Patellofemoral Resurfacing Arthroplasty in the Active Patient

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Introduction

Isolated PF arthritis is more common than often assumed. Several authors have evaluated patients presenting for arthroplasty and have found that up to 20 % had isolated PF arthritis [1]. Obviously, nonoperative treatment is the first approach, but over time this will fail. For the younger patients, cartilage restoration is a viable option. In certain situations, however, the extent of the chondrosis or arthrosis may exceed the capabilities of cell therapy, marrow stimulation, and autograft osteochondral plugs. Treatment options for these patients are patellectomy, tuberosity osteotomy, bipolar osteochondral allograft transplantation, TKA, and PFA.

Patellectomy was once a popular option not only for PF arthritis but persistent PF pain as well. It is now recognized that the loss of the mechanical advantage that the patella affords the knee results in permanent weakness often at a clinically significant level. For the active patient, this is problematic. In addition, the increased muscle forces required for any activity involving the knee often result in medial compartment wear. As these patients often have both patella *and* trochlear wear, the pain from the trochlea is obviously not addressed. As a result, patellectomy is now relegated to the treatment of highly comminuted patellar fractures and not pain, chondrosis, or arthrosis.

Tibial tuberosity osteotomy for the treatment of knee pain and arthrosis was first popularized by Maquet [2]. With his procedure of straight anteriorization, the patella is rotated proximally in the sagittal plan: distal lesions are unloaded and the contact areas during range of motion are altered. In addition, the PF resultant forces are decreased by changing the force vectors. The decrease in forces, as noted by modern means (Tekscan® Boston, MA) direct force/pressure transducers and Fujifilm Prescale® (Tokyo, Japan) pressure-sensitive paper directly or finite element analysis (FEA) mathematically, is closer to a 20–25 % reduction as opposed to the 50 % reduction suggested by Maquet using two-dimensional vector analysis [3–5]. Fulkerson modified the

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straight anteriorization to add a component of medialization (thus anteromedialization or AMZ) [6]. This has been shown to be effective for distal lateral patellar chondrosis/arthrosis, yet it is much less effective for other areas of the patella especially if the trochlea is involved [7].

For extensive bipolar PF arthrosis, there is one biological option: bipolar osteochondral allograft. Procurement of pristine bipolar donor grafts is extremely difficult because of very limited availability. While transplantation is rather straightforward and initial transplant to host bone healing occurs, the current "stored fresh" grafts have only 50 % survival at 5 years per Bugbee and coworkers [8] compared to the 11 of 13 survivorship up to 10 years reported by Teitge using truly fresh grafts (no longer available) [9]. As a result, this technique is typically reserved for young patients in an attempt to avoid joint replacement surgery and the inherent eventual revisions.

Total knee arthroplasty remains a treatment option for isolated patellofemoral degenerative joint disease. This has been vigorously argued in the literature between total knee proponent Dr. Michael Mont and patellofemoral arthroplasty proponent Dr. Alan Merchant [10, 11]. The basis for the total knee arthroplasty argument was superior long-term results and reliability of total knee arthroplasty versus the historical results after patellofemoral arthroplasty. However, the large majority of patellofemoral arthroplasty series since 1995 have demonstrated that a properly implanted modern generation patellofemoral arthroplasty can be reliable and durable [12]. Even the older generation implants typically did not loosen, but had problems with stability or pain. With these issues largely resolved, the major factor in reliability is surgical technique which depends upon a thorough understanding of patellofemoral biomechanics.

Patellofemoral Biomechanics

Current patellofemoral arthroplasties are resurfacing arthroplasties and thus have the potential to maintain normal kinematics. With normal kinematics reestablished, the knee can "feel" natural to the patient, which is very important for a return to athletics. To achieve this outcome, the forces acting on the patella need to be normalized at the time of implant placement. For the trochlea, it is necessary to appreciate that the trochlear implant is not one-third of a total knee arthroplasty, but rather shaped in a somewhat "normal"-appearing trochlear groove appearance. As the normal trochlear groove has higher lateral facets than medial facets, placing the trochlea implant anatomically yields the appearance (to a total knee arthroplasty surgeon) that the implant is in internal rotation relative to the posterior condylar axis or trans-epicondylar axis. Once again, the goal is to establish a trochlear implant similar in position to a normal trochlea, not to reference to the tibiofemoral compartment. (For a TKA the reason for cutting the trochlea in mild external rotation is to balance the flexion-extension gaps noting the inherent coronal plane joint tibiofemoral alignment, which dictates this external rotation cut.)

With normal lateral to central tracking of the patella during flexion, the soft tissues must duplicate this after PFA. It is very common for the isolated patellofemoral arthritis patient to have excessive contracture in the lateral tissues, loss of lateral bone (when resized to "normal thickness," these lateral tissues will be tensioned), and/or lateral subluxation. To balance these lateral tissues during PFA, there will be a much higher incidence of lateral release or lateral lengthening associated with patellofemoral arthroplasties than total knee arthroplasty. This balancing of the lateral soft tissue is the most common surgery performed concomitant with patellofemoral arthroplasty. If these lateral soft tissues are neglected, the postoperative result may be lateral soft tissue pain or a markedly tilted patella that could lead to uneven stress in the implant.

A subset of patients (especially the dysplastic subset) will have a remote history of recurrent dislocations. They may no longer have dislocations because of the high friction associated with degenerative change. However, when the compartment is resurfaced with low-friction materials, the inadequacy of the medial patello-

femoral ligament (MPFL) may be quite evident postoperatively. Therefore, it is important to obtain a thorough history regarding recurrent dislocations in the past and then intraoperatively testing the adequacy of the remaining MPFL tissues. At times it may be possible to shorten the MPFL during the medial arthrotomy repair, but in patients where the tear never fully healed (especially near the femoral attachment), shortening the MPFL will not reestablish the checkrein restraint. In these cases, formal MPFL reconstruction will be necessary. Obviously, in most cases there will be a polyethylene button and thus thinner patellar bone stock. As a result, soft tissue or anchoring in trough techniques would be preferable to bone tunnel techniques [13]. The same principles of MPFL reconstruction for non-arthroplasty patients must be followed. That is, the femoral attachment site is critical for an anatomometric graft. With proper placement the distance between the attachment sites is longest at 20–30° of flexion and becomes closer with flexion. This allows a checkrein at lower flexion angles (such as with sporting activities), and the MPFL becomes lax in flexion as stability is maintained by the intercondylar notch.

The position of the tibial tuberosity affects the quadriceps vector and the timing of entrance into the trochlear groove (e.g., patellar alta delays entrance during early flexion). If it is too lateral (20 mm or greater), there will be a high probability of lateral patella tracking, which may result in either a subluxed appearance or in some cases abnormal tracking with abrupt patellar movement changes [14]. Both of these occurrences may contribute to patient dissatisfaction as well as to polyethylene wear. In these cases straight medialization of the tuberosity would be performed after the implants were in position with a goal of normalizing the tuberosity distance in the range of 10–13 mm [14, 15]. Distal osteoclasis and fixation with inter-fragmentary screws will allow range of motion, weight bearing, and exercise to be unaltered from a standard PFA postoperative protocol. With newer implants having proximal extension of the trochlear component (relative to the native trochlea), even with mild patellar alta, the patella will be engaged in the trochlea at full extension of the knee. In cases of extreme alta, if the patella does not engage at full extension, then a tibial tuberosity distalization will be necessary.

The PFA patella is typically resurfaced in a similar manner to total knee arthroplasty and most implants are either full resurfacing (dome or oval dome) or an inset (dome). These implants allow maintenance of a high level of the contact area even with subtle malpositioning of the patella compared to the trochlea. As PFA is being used not infrequently in the younger patient (40s), it is important to consider that at some point revision may be necessary. With properly positioned patellar buttons, the patellar component may be maintained, if there is no wear or evidence of loosening. In the cases where the button will need to be revised, it is important to have adequate remaining bone stock. Therefore, thicker patellar bone preservation is preferred (compared to TKA). Scott demonstrated that the concept of "overstuffing" the patellofemoral compartment does not occur with maintenance of moderately more patellar bone [16].

