Focal Anatomic Patellofemoral Inlay Resurfacing: Theoretic Basis, Surgical Technique, and Case Reports

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Isolated patellofemoral degenerative changes range from 11\% in men to 24\% in women over the age of 55 years with symptomatic osteoarthritis of the knee [1]. Reports show an incidence of isolated patellofemoral arthritis in 9.2\% of patients over 40 years [2]. The review of patients undergoing patellofemoral arthroplasty shows that the majority are women [3–8]. This may well be attributed to a higher incidence of congenital malalignment and dysplasia in women [9]. In their study of 31,516 knee arthroscopies, Curl and colleagues [10] reported approximately 20\% of cases with patellar articular defects and 15\% with trochlear articular pathology. Although these findings may have variable clinical significance at the time of index arthroscopy, the biomechanical alteration of the articulation may indicate a tendency for progressive degeneration. Anterior knee pain associated with patellofemoral degeneration is a very common presenting complaint to musculoskeletal health care providers, especially in active or elderly women.

A multitude of factors guide treatment of patellofemoral pathology, including patient age, presenting symptoms, body type, articular morphology, static and dynamic alignment, and imaging studies. When conservative measures fail, the most common surgical procedures include debridement, chondroplasty, soft tissue or bony realignment, biologic cartilage restoration, patellectomy, total knee arthroplasty, and patellofemoral arthroplasty [8,11–18].

In patients with normal patellar alignment and traumatic localized defects, standard biologic treatment options have been the mainstay of first-round surgical interventions. Biologic resurfacing described for the patellofemoral joint includes marrow stimulation techniques or biologic reconstruction. Marrow stimulation techniques include microfracture, abrasion, picking, and drilling. Biologic restoration methods include osteochondral autografts, osteochondral allografts, chondrocyte implantation, and scaffold resurfacing. Results from the biologic spectrum of treatment options have been reported with variable success rates [19–22]. Patients with chronic malalignment or dysplasia typically show degenerative, rather than focal, patellofemoral articular disease. These patients often require concomitant soft tissue and bony procedures to address the entire realm of pathologies related to the extensor mechanism and anterior knee.

Prosthetic patellofemoral inlay resurfacing is a novel treatment concept introduced to the orthopedic community in 2006. The theoretic basis of this type of arthroplasty entails recreating ambient anatomy based on intraoperative topographic mapping. The implant is intrinsically stable by virtue of the inset position relative to the surrounding joint surface. Furthermore, using this strategy, concurrent soft tissue and bony surgery is facilitated, because volume is not extrinsically added to the joint. This type of surgery, in contradistinction to some procedures labeled as “minimally invasive” is in fact “microinvasive.” This is accomplished with smaller exposures, shorter operating times, simple and cannulated implantation technique, minimal bone resection, and typically less peri-operative blood loss. Resurfacing, per se, has been widely accepted for shoulder and hip
indications with typically near-complete unipolar articular coverage. The HemiCAP resurfacing platform technology (Arthrosurface, Inc. Franklin, MA, USA) reflects a new paradigm in joint resurfacing, based on intraoperative joint surface mapping, making use of a corresponding patient-specific implant. This system allows for restoration of complex geometric surfaces in a variety of morphologic and pathologic states. Various diameter sizes are available across a multitude of joints, using the same platform technologic principles [23–28]. The current patellofemoral HemiCAP resurfacing prosthesis is available in 20-mm diameter and focuses on relatively localized defects of the distal trochlear surface and patellar defects. The prosthesis incorporates a trochlear articular component that is connected to a fixation stud via a taper interlock and a modular polyethylene patella component (Fig. 1). A choice of 13 different offset dimensions allows for a patient-specific geometry match in the distal trochlear. Larger diameter implants are pending, to address more diffuse patellofemoral disease.

**Patient assessment**

It is important to determine the source of anterior knee pain. Physical examination includes assessment of the kinematic chain during normal gait and deep knee flexion from hip to ankle. Particular attention is directed to patellar alignment with signs of tilt and subluxation. In addition, the examination assesses the medial and lateral facets, articular crepitus, particular local pain foci, and quadriceps strength.

