Review

Optimizing patellofemoral arthroplasty

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Received 26 September 2007; received in revised form 23 April 2008; accepted 29 May 2008

Abstract

Patellofemoral arthroplasty (PFA) has been an option for patients with symptomatic patellofemoral osteoarthritis since the 1950’s. Many of the early failures resulted from a combination of implant design and surgeon technique. The goal of this overview is not to review the history of PFA, but rather to explore options for surgeons to optimize long-term outcomes and improve patient knee function, while highlighting the differing techniques required in PFA with those routinely adopted in total knee arthroplasty (TKA).

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Keywords: Patellofemoral; Arthroplasty; Osteoarthritis; Degenerative; Joint; Surgery

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Available online at www.sciencedirect.com


doi:10.1016/j.knee.2008.05.008
1. Introduction

Patellofemoral arthroplasty (PFA) has suffered from a checkered past. First generation implant systems exhibited failures as a combination of implant and technical issues. Second generation systems reduced implant related failures. As many systems are entering a third generation phase, there continue to be surgeon and patient specific parameters that keep some arthroplasty surgeons from adopting this bone and ligament sparing technique. The goals of this paper are to explore options and controversies that may allow surgeons to optimize long-term outcomes, to improve patient knee function and to highlight the differing techniques required in PFA compared with those routinely adopted in total knee arthroplasty (TKA).

2. Background

PFA is a salvage procedure for treatment of isolated patellofemoral (PF) osteoarthritis (OA) unresponsive to nonoperative management. Available since the first tibiofemoral arthroplasties, the number of PFAs performed remains very low [1]. These numbers are even lower than would be predicted by the incidence of isolated PF OA cases [2]. Two opposing views are held:

i) Newer PF implants and surgical techniques deliver good results beyond 10 years with failures predominantly resulting from tibiofemoral (TF) compartment arthritis progression [3,4].

ii) PFA results are so unreliable and inferior to TKA that isolated PF arthritis is best treated by TKA [5].

This debate could continue until 20 year results of PFA equal 20 year results of TKA; however, there may be a place for PFA if greater than 95% of implants survive 10 years, with failures occurring as a result of TF progressive arthritis [4]. In this case, the patient has enjoyed kinematics and range of motion that more closely resemble a normal joint. Subsequent revision to a primary TKA or addition of a unicompartmental TF arthroplasty is technically easier and more functional than a revision TKA. Approached as a “bridging surgery” to avoid TKA in midlife, PFA may become more acceptable. Excellent current reviews by Lonner, Leadbetter et al., and Donnell et al. are recommended background reading [6–8].

3. Evaluating the patient

3.1. Approach

The patient should have isolated PF OA and isolated PF pain. Because PF pain is complex and multifactorial, treatment should initially err towards a conservative approach. Conservative treatments include physical therapy, bracing/taping, medication, injections, activity modification, weight loss and rest [8]. During this treatment, the surgeon is better able to appreciate the patient’s unique pain response. When pain is proven as a direct result of isolated PF arthritis following the failure of conservative management, surgical planning for PFA is appropriate with a few caveats.

3.2. Patient history

Patient history is exceedingly important. A subset of PF OA patients will have a history of trauma or patellar instability; this plays a role in prognosis. Furthermore, many of these patients have had multiple previous surgeries that may influence the surgical approach (prior incision scars) or the need for concomitant surgery (prior overzealous lateral release causing iatrogenic medial patellar instability).

3.3. Physical examination

The physical examination is vital. The pain should be localized to the PF compartment without atypical patient reactions. If complex regional pain syndrome is even minimally suspected, it should be thoroughly evaluated and treated (paralumbar sympathetic block). Lower extremity alignment variations need complete documentation. Evaluation of medial and lateral patellar displacement, patellar tilt, patellar dynamic tracking and focal areas of pain is important.

4. Imaging studies

4.1. Radiographs

Radiographically, the low flexion angle axial view (Merchant), standing flexed PA skier view, AP view and true lateral radiographs are considered the benchmark for evaluating the PF
joint. Nevertheless, Staubli et al. demonstrated the mismatch between osseous elements and the cartilage surfaces (i.e., lateral excessive position of the patella relative to the trochlear groove may be over or under estimated by bony contours). Medial or lateral patellar positioning/tilt may also be on the basis of focal cartilage loss rather than static resultant forces (the unshoul-dered cartilage defect allows the patella to “sink” or “shift” to a pattern of tilt or subluxation) [9]. The primary information points gained by these radiographs for PFA are:

i) The trochlear morphology: Normal or atypically shallow morphology (dysplasia) as classified by Tecklenburg et al. [10].