Authors' Experiences with Specific Implants

As PFA reports are typically level of evidence 4, we will present the outcomes at five centers that perform a relatively high volume of PFAs. There are many different implants available to surgeons. To give an overview of the broad categories, the following implants will be highlighted:

1. Focal "inlay" patellofemoral resurfacing
2. Regional "inlay" patellofemoral resurfacing
3. Custom patient-specific patellofemoral resurfacing
4. Second-generation symmetrical "onlay" patellofemoral resurfacing
5. Third-generation asymmetrical "onlay or inlay" patellofemoral resurfacing

Focal "Inlay" Patellofemoral Resurfacing (PF HemiCAP)

Personal Experience of Willem van der Merwe, M.D.

PF HemiCAP (Arthrosurface, Franklin, MA) is indicated in patients with localized patellofemoral osteochondral damage that have failed bone marrow stimulation techniques, mosaicplasty, or other focal cartilage restoration/repair. The advantage of the procedure is that the recovery time is short and the joint can be loaded from day 1. The disadvantage is obviously that the knee now has metal (and, at times, plastic) with the associated problems of wear potential and revision surgery.

The procedure really restores the contour of the joint. The rationale for the implant is that by creating a smooth and congruent surface, there will be minimal friction and improved contact area and thus a reduction in pain. The surgery is performed open to get adequate access to allow bone and cartilage preparation with precise instruments, which were designed to afford flush and congruent fit.

The keys for success of the procedure are following the correct indications and meticulous attention to following the precise surgical implantation. The positive aspects of the implant I have observed are the predictable results, a rapid postoperative rehabilitation, and there is no limit to the activity level that these patients can resume. This is not typically a first-line surgery, but in certain cases I will consider it in patients that are unable to adhere to the long rehabilitation with the bone marrow stimulation techniques.

Technique

Figures 8.1, 8.2, 8.3, 8.4, and 8.5 illustrate the HemiCAP implant.

Activity Levels

Provided that the indications were correct, I place no restriction on the activity level of patients receiving only the metal trochlear implant. Seventeen patients have been implanted: 11 with trochlea on and 6 with trochlear and focal polyethylene patellar implant. The only problem that

Fig. 8.1 Trochlear implant

Fig. 8.2 Focal trochlear osteochondral lesion

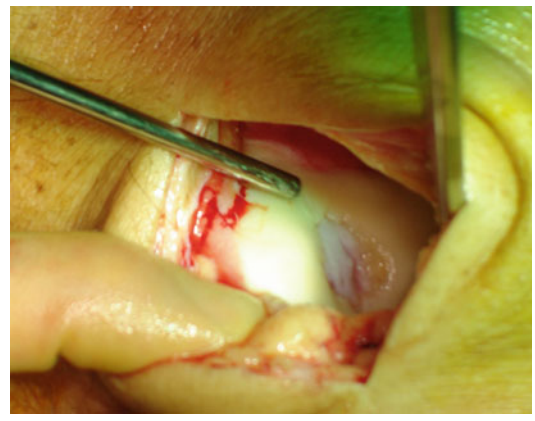

Fig. 8.3 Open appearance of osteochondral lesion

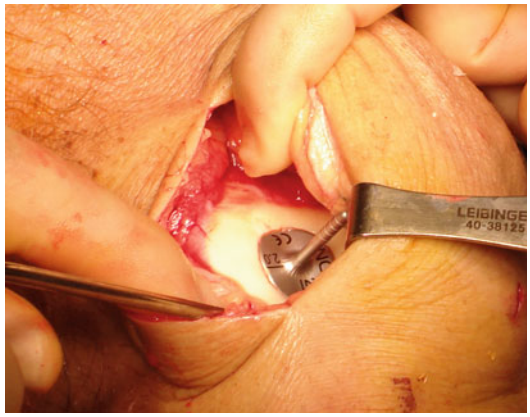

Fig. 8.4 Trail demonstrates flush fit

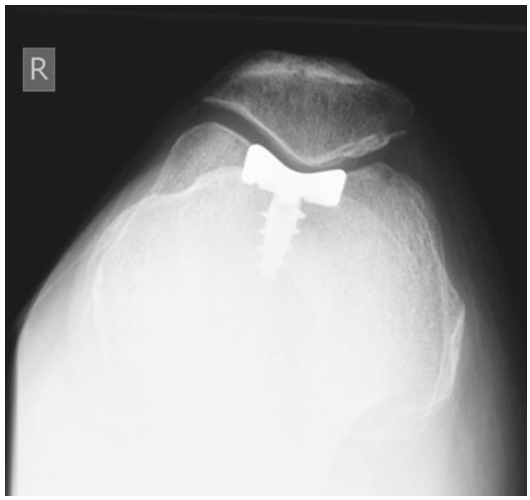

Fig. 8.5 Radiograph of implanted HemiCAP noting metal is flush with the trochlear cartilage, not bone, and thus the "proud" appearance

I found was when we did focal patella resurfacing with polyethylene. Some of those patients had effusions and discomfort. Thus, my use has been primarily to treat focal trochlear lesions with the metal HemiCAP. Trochlea-only patients have gone back to marathon running, cutting, and rotational sports with no deterioration of the knee or function in 5 years.

We have had two failures:

1. Patient had ongoing effusion and pain was diagnosed with RA and had to be converted to TKR.
2. Patient developed medial compartment OA not appreciated during initial evaluation and had to be converted to TKR.

Regional Inlay Patellofemoral Resurfacing (The Wave)

Personal Experiences of Matthias Cotic, M.Sc., and Andreas Imhoff, M.D.

Indication

The HemiCAP Wave (Arthrosurface, Franklin, MA) prosthesis is indicated in patients with symptomatic high-grade OA of the patellofemoral compartment (PFA grades III and IV according to the Kellgren classification), osteochondral lesions (ICRS grades III and IV) and failed conservative treatment (anti-inflammatory drugs/injections, stretching of the quadriceps muscle, and functional training of leg axis), or other failed focal cartilage restoration/repair. Compared to other implants, the advantage of this implant is its inlay design which fits optimally into the trochlea groove of the femur. By leaving the congruent surface of the trochlea, there will be less overstuffing compared to onlay implants, and thus there will be an anatomical surface with minimal friction in the patellofemoral joint involving reduced subchondral pressure. The disadvantage is that this prosthesis does not fit optimally in every kind of trochlea. For example, for patients having a convex or even "bumped" trochlea (type D), we do not recommend to implant the HemiCAP Wave isolated and would implant another implant with an onlay design, which creates a deepened trochlea groove. The key for success of the procedure is to accurately differentiate between the indications for a combined or isolated procedure. Indications for an isolated procedure are severe PFA due to trauma or ongoing hyperpressure due to overload. The decision for a combined procedure is based on our clinical algorithm for treatment of secondary overload and degeneration due to symptomatic patellofemoral instability (PFI).

If the patient's history and clinical examination (positive apprehension sign in 0–30° of flexion) are consistent with instability in early degrees of flexion, PFI is addressed with a concomitant double-bundle MPFL reconstruction. If radiographic (X-ray, CT scan) imaging shows valgus malalignment and/or increased femoral internal torsion, we perform supracondylarosteotomy to either straighten the leg axis or perform a detorsion of the femur. In cases of valgus malalignment, we perform high tibial osteotomy with the aim to set the mechanical axis through 50 % of the proximal tibia plateau width. In patients with a TT-TG > 20 mm, we do tibial tubercle osteotomy and a medialization, whereas in patients with a TT-TG < 8 mm and medial pain, we do tibial tubercle osteotomy and a lateralization with the aim to reach a normal TT-TG between 10 and 12 mm (range 8–20 mm). Due to the specific inlay design of the implant, we can address mild to moderate trochlea dysplasia. In cases of a type A or B trochlea, we perform an isolated procedure, whereas in patients with a type C trochlea, we do an additional MPFL reconstruction. We do not recommend implantation of the HemiCAP Wave as described above to patients having a type D trochlea.

