in type of prosthesis.[20] However, not all second generation implants have been successful. The low contact stress (LCS) patellofemoral implant consisted of a trochlear component and a modular patellar component with a metal-backed mobile polyethylene bearing. In a study of 51 implants at 2 years follow-up by Charalambous, 33% had required revision.[21] During revision surgery, the polyethylene bearing was frequently found to have diminished mobility secondary to overgrown surrounding soft tissue. Further studies also reported dissociation of the mobile polyethylene bearing from its metal backing, and use of this prosthesis has subsequently been discontinued.[22,23]

The United Kingdom National Joint Registry uses Kaplan-Meier estimates to calculate the cumulative percentage probability of first revision of a PFA by implant brand at varying years since primary operation.[3] The Avon prosthesis has the greatest body of evidence (4842 knee joints) and exhibits the second lowest revision rate at 1 year (0.79%) with the lowest revision rate at 7 years (10.21%). The Zimmer PFJ demonstrates the lowest revision rate at 1 year (0.64%), but currently has insufficient data for longer term survivorship to be calculated. The Sigma HP implant exhibits the highest revision rate at 1 year (2.61%) and is the least frequently used prosthesis (Table 1).

3. Patient selection

Patient selection is critical to the success of PFA. Patients with patellofemoral instability and/or trochlear dysplasia are particularly likely to benefit because secondary pathologies are corrected;

Table 1
Kaplan-Meier estimates of the cumulative percentage probability of first revision (95% CI) of a PFA by implant brand at indicated number of years since primary operation.[3] Estimates in italics indicate fewer than 250 cases remain at the time shown.

Brand	Number of knee joints	Median age at primary	Cumulative percentage probability of a first revision (95% CI) if time elapsed since primary operation is:				
			1 year	3 years	5 years	7 years	10 years
Avon	4842	59 (51–68)	0.79 (0.57–1.09)	4.25 (3.67–4.91)	7.55 (6.75–8.45)	10.21 (9.22–11.31)	14.86 (13.31–16.57)
FPV	1537	59 (51–68)	0.95 (0.56–1.59)	6.54 (5.34–8.01)	9.78 (8.21–11.62)	*11.34 (9.54–13.46)*	
Journey PFJ Oxinum	1454	58 (50–67)	2.21 (1.55–3.15)	7.24 (5.92–8.83)	12.49 (10.62–14.67)	*18.43 (15.84–21.39)*	
Sigma HP	1023	59 (51–67)	2.61 (1.77–3.84)	8.03 (6.32–10.17)	*12.65 (10.10–15.79)*	*18.12 (12.00–26.87)*	
Zimmer PFJ	1448	57 (50–66)	0.64 (0.32–1.28)	3.99 (2.90–5.48)	*5.09 (3.72–6.96)*	*10.26 (5.29–19.41)*	

Dahm reported that patients with preoperative radiographic evidence of trochlear dysplasia exhibited reduced progression of tibiofemoral osteoarthritis.[24]

Contraindications are numerous and demand careful consideration. The vast majority of patients with patellofemoral arthritis can be treated symptomatically using conservative measures such as physical therapy, weight reduction, anti-inflammatory medication, bracing and injections. Patients should not be considered for PFA unless reasonable attempts at non-operative management have been made. Lonner reiterated the importance of a comprehensive history and examination – arguing patients should have reproducible symptoms on physical examination with squatting and patellar inhibition testing.[25]

Further, arthritis must not be inflammatory and must be isolated to the patellofemoral joint. Van der List reported the causes of failure in 938 patellofemoral arthroplasties with osteoarthritis progression being the most common (38%). The author concluded that appropriate patient selection could prevent failure.[20] Willekens argued that PFA should be avoided in patients with tibiofemoral arthritis exceeding Kellgren Lawrence radiographic grade II – demonstrating a significantly worse outcome comparative to radiographic grade I.[26]