ii) The extent of bony loss (compromised bone for fixation).

iii) Patellar height (potential of patellar alta or “shortened trochlea” morphology as per Biedert and Albrecht [11]: Critical for ensuring that the patellar implant articulates with the trochlear implant at full extension/hyperextension.)

iv) Absence of tibiofemoral arthritis.

v) Tibiofemoral alignment: If excessive varus or valgus is suspected, a hip to ankle view can determine the me-

4.2. CT, MRI and fused scans

Other imaging studies are also useful. CT scans are often used to document patellar position, tilt and tibial tuberosity—trochlear groove (TT–TG) distance. An MRI will reveal the TT–TG distance and the true cartilage Caton–Deschamps ratio (evaluation of patellar alta/infera). In atypical patients, a bone scan may show areas of bony overload, especially when there is concern for tibiofemoral involvement. SPECT bone scans may be overlaid onto an MRI or CT (fusion) to correlate bone activity with specifics of anatomy (Fig. 1).

If abnormal femoral anteversion or tibial external torsion is suspected, the limb may be evaluated by hip, knee and ankle CT.

4.3. Patient classification by imaging

With the patient’s history, physical, and imaging studies, it is possible to classify them into one or more of the following categories. These categories aid in surgical planning and are a guide to outcome and long-term prognosis.

4.3.1. Normal morphology PF arthritis

“Isolated” PF arthritis may be a precursor for generalized knee arthritis. These patients are at risk of TF arthritis progression, especially if there is associated TF malalignment and/or obesity. Full tibiofemoral alignment assessment is critical as is intra-operative chondral assessment of the TF joint. Articular damage at the tibiofemoral compartments may suggest bicom-partmental arthroplasty or TKA as the best treatment; thus, these options need to be discussed and consented preoperatively.

4.3.2. Post traumatic PF arthritis

Even those without dysplasia may have potential to do well if not involved with other knee pathology, such as excessive scarring, patellar infera or abnormal post fracture healing morphology.

4.3.3. Dysplastic PF arthritis

These patients often achieve good PFA results as the primary pathology is the pathoanatomy rather than genetic articular
cartilage pathology. These patients often have patella alta, elevated TT–TG distances, and/or patholaxity of the MPFL, each of which may require concomitant intra-operative treatment.

5. Comprehensive surgical approach to PFA

5.1. Preoperative expectations

Patients need to understand that PFA activity limitations will duplicate those of TKA and that repetitive loading with the patella in the intercondylar notch may cause excessive noise, some degree of pain and possible effusion. Patients should appreciate that if the surgery and post-operative courses proceed as desired, they may still eventually have significant polyethylene wear and/or progression of tibiofemoral arthritis. It is important to obtain informed consent for intra-operative conversion to TKA or bicompartmental arthroplasty.

5.2. Skin incision

Patients often have prior scars that may be incorporated into a midline longitudinal incision. For the knees without scars in the region of the anterior knee, whether a medial or lateral deep approach is planned, a midline incision is recommended to allow for future unicompartmental or total knee arthroplasty.

5.3. Surgical approach

Quadriceps tendon, midvastus and subvastus approaches are all options, but early and full VMO activation for PFA patients is important. Special emphasis must be placed on the MPFL as this may be deficient or pathologically lax in patients with a history of patellar instability. Proponents of the lateral approach would suggest many patients have maximal wear laterally with marked loss of patellar height. Unlike typical TKA patients, the reestablishment of normal patellar height in the absence of component external rotation (see below) will relatively tighten the lateral soft tissue. Some patients will require lateral soft tissue balance through a titrated lateral release or step cut lengthening of the lateral retinaculum. (As described by Biedert at the 2006 International Patellofemoral Study Group meeting, step cut lengthening is separation of the iliotibial band extension patellar ligament and the capsule/lateral patellofemoral ligament.) The majorities of patella implants are dome or oval dome rather than anatomically shaped. As a result, if a natural patella is resurfaced with a dome, the implant may be tilted (Fig. 2). Thus, close constant reevaluation of the lateral soft tissues is essential. Additionally, the patient may have had an overzealous lateral release which may require direct repair or reconstruction that is aided by this approach.

5.4. Patellar cut

An early patellar cut allows for easier displacement of the patella into the lateral or medial gutter without need for eversion. Scar, synovium and fat are cleared to allow visualization of the patellar and quadriceps tendon attachment sites.

Using the tendon attachment sites as references, the patellar cut is made to leave a minimum of 12–14 mm of patella or a level to reestablish the original thickness with implant in place.