Technique

In the symptomatic (high-grade OA) patellofemoral compartment of a 36-year-old female patient (Fig. 8.6), the Wave was implanted via an open procedure. The superoinferior curvature and the depth of the preexisting trochlear groove were determined via template (Fig. 8.7).

Then the manufacturer's guiding instruments (Fig. 8.8) were used to develop a working axis normal to the central trochlear articular surface and to cut the cartilage out of the defect of the trochlea (Fig. 8.9).

After satisfying patellar alignment without femoral overstuffing, which was tested with the trial implant (Fig. 8.10), the final implant was inserted and fixed via pilot drill/central screw (Fig. 8.11). Figure 8.12 shows a patient's implant after 2 years.

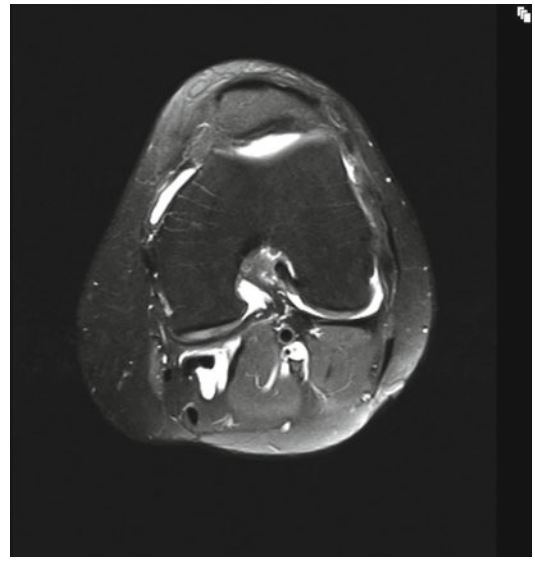

Fig. 8.6 Preop MRI demonstrating OA in the patellofemoral compartment

Demographics of Operated Patients

From October 2009 to July 2010, we implanted 28 HemiCAP Wave prosthesis (Arthrosurface, Franklin, MA) in 27 patients, 18 knees with an isolated and 10 knees with a combined procedure. It was about 14 women and 13 men with a mean age of 41.0 ± 12.4 years at surgery. Seventeen patients with the isolated procedure had a history of previous patellofemoral surgeries (6× retropatellar debridement/shaving, 1× microfracture, 1× OATS), and previous patellar fractures were found in one patient. In four of these isolated cases, patellar resurfacing was performed concomitantly.

Of those undergoing the combined procedures, four had reconstructions of the MPFL, one MPFL in combination with a tibial tubercle osteotomy, two high tibial osteotomies (HTO), one distal femoral osteotomy (DFO), one tibial tubercle osteotomy, and one MPFL in combination with a DFO and a tibial tubercle osteotomy. Previous patellofemoral surgeries in these patients included 4× retropatellar debridement/shaving, 1× microfracture, and one patient had a history of previous patellar fracture. In none of these combined cases was patellar resurfacing performed.

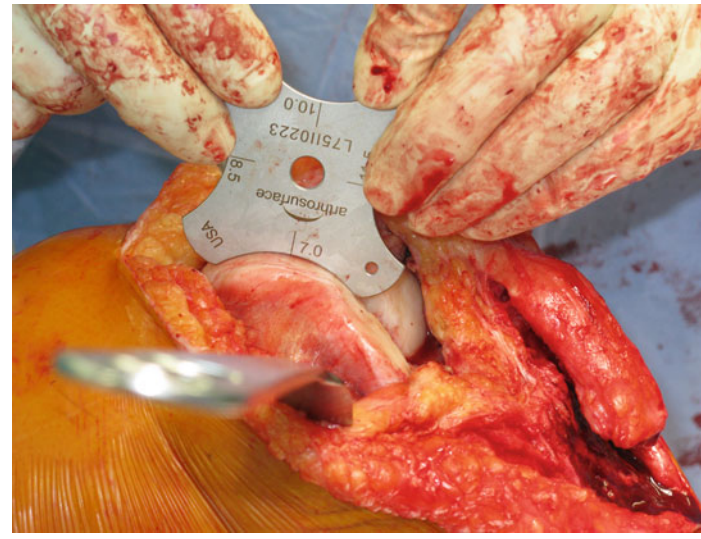

Fig. 8.7 A template is used to measure the depth and curvature of the trochlear groove

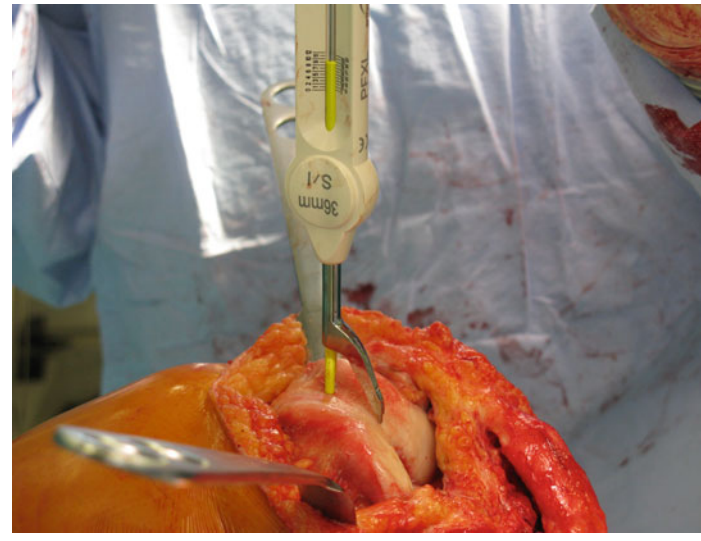

Fig. 8.8 Creating the working axis normal to the trochlear articular surface

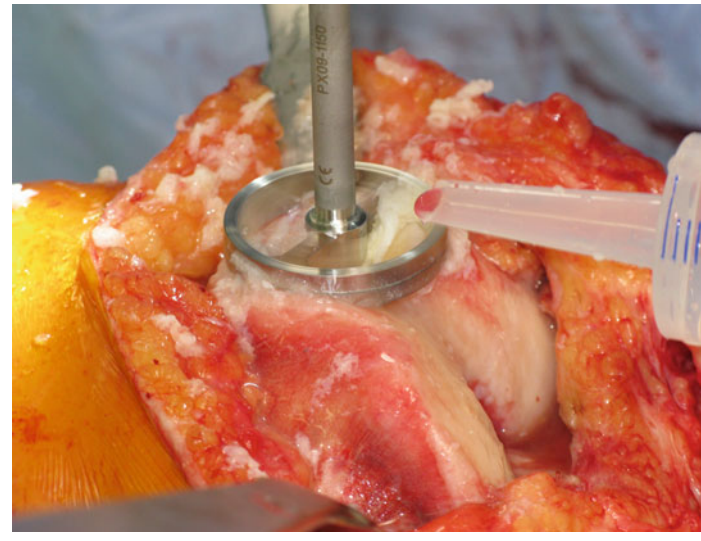

Fig. 8.9 A template to cut the damaged articular cartilage from the trochlea

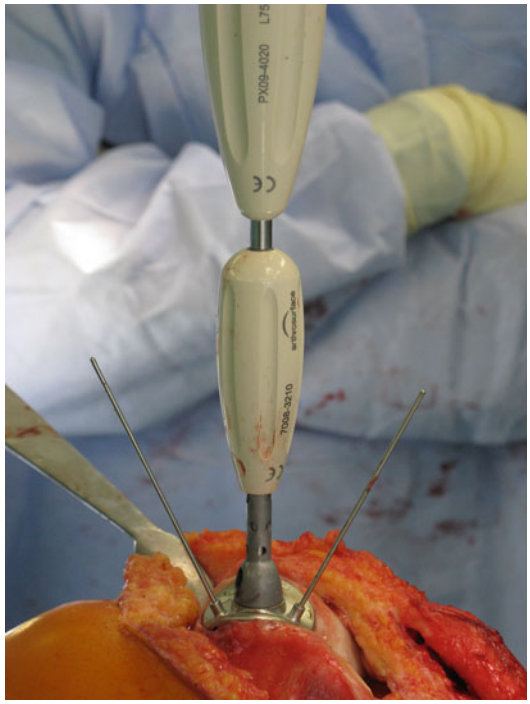

Fig. 8.10 Trialing the implant. The implant must be tested for overstuffing of the patellofemoral compartment