Patients suffering from patellofemoral disease typically exhibit anterior knee pain with the extensor mechanism under load. Weight-bearing radiographs allow for improved patellofemoral assessment and include standard anteroposterior, notch view at 30° of flexion, lateral, and an axial weight-bearing Merchant view at 45° of knee flexion [23]. Chondral damage, soft tissues including patellar and quadriceps tendons, and patellofemoral joint symmetry or dysplasia can be assessed further and quantified on magnetic resonance imaging.

Focal patellofemoral resurfacing alone cannot be effective in global degenerative joint disease. Therefore, relatively monocompartmental pathology has to be verified. Patellofemoral pathology must be confirmed at the time of surgery to consider patients for patellofemoral resurfacing.

**Indications and contraindications**

The HemiCAP patellofemoral resurfacing prosthesis is intended for patients with pain and functional limitations who have not responded to conservative treatment measures or previous surgical procedures and have cartilage defects or degeneration limited to the patellofemoral joint. Both medial and lateral tibiofemoral compartments should be substantially normal or surgically addressed to render them such. Patients should show normal patellofemoral alignment, or as an alternative, improved patellar tracking can be addressed intraoperatively with concurrent procedures. Normal joint stability, both tibiofemoral and patellofemoral, and relatively good range of motion should be demonstrated before surgery.

Contraindications include diffuse full-thickness articular cartilage loss extending beyond the implant, extensive bone loss, infection, advanced osteoporosis, and other metabolic or inflammatory disorders that may negatively affect implant fixation or render the joint prone to continued degeneration.

**Surgical technique**

Patellofemoral HemiCAP implantation is performed with a combination of arthroscopic and

![Fig. 1.](image.png)
open surgery. The patient is positioned in the supine position, standard arthroscopic portals are placed, and the joint is inspected. Arthroscopic treatment is performed for concurrent pathologies and to confirm proper indication for prosthetic implantation. At the conclusion of the arthroscopic procedure, an arthroscopic lateral release may be performed. This may be indicated for patellofemoral realignment purposes and may also be used to facilitate exposure subsequently. The procedure is now converted into an open surgery by extending the medial portal between 4 and 7 cm, depending on the size of the patient. Alternatively a midline incision may be used. Electrocautery is used to incise the medial capsule and patellofemoral retinaculum with care to prevent damage to the underlying articular cartilage. The capsular incision can be extended either proximally or distally, depending on the patient morphology. A soft tissue sleeve of approximately 1 cm is left attached to the patella for subsequent closure and medial plication, if necessary. Bony realignment, when indicated, can be performed at this point in the procedure. The medial tissues are tagged and reflected, and the patella can be inverted to either 90° or 180°, depending on surgeon preference. A retractor is placed over the lateral condyle, reflecting the patella in the lateral direction, providing access to the trochlear groove.

With the knee in 90° of flexion, the HemiCAP drill guide is seated with four points of contact. The footed guide is placed in an anterior position to develop a working axis normal to the distal trochlear articular surface (Fig. 2).

The fully cannulated instrumentation initiates prosthetic alignment by placing a guide pin into the center of the trochlear defect. A step drill is advanced over the guide pin until the proximal shoulder is flush to the articular surface. Care is taken to avoid overdrilling, so as not to compromise subsequent screw fixation in subchondral bone. Standard tapping technique is used before the fixation screw is placed into the center of the defect. Etched depth markings provide external reference points while advancing instruments to ultimately achieve flush prosthetic implantation. Once peak height placement of the fixation screw is verified with a trial cap, a centering shaft is seated into the taper head of the fixation component to enable its navigational properties.

A contact probe is placed over the centering shaft and rotated to obtain superior/inferior and medial/lateral offsets (Fig. 3). A corresponding reamer prepares the implant bed (Fig. 4). A sizing trial with matching offsets is used to confirm a congruent fit of the trochlear component to the edge of the surrounding articular surface. Before placement of the final trochlear component, the procedure is directed toward preparation of the patellar implant.

The patella’s anterior-to-posterior thickness is verified to accommodate the patella component with a reaming depth of typically 6.5 mm. With the knee at 90° flexion, an alignment guide facilitates target placement of the patella component while observing range of motion. A guide pin is placed into the previously identified location—a drill guide again provides placement

![Fig. 2. Drill guide placement in the center of the trochlear defect, perpendicular to the joint surface.](image1)

![Fig. 3. Contact probe inserted over centering shaft, which is placed in the fixation component.](image2)
within a normal working axis to the patellar surface (Fig. 5).