Fig. 3. a. Close up comparison of the on-lay technique for the trochlear component. b. Close up comparison of the in-lay technique for the trochlear component. c. On-lay trochlear component. d. Postoperative radiographs of on-lay trochlear components. e. In-lay trochlear component. f, g. post-operative radiographs of in-lay trochlear components.
Alternatively, some systems have proprietary inset jig reaming systems, which do not alter the original patellar thickness and may avoid polyethylene contact with the intercondylar walls in deep flexion.

5.5. Trochlear preparation

Surgeons should strive to remain current in this controversial debate to assure optimal implantation. The first step is to remove synovium, osteophytes and fat from the anterior femur immediately adjacent to the most proximal extent of the trochlea. This allows direct visualization of the anterior femoral cortex, which will dictate the most posterior extent possible for the trochlear cut in both in-lay and on-lay techniques (to avoid anterior femoral notching) (Fig. 3a–g). The proximal extent of the trial implant should allow the patella to be engaged in the trochlear implant during full extension of the knee with activated quadriceps (traction applied to duplicate this in surgery) and should allow for smooth transition as the patella tracks distally. Valgus/varus positioning is determined by aligning the component’s proximal trochlea groove with the entry of the natural trochlea or in the case of severe dysplasia, lateral to the midline of the femur. This will allow lateral to central patella tracking as dictated by the local anatomy and quadriceps resultant vector. This approach differs from typical TKA surgery in which the emphasis is flexion extension gap balancing and defined external rotation of the entire

Fig. 3 (continued).
femoral component without directed attention to patellofemoral tracking during initial trial planning.

The distal tip of the trochlear component is placed above and adjacent to the apex of the intercondylar notch and must avoid overhang and ACL impingement. Notch osteophytes are removed to visualize the anatomic roof. The anterior femoral cortex and the apex of the intercondylar notch represent the first two of three points which determine prosthetic placement (A rigid body can be defined in space by three points).

The means to select the third point remains controversial with the main debate focused on the reference points used to determine rotation. That is, should local anatomy (trochlea itself and the anterior distal femur immediately adjacent to it) or regional anatomy (e.g., posterior condyles, epicondylar axis, or Whiteside’s line) be used (Fig. 4)? This debate is a continuation of the TKA femoral (and thus trochlear) component orientation. TKA implant techniques typically call for balanced flexion and extension gaps which are tied to a tibial cut perpendicular to the long axis of the tibia. To compensate for the natural tibial plateau varum, the femoral component is externally rotated when the knee is flexed to 90°. In TKA this concept has resulted in better-balanced knees and less need for lateral releases. The goal in TKA is an Insall “grand-piano” sign consistent with mild external rotation [12]. The grand-piano sign is consistently produced when the anterior resection has 3° of external rotation relative to the posterior condylar axis or by resection parallel to the surgical epicondylar axis (Fig. 5a). The butterfly sign (Fig. 5b) was produced by resection with 0° of external rotation relative to the posterior condylar axis [12]. Many PFA techniques would suggest that appearance of a grand-piano sign would be desired (Fig. 5a). However, the PFA is not 1/3 of a TKA and operative techniques differ significantly. The rationale for external rotation of a TKA femoral component may not extrapolate to PFA. As there are no current scientifically based recommendations for rotation of the trochlear component, the empiric recommendations are as follows.

5.5.1. Trochlear component rotational considerations

i) Internal rotation should be avoided as the patella begins laterally at full extension and an internally rotated trochlea would increase lateral soft tissue tension and possibly promote lateral soft tissue pain.

ii) Distal native trochlea is used as a “starting rotation” orientation with “errors” to be on the side of external rotation.

iii) Excessive external rotation should be avoided as this will decrease the lateral trochlear implant “height” and may allow dislocation.
For the in-lay implants, bone is removed to allow the implant to sit flush distally with the articular cartilage both medially and laterally. Proximally, the lateral cartilage takes precedence over the medial congruity in light of the lateral to medial tracking of the patella during flexion. Varus and valgus alignment is largely set as a result of matching the articular surface medially and laterally. For in-lay techniques, the local anatomy is followed rather than regional anatomy to set rotation of the trochlea. It is acknowledged that there are often compromises in matching the margins of the implant to the remaining articular cartilage. An orderly approach to the “priority of congruency” is useful in determining optimal trochlear position.

### 5.5.2. Priority of trochlear implant marginal congruency

- **i)** Distal tip of the implant cannot be proud or below the roof of the notch.
- **ii)** Distal triangular area of the implant congruent or slightly below the adjacent articular cartilage.
- **iii)** Proximal implant margin should avoid notching the anterior distal femur.
- **iv)** Lateral and medial proximal implant margins with rotational limitations as discussed under trochlear component rotation.