Fig. 8.11 The implant secured in the trochlear groove

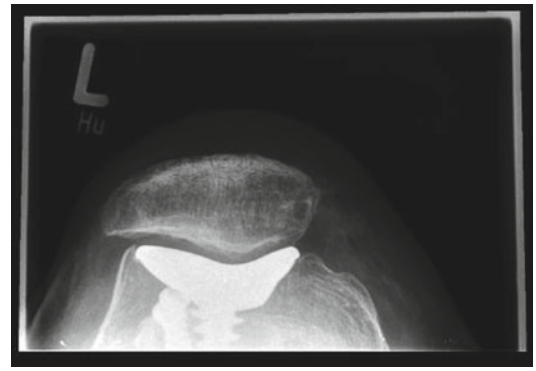

Fig. 8.12 Radiographic axial control 2 years after HemiCAP Wave implantation combined with a MPFL and a tibial tubercle osteotomy

Pain, Functional, Osteoarthritic, and Activity Levels

For the clinical program Visual Analog Scale for knee pain (0 = no pain, 10 = extreme amount of pain), Lysholm, Tegner, and WOMAC scores were recorded preoperatively and at 24 months postoperatively (Table 8.1, Figs. 8.13, 8.14, 8.15, and 8.16) [17–19]. Two patients did not complete the questionnaire and one patient was converted to TKA 1 year after surgery (see revision surgeries below). Therefore, 24 patients (25 knees) were included for statistical analysis. The Wilcoxon signed-rank test for two related samples revealed that all patients showed significant improvement (*, $p < 0.05$) 2 years after surgery based on the following medians:

Sport Participation

To avoid deteriorations of the knee or function, we generally recommend our patients after HemiCAP Wave implantation to do low- to moderate-impact sport activities. Mean time of sport participation per week was 2.1 h (SD ± 1.9) before surgery and 2.9 h (SD ± 2.7) 24 months postoperatively. The number of sport participations increased from 20 (preoperative) to 33 (postoperative status) (Fig. 8.17).

Whether patients received patellar resurfacing or not, we did not place any different limitations on their activity levels. However, we observed in the isolated cases that patients who received patellar resurfacing do have a tendency of higher activity

Table 8.1 Pre- and postoperative scores of patients implanted with the HemiCAP Wave prosthesis

	VAS_pre	VAS_24mo	Lysholm_pre	Lysholm_24mo	WOMAC_pre	WOMAC_24m	Tegner_pre	Tegner_24m
N Valid	25	25	25	25	25	25	25	25
N Missing	3	3	3	3	3	3	3	3
Median	6	3	34	75	40	10	2	3
Standard deviation	2.02731	2.41523	12.56317	19.31735	17.37604	16.12586	1.15470	2.24944
Minimum	3	0	15	20	5	2	0	0
Maximum	10	10	70	95	70	80	5	8

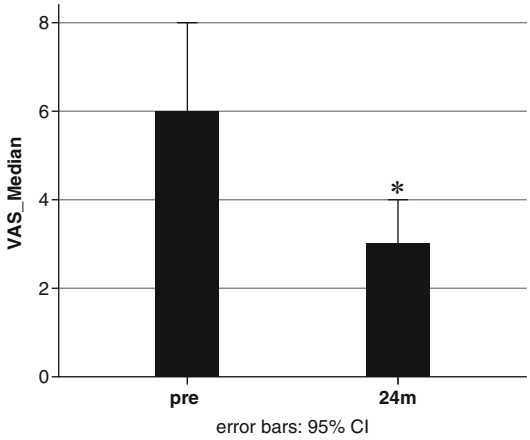

Fig. 8.13 Median VAS (Visual Analog Scale) scores show an improvement at 24 months

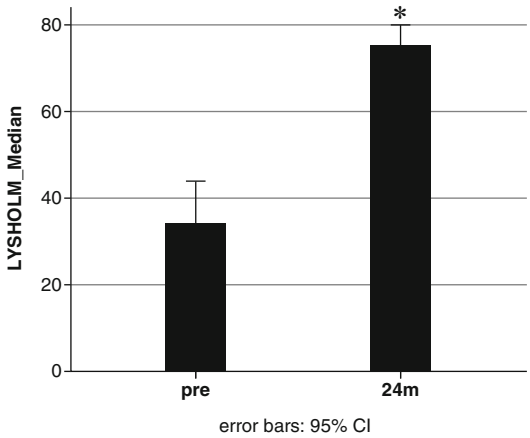

Fig. 8.14 Average Lysholm scores show an increase when compared to reported outcomes preoperatively

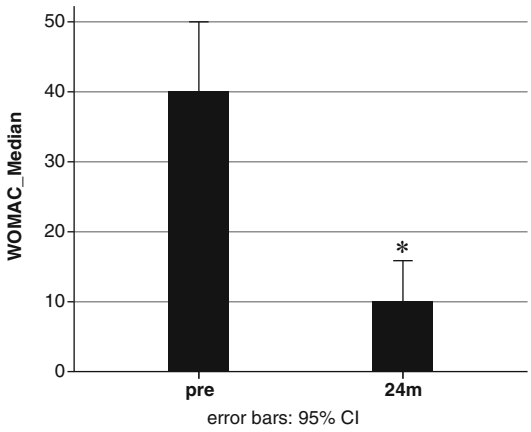

Fig. 8.15 Median WOMAC scores improved from pre- to post-op

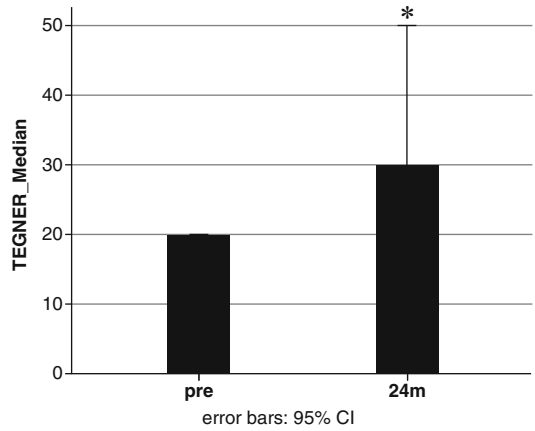

Fig. 8.16 Tegner scores show improvement over a 24-month period

status (mean Tegner score: 4.5, SD±2.5) than patients without patellar resurfacing (mean Tegner score: 2.5, SD±1.8) 24 months after surgery.

We have had three revision surgeries:

- After 1 year, one patient with ongoing effusion and pain was allergic to chrome and nickel and had to be converted to oxinium-coated TKA.
- In one patient we diagnosed a loosening of the central screw 5 days postoperative which had to be repositioned in the revision surgery.
- Two months postoperative, one patient with a combined MPFL reconstruction showed ongoing effusion and pain after spontaneous hyperflexion. We diagnosed a graft slippage at the femur insertion of the MPFL through a screw loosening and refixed the graft with a new screw.

Custom Patellofemoral Resurfacing (Kinamed® Camarillo, CA)

Personal Experience of Ronald Grelsamer, M.D.