Given the importance of establishing IPA, preoperative imaging is integral. Radiographic evaluation should consist of weight-bearing AP and lateral views with a skyline view at 45° knee flexion. Radiographic evidence of patellofemoral arthritis should be clearly evident – with deDeugd demonstrating patients with minimal radiographic evidence of patellofemoral arthritis exhibited reduced improvement in pain and function comparative to patients with radiographic evidence of advanced arthritis.[27] Lonner also advocated preoperative magnetic resonance imaging to assess the tibiofemoral compartments for evidence of chondral damage or reactive oedema.[28]

Obesity with a BMI exceeding 30 kg/m^2 is considered a contraindication due to concern regarding overloading the prosthesis and increased propensity for osteoarthritic progression. This was corroborated by van Jonbergen who reported higher rates of revision in obese patients in a study of 185 Richards II prostheses.[13] Similarly, in a study of 51 patients at 4 year follow-up, obesity was associated with reduced patient satisfaction and no significant improvement in the Melbourne Knee score.[28] Other contra-indications include patella baja, uncorrected tibiofemoral malalignment, fixed loss of knee range of motion and evidence of complex regional pain syndrome (Table 2).

4. Patellofemoral arthroplasty versus total knee arthroplasty

Many surgeons still consider total knee arthroplasty the benchmark for IPA with multiple studies demonstrating excellent outcomes in older patients. In a study of 30 TKRs with a mean patient age of 73 years, Mont reported 97% of cases had a Knee Society Score greater than 80 at a mean follow-up of 81 months, with no re-operations or revisions.[29] Thompson presented a series of 33 TKRs at a mean patient age of 73 years, and reported 21 knees were pain-free with the remaining 12 describing only occasional pain at a mean follow-up of 20 months.[30]

In a series of 33 TKRs in a younger patient cohort with a mean age of 52 years, Meding reported a mean Knee Society Score of 88 (pre-operatively 49) at a mean follow-up of 6 years.[7] In a meta-analysis of 374,934 arthroplasties, annual revision rates were lowest for TKR (0.49%) and highest for PFA (1.75%).[31]

None of these studies specifically assessed recreational activity or quality of life limitations. Conservation of the native knee anatomy in PFA via preservation of the femorotibial compartments and cruciate ligaments results in improved knee joint kinematics and proprioception.[32] Therefore, PFA is likely to provide a more functional knee in the younger, active patient. Indeed, PFA patients are documented to have resumed activities including tennis, ballet and skiing.[15] Moreover, in the shorter term, PFA is associated with reduced blood loss, shorter operative times and faster rehabilitation.[34]

Although revision rates are lowest for TKR, in a young patient a TKR may have to survive upwards of 30 years. The literature suggests young patients undergoing TKR have a three-fold greater risk of requiring revision in later decades.[35] Therefore the lower survivorship of PFA is of less relative consequence to patients already facing an increased risk of revision after TKR. Revised TKRs themselves have a failure rate of around 20% at 5 years – meaning young patients undergoing TKR face the potential risk of multiple revision procedures in later life.[37] In such patients, PFA offers the chance of a sustained period of improved function whilst delaying TKR. Moreover, second generation PFA has already exhibited significantly reduced annual revision rates comparative to earlier prostheses, and recent technological advances involving customised implants and robot-assisted procedures may improve this further.[18,19]

When PFA revision is required, multiple studies demonstrate this is comparable to primary TKR with regard to surgical characteristics and clinical outcomes, and superior to revision TKR. In a study of 21 PFAs revised to TKRs, Parratte reported the minimal femoral bone loss associated with PFA enabled a standard primary device to be used without need for supplemental stems, augments or bone grafting.[36] Median blood loss was 405 ml for primary TKA, 460 ml for revision PFA and 900 ml for revision TKA while median operative time was 52 min for primary TKA, 72 min for revision PFA and 115 min for revision TKA. Lonner and van Jonbergen also reported similar Knee Society scores for PFA revision and primary TKR at a mean 3 year and 5 year follow-up.[37,38]

Analysing the cost-effectiveness of PFA and TKR, Chawla concluded that PFA represented a clinically superior and more economically beneficial joint-preserving procedure in younger patients – delaying TKR until implant failure or tibiofemoral osteoarthritis progression.[39] Using a Markov transition state

Table 2
Patient selection for PFA.