### 5.6. Tuberosity surgery

The tuberosity may be moved medially, laterally or distally. Proximalization is not indicated as this would imply patellar infera, which is a contraindication to PFA. Distalization is performed if, after an optimally sized trochlear component trial is implanted, the patella does not engage with quadriceps tendon traction (to simulated full activation) at maximal knee extension. The tuberosity is distalized to allow engagement at this full extension, quadriceps active position. The decision to move the tibial tuberosity medially or laterally should be determined preoperatively by measuring the TT–TG distance, the tibial tuberosity to trochlear groove (TTG) distance, the tibial tuberosity to intercondylar notch and vice versa; smooth motion should also occur within the notch. If there are abrupt movements, the most common cause is the trochlear component not being seated flush with the surrounding articular cartilage. The trial would need to be refitted and motion retested.

If the approach is medial and the patellar component is tilted laterally or rides laterally despite repair of the medial incision, a lateral lengthening (detailed above) or titrated lateral release is performed. Some TKA surgeons view lateral release as an admission of an early technical error (especially insufficient external rotation). It would be expected that there would need to be more lateral lengthening/lateral release procedures in PFA patients as the implanted patella plus trochlear component thickness is often reestablished to “normal”, but this thickness is greater than the soft tissues have seen in years in light of PF bone and cartilage attrition. This lateral lengthening/lateral release should be recognized as a potential necessary component of PFA surgery.

### 5.8. Medial and lateral closure

The goal is to not over-constrain the patella. The MPFL checkreins the patella from abnormal lateral displacement rather than pulling (constraining) the patella into position. Note that lateral soft tissues naturally have increased tension with flexion and medial have less tension with flexion, reinforcing the need to test the knee through all aspects of motion. If there is abnormal medial or lateral displacement after soft tissue reapproximation (greater than 2 quadrants of the trochlea), the MPFL or lateral restraints may require tightening, repair or formal reconstruction.

### 6. Avoiding common historical modes of failure

#### 6.1. Patellar instability

The primary reason for lateral patellar instability is patholaxity of the medial patellofemoral ligament (MPFL). Less intuitively obvious, the lateral restraints (iliotibial patellar ligament and deep lateral patellofemoral ligament (LPFL)) also serve to restrain excessive lateral instability [14]. The dysplastic subgroup of patients may follow a pattern of recurrent instability followed by a time of stability secondary to arthrosis. These patients can return to instability after the coefficient of friction is decreased through PFA. Patients may have undergone previous lateral releases, which may further decrease the restraint to lateral patellar instability. Both of these problems may be exacerbated by patella alta. The goal with PFA is to assess the patellar displacement and engagement preoperative and intraoperatively. The modern minimally constrained PFA is not designed to afford primary stability. Patellar height and soft tissue restraint should be normalized by surgical technique. In patella alta cases that do not allow engagement in all degrees of extension, the tibial tuberosity is distalized. The soft tissue checkreins are reevaluated. These checkreins are balanced to reestablish medial and lateral physiologic displacement through formal reconstruction (e.g., MPFL reconstruction) or repair/tightening. In some cases, the force vectors are such that even properly balanced ligaments will be overburdened as in the case of an excessive lateral position of the tibial tuberosity, abnormal femoral anteversion, and external tibial torsion. The pathology in each case is addressed at the source of pathoanatomy that is determined PREOPERATIVELY. In the case of excessive lateral tibial tuberosity to trochlear groove (TT–TG) distance, the tibial tuberosity position is normalized through medialization osteotomy and then soft tissues are reassessed and balanced [10,15].
Infection, gout, pseudogout or inflammatory arthropathy should be excluded through knee aspiration. If the effusions are non-inflammatory, the most common cause is chondral debris as a result of patellar component wear on the articular cartilage of the intercondylar notch or arthritic progression in the tibiofemoral (TF) compartments. At this point, the TF joint space is reassessed with weight bearing PA flexed view and standing AP then treated in the standard fashion for the degree of arthritis. Chondral wear may arise from notch osteophytes or mismatch between the patella component and the dimensions of the notch. This may be avoided by clearing protruding osteophytes and evaluating the articulation of the patellar component in the notch during patellar component sizing. While maximal patellar sizing for full bone coverage is often used when selecting a patellar component in TKA, a slightly smaller patella component may be selected for PFA, especially when there is deficient bone stock of the lateral patella. A common TKA technique is to medialize the patella to improve patellar tracking, yet in PFA this may increase notch impingement. Where impingement remains a concern, an inset patellar component is an option if there is sufficient patellar bone/cartilage stock. The inset patellar component may allow the patellar cartilage to articulate with notch cartilage in deep flexion. In some patients, shedding occurs several months after PFA as knee flexion and other activities are increased, but then may gradually subside as the chondral wear stabilizes. Bicompartmental or TKA may be indicated for persistent non-inflammatory, noninfectious effusions.