A custom PFA is an attractive option for the active patient. Compared to other forms of patellofemoral arthroplasty, a custom PFA offers [20, 21]:

1. Greatly diminished operative time
2. An intact femur upon revision

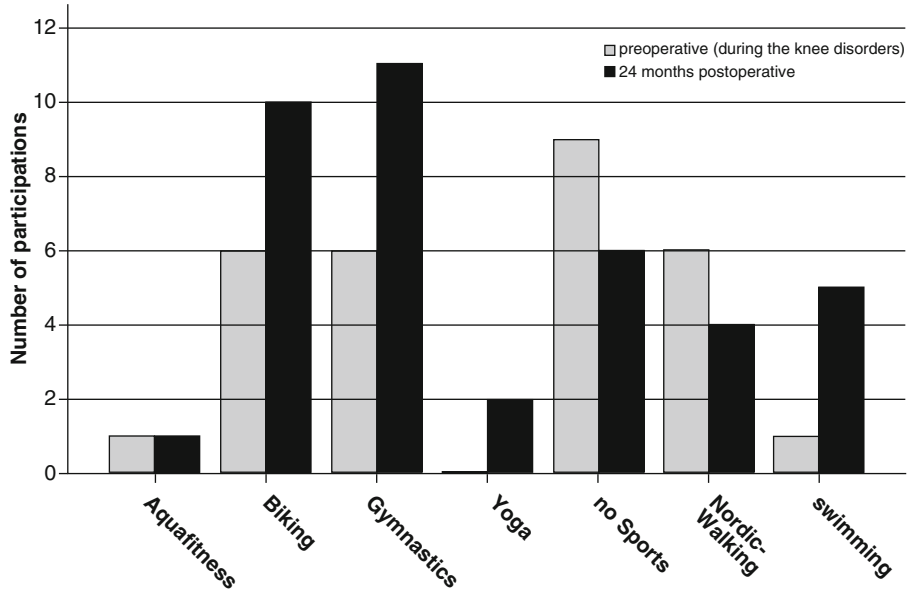

Fig. 8.17 Sport participation before and after HemiCAP Wave implantation

The diminished operative time is the result of the preoperative work performed by the surgeon and the manufacturer. The intact femur upon revision is the result of the onlay aspect of the (trochlear) implant (no bone is removed from the trochlea). There are two components to a custom PFR: the patellar button which is round (and no different from that of a TKR or other PFA) and the metallic trochlear component—the custom piece.

Design Rationale

Despite all attempts to screen out patients at risk for developing tibiofemoral arthritis, a patient receiving a PFA stands a chance of requiring a TKA at some point in the future. When an anterior cut has to be made, the subsequent surgeon will have to address this anterior cut; the inclination of that cut relative to the desired rotation of the new femoral component will determine the ease or difficulty of this step. On the other hand, with the exception of the anchoring drill holes, the femur upon removal of the custom trochlear component will be intact.

Trochleas present a remarkable variety of shapes and sizes. Some appear wide while others are narrow. Off-the-shelf implants can address sizing issues but not morphologies. The quality of the off-the-shelf fit will therefore vary from patient to patient; the long-term effects of this have yet to be determined. A custom trochlea, by definition, will fit every patient. Contrary to first incarnation of custom trochleas (Techmedica®), this custom implant features two differing surfaces: the surface facing the trochlea, which is a *negative* of the trochlea, and the surface facing the patella which *always* matches the patellar button; this concavity provides a measure of stability even in the setting of dysplasia.

Implant Creation and Implantation

A thin-slice CT scan of the distal femur is obtained. From the CT scan pictures, a plaster model is made on which the manufacturer (Kinamed) will outline the contours of the anticipated implant. The surgeon can accept or modify the contour. When all parties agree, the manufacturer creates both a custom drill guide and a custom trochlea (Fig. 8.18). At the time of surgery, the surgeon applies the custom drill guide to the trochlea and outlines it with methylene blue. (At this point, the fit is imperfect due

Fig. 8.18 After the contours of a patient's trochlea are outlined, a custom guide and trochlear implant from Kinamed are created. From Sisto DJ, Grelsamer RP, Sarin VK (2012) Patient-Specific Patellofemoral Arthroplasty. In: *Recent Advances in Hip and Knee Arthroplasty*, Edited by S.K. Fokter. InTech Publishing. Rijeka, Croatia. Open Access: http://www.kinamed.com/pdf/Sisto-Grelsamer-Sarin%20-%20Patient%20Specific%20PFR%20-%20Recent%20Adv%20in%20Hip%20and%20Knee%20Arth%20-%20InTech%20%202011.pdf

to the remaining cartilage.) The surgeon removes this cartilage within the outline. The drill guide is reapplied and three holes are created.

The real trochlear implant is applied to the trochlea; the patella is resurfaced. Care is now taken to insure proper tracking of the patella. If the patella is malaligned, the realignment options are the same as for any unstable patella (lateral release, medial imbrication, MPFL reconstruction, tibial tuberosity transfer, etc.).

The following issues have been raised in relation to this implant:

(a) In the setting of dysplastic trochleas, is there overstuffing of the patellofemoral compartment?
   - The recent literature has tended to refute the concept of overstuffing as a cause of limited flexion [16].
   - Trochlear dysplasia is most pronounced proximally; yet it is the *distal* portion of the trochlea that is in contact with the patella during flexion. The patellofemoral compartment is not overstuffed during flexion regardless of any proximal dysplasia.

   A surgeon nevertheless concerned with overstuffing can fashion the plaster model *any way* he/she wishes. The dysplasia can be removed from the plaster model, and an implant will be created to fit this "new" trochlea.

(b) The implant does not extend far enough proximally.
   - The surgeon can ask for the implant to be extended proximally beyond the native trochlea.

(c) The implant is expensive.
   - The cost of the implant is in line with other PFAs, and the implant may be considered less expensive when operating time is factored in.

Athletics

The custom PFA has not been formally investigated in the setting of sports. A distinction has to be made between a patient's ability to perform a given sport and the wisdom of performing such a sport. I define the "Bo Jackson" syndrome as a person's ability to perform a sport—only to see the implant worn or loosened as a result of that activity (Bo Jackson returned to baseball with a hip replacement—and promptly needed a revision).

A number of my patients have resumed athletic activities; I discourage activities involving repeated knee bends and, in patients with poor VMOs, uncontrolled twisting. Barring these restrictions, I allow patients a return to sports, with the understanding that we (the patients and I) are in unchartered waters.

Second-Generation Onlay Patellofemoral Arthroplasty

Two Surgeons' Experience with the Avon™ (Kalamazoo, MI) PFA

Elizabeth A. Arendt, M.D., and Diane L. Dahm, M.D.

Partial knee replacements by design are indicated for patients who have preservation of two joints with isolated arthritis in the third compartment. An ideal patellofemoral arthroplasty (PFA) patient is somebody with a functioning aligned patellofemoral (PF) joint or one that can be realigned surgically. The disease is isolated to the PF joint with minimal to no coexisting arthritis in the tibiofemoral joint. Although some patients may have a mild valgus alignment of the limb, it is important that there is no narrowing of the lateral joint space, suggesting early lateral compartment wear. Mild valgus limb alignment due to varying degrees of hypoplasia of the lateral femoral condyle is common with PF arthrosis; often the joint line remaining parallel to the floor and the tibiofemoral compartment is not compromised. Trochlear dysplasia is often present as a morphologic feature [22]. Ideally there should be no systemic arthropathies.

Design Features

The prosthesis of choice for the authors has been the Avon™ prosthesis, which is a second-generation implant developed in 1996. Early (5 years) results have been published and are encouraging for improvement in function with essentially no incidence of loosening [23].