Indications for PFA	Contraindications for PFA
Isolated patellofemoral osteoarthritis (with clear radiographic evidence)	Presence of tibiofemoral disease (tibiofemoral arthritis exceeding Kellgren Lawrence radiographic grade II)
Severe symptoms affecting ADL	Inflammatory arthropathy
Non-responsive to non-operative management (at least 3–6 months)	Uncorrected patellofemoral malalignment or instability
Absent patellofemoral malalignment	Tibiofemoral malalignment
Absent tibiofemoral disease	Obesity (BMI > 30)
Neutral tibiofemoral alignment	Fixed flexion contracture >10°
No evidence of inflammatory arthritis	Complex regional pain syndrome
No obesity (BMI < 30)	Patella baja

model, lifetime costs, quality-adjusted life year (QALY) gains and incremental cost-effectiveness ratio (ICER) were calculated. Although PFA ($49,811) was more expensive than TKR, ($46,632) it was more effective (14.3 QALYs versus 13.3 QALYs) over a lifetime horizon. The ICER associated with the additional effectiveness of PFA was $3097. Furthermore, Chawla demonstrated that although PFA is already cost-effective, a further 24.5% decrease in annual rates of revision would make PFA both less expensive and more effective than TKR.[39]

5. The future

Technological advancements have facilitated the development of custom implants which use three-dimensional reconstruction to reproduce the radius of curvature of the patellofemoral joint. Researchers contend these prostheses maximise bone coverage without exerting excessive loads on the patella. In a study of 22 PFAs at 5 years follow-up, Butler reported improvement in pain, stiffness and function.[40] No revisions were required although 2 patients underwent arthroscopic procedures for stiffness. Similarly, in a study of 25 custom implants at 11 year follow-up, all patients described themselves as being very satisfied with the procedure, with no patients requiring revision.[41]

Early results suggest intra-operative computer navigation has the potential to ensure accurate prosthesis alignment. In a control trial comparing 15 PFAs performed with navigation to a group of 15 PFAs performed without navigation, the group with navigation had no patellofemoral complications and improved clinical scores.[42] Contrastingly, the group without navigation exhibited abnormal patellar tracking in one third of cases with post-operative computed topography (CT) scans suggesting excessive internal component rotation was responsible. A further review of 4 PFAs performed using intra-operative computer navigation also demonstrated excellent anatomical positioning on post-operative CT scans – suggesting intra-operative navigation may improve the reliability and reproducibility of prosthesis positioning in PFA.[43]

Despite the fact that 11–24% of patients with knee pain have IPA, PFA only accounts for 1.3% of all knee replacements in the UK. The reasons for low usage of IPA include inconsistent results achieved with currently available implants and instruments. For commercial reasons, manufacturers are reluctant to invest in the research and development of newer designs of implants and better instrumentation (i.e. congruous implants).[44]

6. Conclusion

Improvement in survival rates for second generation implants has lead to a resurgence in support for PFA. By conserving the native knee anatomy, PFA improves knee joint kinematics and proprioception comparative to TKR, and offers younger, active patients the chance of a more functional knee. Patient selection remains critical – the ideal candidate for PFA is a non-obese patient younger than 65 years of age with isolated, non-inflammatory patellofemoral arthritis and severe symptoms unresponsive to non-operative management. Further, the patient should have neutral tibiofemoral alignment and no evidence of uncorrected patellofemoral malalignment, fixed flexion contracture, complex regional pain syndrome or patella baja.

In younger patients, PFA is associated with reduced blood loss, shorter operative times and faster rehabilitation. Early research into custom implants and intra-operative computer navigation is also promising and may improve the reliability and reproducibility of prosthesis positioning. If PFA revision is required, studies demonstrate this is comparable to primary TKR with regard to surgical characteristics and clinical outcomes, and superior to revision TKR. Therefore, in appropriate patients, PFA is worthy of consideration as a clinically superior and financially beneficial joint-preserving procedure – delaying TKR until implant failure or tibiofemoral osteoarthritis progression.

Conflict of interest

None.

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