6.4. Clunking

Clunking is caused by excursion of the extensor mechanism over component/cartilage mismatching or scar tissue. While scar tissue may gradually diminish with remodeling, congruency mismatches typically do not “self correct”. The most problematic clunking problems are a result of abnormal abrupt movement of the patellar component as it enters and exits the trochlear component. Proximally, assessment should be performed intraoperatively by passively tensioning the quadriceps tendon to evaluate the most proximal position of the patella in relation to the trochlear entrance with the knee in maximal extension. If clunking occurs during trialing, the trochlea may be reevaluated for a larger (more proximal extension) sizing. If this occurs after the implants are cemented and the problem is residual alta, the tibial tuberosity should be distalized to assure the patella is engaged at all degrees of extension/hyperextension. Distally, clunking must be prevented by closely matching the component to the distal trochlear articular cartilage. Occasionally, notch osteophytes may cause abrupt movement change in the tracking of the patellar component and create a clunk and should be considered and removed. A unique clunk may be encountered with bicompartamental arthroplasty (PFA plus a UKA). Not all PFAs and UKAs are compatible. Components may be repositioned to achieve a smooth transition of the patella between the two surfaces, but if this is not possible, then TKA is a better option.

6.5. Recurrent effusions

The absence of risk factors for generalized arthritis and a well-positioned PFA results in an excellent longevity potential. In the well-advised patient with marginal risk factors, the patient and the surgeon may be willing to accept possible failure through tibiofemoral arthritis progression especially as an alternative to TKA in young patients (e.g. in their 40’s). From a slightly different perspective, as there is potential of adding a UKA to a stable PFA, planning for this potential is imperative.

6.6. Persistent patellofemoral and soft tissue pain

Patellar infera (baja)

Patellar infera is rare in the knee without prior surgery or trauma. Caton–Deschamps ratios of less than 0.8 suggest clinically relevant infera. Patellar infera is a contraindication for PFA; the patient can only be considered for PFA through staged correction. The normalization of patellar height may be performed by using a combined proximal tuberosity slide with some degree of skeletonization of the proximal tibial tuberosity or soft tissue traction lengthening described by Paley [16]. The persistence of a normal patellar height and the absence of arthrofibrosis after such a corrective procedure must be confirmed over time before performing PFA.

6.3. Tibiofemoral compartment OA progression

The most important aspect of avoiding persistence of patellar pain postoperatively is to make an accurate diagnosis preoperatively. Performing a PFA on a patient suffering from other underlying causes of PF pain will result in disappointment for both the surgeon and the patient [17]. Some patients with correct indications and PFA implant may still have PF pain. A subset may have developed muscle dehabilitation pain that can resolve with a structured rehabilitation program with emphasis on a core strengthening and balancing program. As with any trauma or surgery, sympathetic pain may occur and should be evaluated promptly. When technical problems are excluded, sources of PF pain in the TKA have been suggested to include overload stress reaction (both weight and activity), dysvascular/vascular state from dissection at surgery, and inadequate load transfer from the component through the cement to bone. Overload can be decreased with proper patient selection and dysvascular problems can be minimized with care to maintain a proximal geniculate blood supply. After PFA, a normal patellar height may be achieved; however, this may be in a compartment that has adapted over years to a thinner arthritic PF compartment. The new PF height may create elevated tension in medial and lateral soft tissues. As the lateral tissue tightens during flexion and the MPFL loosens during flexion, the problem often presents as lateral soft tissue pain. The trochlear component of an on-lay component may add considerably more metal than the compartment was accustomed, especially in the dysplastic patient. This situation may be improved by downsizing the trochlear trial and reassessing, followed by lateral release or lengthening as needed to balance the soft tissues.
7. Conclusion

PFA has the opportunity to improve the lives of patients with isolated PF arthritis if there is strict attention to details preoperatively, operatively, and postoperatively. Hopefully, by applying lessons learned from past PFA series, the current generation of implants may serve patients for many years. Surgeons should be aware of the differing criteria for patient selection and unique operative techniques that are essential to succeed in PFA surgery.

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