The characteristics of the design of the trochlea come from the Kinemax total knee. There are four sizing options on the femur, no left or right differences. There are two options for the patella: a domed polyethylene symmetric button and an asymmetric button. Both are compatible with revision knee systems. The design of the trochlea is an onlay-style prosthesis that is implanted flush with the anterior cortex. It offers a broad trochlea upon which to capture the patella, making it one of the least constraining trochleas on the market.

Fig. 8.19 Lateral radiograph of left knee with patella alta (Insall/Salvati ratio >1.6), S/P Avon PFA. The kneecap remains contained in the flange of the femoral prosthesis

The length of the anterior flange is designed to have the patella component articulate with the trochlear component in extension, eliminating the potential to have the patella component catch on the superior extent of the trochlea component in early flexion. This longer trochlear design is useful, as patella alta is often associated with isolated patellofemoral arthritis (Fig. 8.19) [22]. Another advantage of this design is the initial femoral cut, which is an anterior cut, similar to that of a total knee. This anterior cut essentially removes the condylar deformity that is associated with trochlear dysplasia. The surgeon can then place the "normalized" trochlear component in the appropriate anatomic position.

In our hands it is rare that formal patella realignment is necessary. This is due in part to the trochlear design being very forgiving. In addition, the lateral patella tilt which is often present

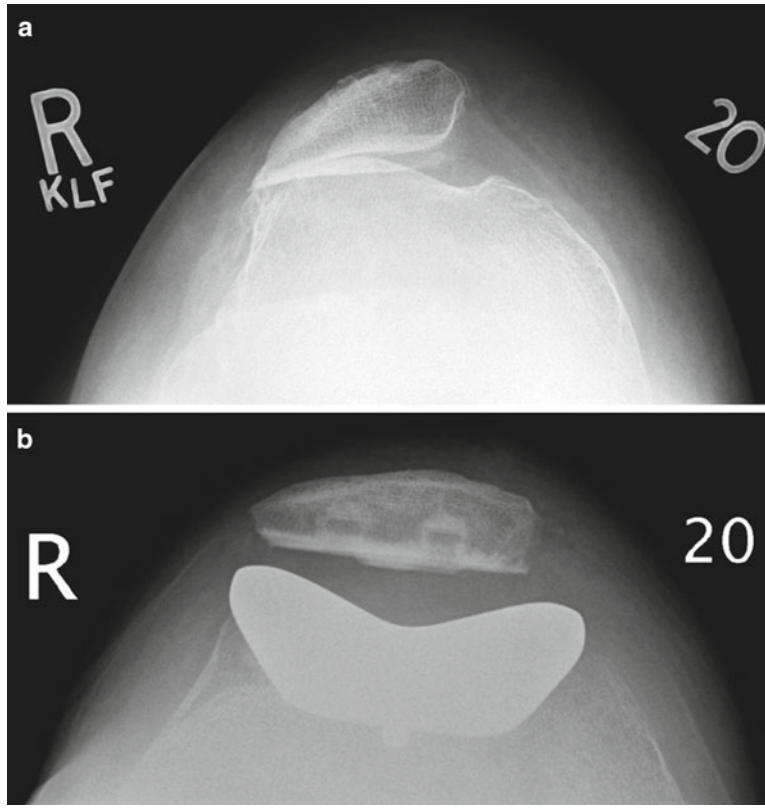

Fig. 8.20 (**a**) Lateral tilt on the axial views is (in part) due to grade IV chondral and bone loss in the lateral PF compartment. (**b**) Prosthetic restoration of the trochlear and lateral facet surface volume recreates more normal tracking

in patients with PF arthritis is in part due to wear of the lateral patella compartment (loss of bone and cartilage) (Fig. 8.20). This volume loss is "restored" with the arthroplasty resurfacing. Lateral soft tissue tightness can be managed with a peri-retinacular release (Ackroyd, CE, personal communication) [24]. At times, a formal lateral retinacular release or lengthening is performed. There may be medial retinacular tissue redundancy that can be imbricated.

This brief review outlines the collective experience of two surgeons with separate but similar practices. They have collectively performed over 220 (113; DD plus 111; EAA) patellofemoral arthroplasties from 2003 to June 2012.

To date there has been no concomitant medial tibial tubercle osteotomy associated with this procedure in our patient cohort, though some have had this procedure previously to treat PF instability. There have been two cases (EAA) that have had excessive patella alta, with the patella not being contained within the anterior flange of the trochlear design. A patella tendon imbrication was performed in both cases. Alternatively a distal tibial tubercle osteotomy can be performed provided adequate proximal tibial bone is present.

Activity Levels

The incidence of isolated patellofemoral joint arthritis is more common in females, with trochlear dysplasia commonly seen in this population [22]. The PF complaints are frequently bilateral and coupled with a long-standing history of patellofemoral pathology. As such, many patients have reduced their activity levels over time; even as teenagers they typically did not get involved in traditional jumping and pivoting sports. Therefore, many patients that are appropriate for a PFA are not involved in sporting or athletic

activities that involve running, jumping, and/or pivoting.

At times, a patient may present with PF symptoms due to PF arthritis that occur only with high-level sporting activities (e.g., running), and their day-to-day activities are not compromised. Since we have little information on activity levels after a patellofemoral arthroplasty, we cannot encourage the use of a PFA for this surgical indication. The authors believe that to advise a patellofemoral resurfacing for the *sole indication* of returning a person to a high-level impact activities is not recommended.

We place no absolute restrictions on the patient's postoperative activity but discourage dedicated running defined as one's primary exercise with daily or near daily frequency. To date there is little information about the effect of running on prosthetic wear and loosening over the long term.

In one patient cohort (DD), Knee Society Score (KSS) was used as the outcome tool. In a follow-up of 61 patients operated on between 2003 and 2009, 59 have complete follow-up (minimum 2 years, mean 3.5 years). The Tegner [19] and UCLA activity scores [25] were used to gauge activities. The UCLA scale is a simple scale ranging from 1 to 10. The patient indicates her or his most appropriate activity level, with 1 defined as "no physical activity, dependent on others" and 10 defined as "regular participation in impact sports." The Tegner score is similar to the UCLA scale, a simple scale ranging from 0 to 10, and the patient has to indicate the most appropriate activity level, with 0 defined as "no physical activity, disabled," and 10 defined as "participation in competitive soccer—national and international elite."

Pre- and postoperative means are presented below (Table 8.2). There is improvement in their scores, with mean values in both activity scores representing a moderately active population.

In a previous review comparing total knee arthroplasty patients to PFA patients in 50 matched pairs, specific sporting activity was requested [26]. This is reported in Table 8.3.

In a second patient cohort (EAA), Knee injury and Osteoarthritis Outcome Score (KOOS) was used. Of the 55 knees, 50 knees (91 %) have >2-year follow-up. KOOS subset data included averages of presurgery and 2+ years postoperatively, respectively: pain 50.0 and 74.8, symptoms 39.9 and 54.7, ADL 53.2 and 79.5, sports 26.3 and 53.7, and QOL 18.2 and 53.2. Though sporting activity has significantly improved postoperatively, it remains low compared to a young and active population.

Marx activity scale is designed for knee-injured athletic patients [27, 28]. This scale consists of four questions asking the frequency the patient performs activities such as "running, cutting, decelerating, and pivoting." Each question can be scored from 0 (less than one time per month) to 4 (four times per week or more often) and ranges from 0 to 16 points. Impact activities that are done less than once a month or not at all receive a score of zero. Review of Marx activity scales in a similar cohort of Avon PFA patients reveals a mean preoperative score of 1.94 (range 0–12) and a postoperative mean 2.17 (range 0–12). This indicates that our PFA population on

Table 8.2 Pre- and postoperative means of a cohort of Avon™ patients

	Preoperative mean (SD)	Postoperative mean (SD)
ROM arc	122.7 (9.8)	124.2 (6.6)
KSS Pain	51.4 (7.4)	89.9 (13.6)
KSS function	56.0 (10.9)	77.6 (20.6)
KSS stairs	26.9 (6.7)	38.8 (10.2)
Tegner	2.3 (0.9)	3.8 (1.2)
UCLA	3.4 (0.6)	5.8 (1.8)

Table 8.3 Sporting activities after PFA/TKA

Sporting activity	PFA group	TKA group
Walking	20 (87 %)	18 (81 %)
Swimming/water aerobics	7 (30 %)	1 (5 %)
Running	3 (13 %)	0
Bicycling	7 (30 %)	1 (5 %)
Hiking	3 (13 %)	0
Square dancing	1 (4 %)	0
Camping/fishing	1 (4 %)	0
Racquetball	0	1 (5 %)
No sports	2 (9 %)	2 (9 %)

PFA patellofemoral arthroplasty, *TKA* total knee arthroplasty

average does not partake in high-impact and pivoting activity. Four patients specifically mentioned running as a desired postoperative goal and were able to go back to running activity at some level postoperatively.

In review of our collective experience to date, the authors are encouraged that PFA is a good option for the patient with isolated grade 4 arthritis. It is our impression that the typical PFA patient returns to moderate activity levels, primarily partaking in low-impact aerobic activities. They typically return to these activities postoperatively with less pain and greater frequency than their preoperative situation.

Third-Generation Asymmetrical Onlay PFA Sigma High-Performance Partial Knee Replacement® (DePuy Synthes, Warsaw, IN)

Personal Experience of Jack Farr, M.D.

Several manufacturers now have a third-generation option. The means to optimizing a PFA are detailed in another article [29]. In this third generation, the patella remains an oval or oval dome as with second-generation implants. The trochleas are commonly asymmetrical to allow a narrower component for a specific size of femur in an attempt to decrease soft tissue impingement. With this narrower size, it is therefore possible to insert these implants in an "inlay" technique for those patients with near normal trochleas and use the same implant as on "onlay" for those with more advanced dysplasia. The trochlear aspect is lengthened proximally past the native trochlea, to allow for PF contact in full extension even with mild amounts of patellar alta. As a design surgeon (Farr is a DePuy Synthes consultant, design surgeon for the Sigma HP PKR PFA, and receives royalties), it would be somewhat disingenuous to present results in this article format as lead author. Therefore, the techniques of other authors are outlined, followed by their patients' sports activity levels. The technique for the Sigma HP PFA is demonstrated in Figs. 8.21, 8.22, 8.23, 8.24, 8.25, 8.26, 8.27, and 8.28. Figures 8.29 and 8.30 show a patient's radiographs implanted with a Sigma HP PFA.

Fig. 8.21 Standard flat cut patella maintaining approximately 15 mm thickness

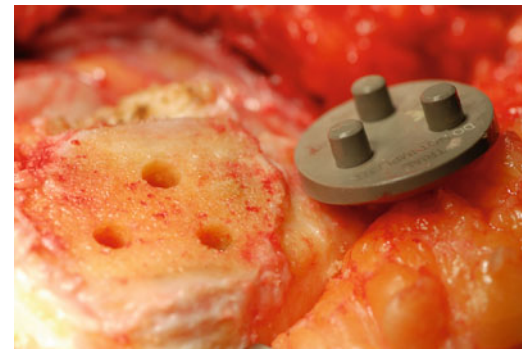

Fig. 8.22 A size 3 peg oval dome trial as would be used for TKA

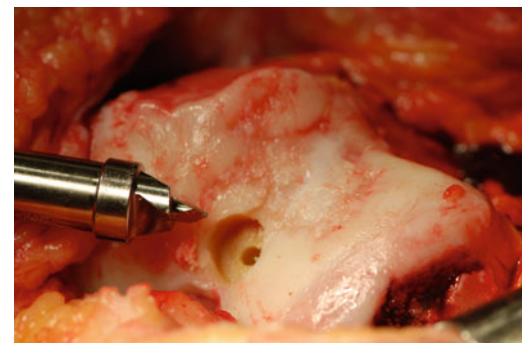

Fig. 8.23 Collared drill bit creates socket with radius same as implant tip and depth to reference all further cuts

Sports After Sigma HP PFA

Of the 213 patients undergoing this PFA from 2008 to 2012, 78 % of patients were either unable

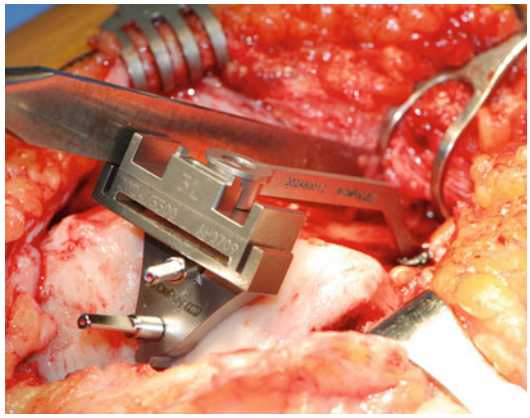

Fig. 8.24 Anterior cutting guide reference distal socket and anterior femoral cortex. Rotation matches anatomy of "normal" trochlea with higher lateral trochlea than medial. Vertical slots may be used when an inset trochlea is desired; otherwise, the horizontal slot captures the saw blade which removes all anterior bone

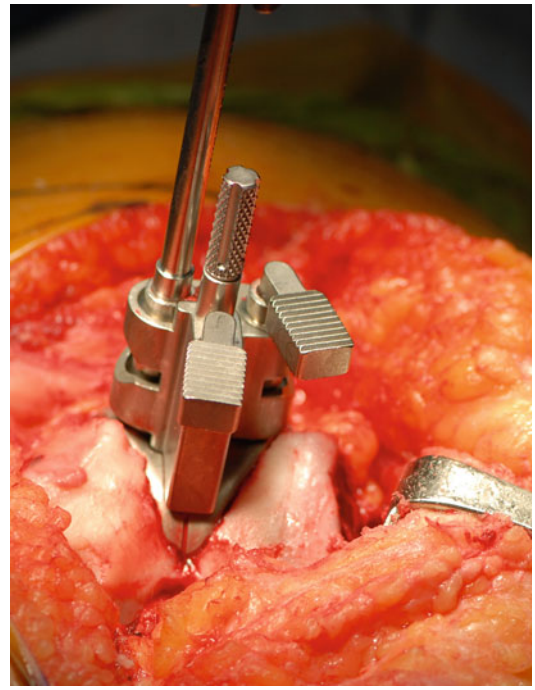

Fig. 8.26 With trial trochlear implant seated flush to adjacent cartilage of distal trochlea, a drilling guide is used to create three holes for trochlear component lugs

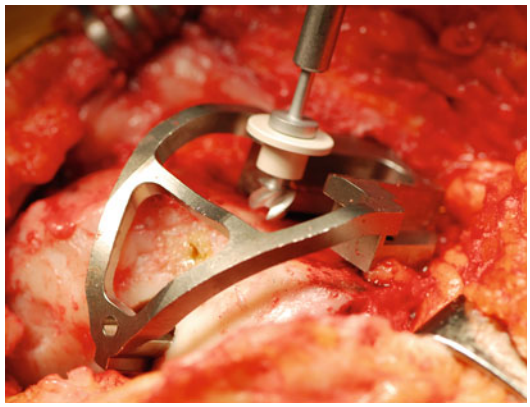

Fig. 8.25 End-cutting mill tracks on guide set in distal reference socket and anterior cut, which creates a depth equal to final trochlear component

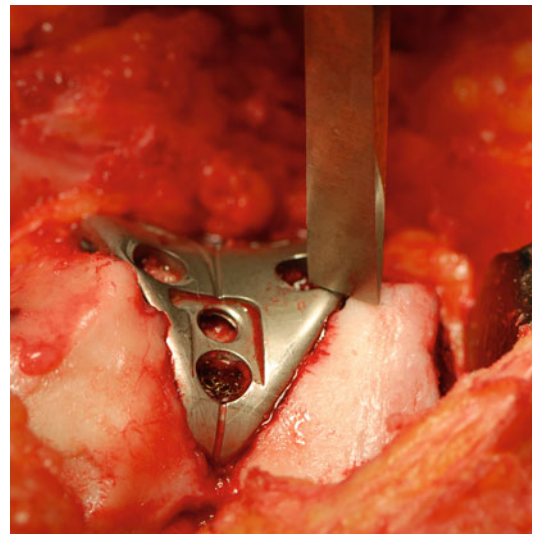

Fig. 8.27 Checking to assure the trochlear trial is flush with adjacent cartilage

or not interested in participating in sports. This group of tertiary referral patient had predominantly patients with long-standing PF degenerative arthritis in conjunction with dysplasia and thus had moderated their activity over many years. All patients who desired to return to "sport" were able to, but in this patient population, there were no high-level athletes who participated in high-demand activities except the two patients illustrated who hiked, skied (low impact), and rode horses (Fig. 8.31). There were no runners, soccer players, basketball players, or tennis players.

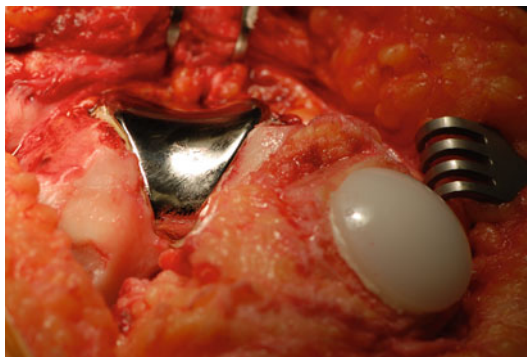

Fig. 8.28 Cemented trochlear and patellar implants

Conclusions

Sports participation after any arthroplasty remains a study in progress. There is no high level of evidence literature reports. The intermediate and long-term problems with loosening are unknown. When only the trochlea is resurfaced as with the Arthrosurface implants, obviously polyethylene wear debris as a cause of loosening is avoided. The early experiences reported are promising, yet these are a subset of PF degenerative patients (e.g., not used in severe dysplasia). As polyethylene wear is the main concern, data from TKA and UKA suggest that wear is a function of load and cycles of use. Therefore, until

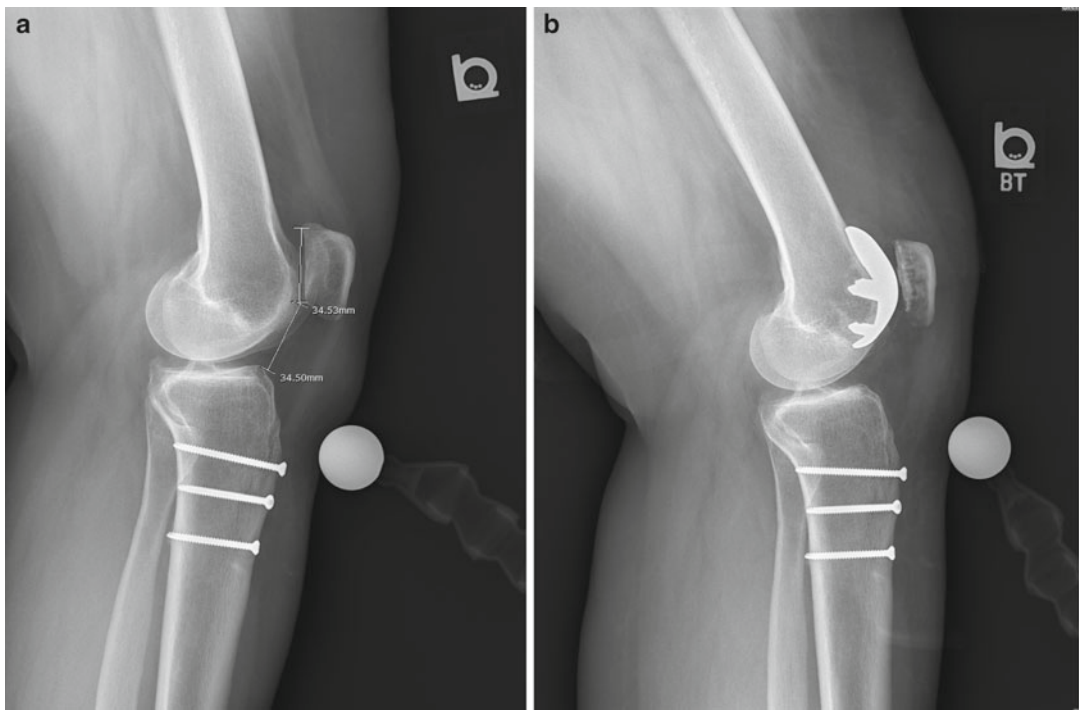

Fig. 8.29 (**a**) Preoperative lateral radiograph and (**b**) postoperative lateral radiograph

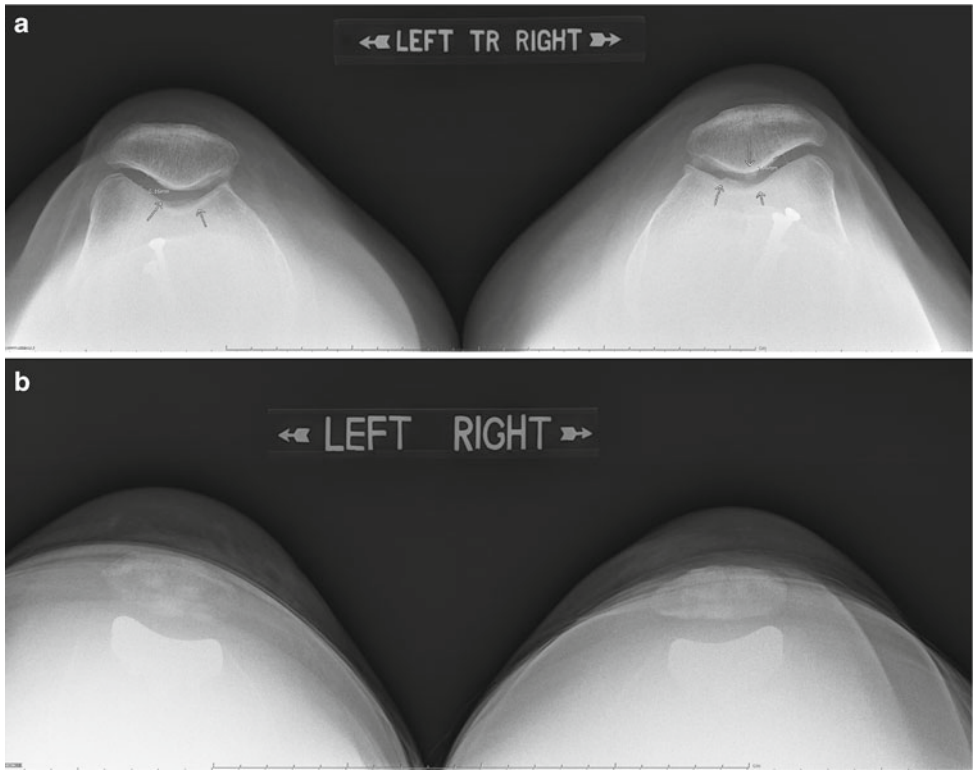

Fig. 8.30 (**a**) Preoperative merchant view and (**b**) postoperative merchant view

Fig. 8.31 (**a**) PFA patient riding. (**b**) PFA patient snowshoeing. (**c**) PFA patient cross-country skiing. (**d**) PFA patient on nontechnical climb

objective laboratory wear data or prospective randomized controlled studies are available, when polyethylene patella button is used in the PFA setting, it is advisable to recommend that patients participate only in low-PF loading sports and concentrate more on low-loading activities such as swimming and cycling.

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