A cannulated drill is advanced over the guide pin until the distal shoulder of the drill is flush to the articular surface. Using a powered drill, the patella centering shaft is placed over the guide pin until it reaches the distal laser marked depth marking. The contact probe establishes patellar offsets in two dimensions. A corresponding reamer is preparing the implant bed in the patella, and a sizing trial allows verification of congruent margin fit to the surrounding articular surface (Fig. 6A and B).

An anatomic or flat patellar contour can be trialed to ensure optimized tracking. The final patellar component is aligned on the implant holder and cemented into the prepared socket (Fig. 6C). The femoral trochlear component is now aligned with the appropriate offsets on the implant holder and placed into the taper of the fixation screw (Fig. 7).

A mallet and impactor firmly seat the trochlear component. Once implantation is complete, a trial range of motion is performed. A stable and balanced extensor mechanism should be present or achieved with concurrent procedures.

Closure of the medial retinacular incision is performed using standard capsular sutures. If a proximal realignment is necessary, the medial capsule can be plicated during the capsular closure. The lateral retinacular incision is left open.

Case reports

Case 1

A 45-year-old woman, an athletically active physical education teacher, presented with bilateral knee pain for more than 20 years not associated with any trauma or patellar dislocations. Both knees had two previous knee arthroscopic debridements and no realignment procedures. None of those surgeries gave sustained relief. At the time of presentation, the patient stated “I cannot do anything because of my knees; I am extremely limited in what I can do. I can’t get up and down from a chair without difficulties, I can’t do athletic maneuvers, and doing my job is nearly impossible. I have a constant sensation of aching made worse with any activities, and it clearly feels like there’s bone on bone.”

Preoperative physical examination showed symmetric findings bilaterally. Range of motion was 0° to 140°. There was painful arc of motion with palpable and audible crepitance from 40° to 140°. Marked pain was noted with patellofemoral compression. The Q angle was 9°, and the patient had symmetric quad atrophy compared with other lower extremity muscle groups. The knee was stable, and she had no specific pain with patellar lateral apprehension testing. The medial and lateral compartments were unremarkable, and the knee was stable with a small effusion. Preoperative radiographs showed advanced isolated patellofemoral arthrosis with lateral patellar subluxation.

Index procedure

The patient underwent left knee diagnostic arthroscopy to confirm the appropriate indications. Intraoperative findings included a 50% full-thickness loss of articular cartilage in the distal...
trochlear. The patella had loss of cartilage on the lateral facet and the patellar ridge. The medial and lateral compartments were without pathologic change.

A mini-open patellofemoral resurfacing with the bipolar Arthrosurface HemiCAP device and an arthroscopic lateral release were performed. During closure, a proximal realignment with medial retinacular plication was performed. The surgery was done as an outpatient procedure with minimal blood loss. The patient had range of motion from 0° to 65° by the first postoperative week and 105° by the third postoperative week, and she returned to work with a cane by the fourth postoperative week. She regained 140° flexion by the eighth postoperative week. Rehabilitation included immediate full weight-bearing, no imposed limitation of flexion, and use of axillary crutches for 4 weeks. After her experience with this procedure, 10 months after the first patellofemoral resurfacing, she elected to have the contralateral knee treated with a similar procedure. Her second knee underwent a nearly identical operation with similar results. At last follow-up, the patient expressed a high degree of satisfaction for both knees (Table 1). Please note that at the time of surgery, excellent articular congruity was achieved for the trochlear component. Fig. 8B shows an apparent offset relative to the subchondral bone, but this implant had circumferential congruity with the ambient surface (Figs. 7–11).

Fig. 6. (A) Preparation of patellar implant bed. (B) Sizing trial to verify congruent articular margins. (C) Final patellar component implanted.

Fig. 7. Final trochlear component implanted.
Case 2
The patient is a 59-year-old woman with a progressive history of more than 10 years of bilateral knee pain. The patient had no previous bracing, surgery, therapy, or dislocations. She complained of bilateral grinding within the front of both knees. She described severe limitations in her ability to perform activities of daily living and recreational activities. She has a sedentary job.

Preoperative physical examination showed symmetric findings bilaterally. Range of motion was 0° to 135°. She had painful arc of motion with palpable and audible crepitance from 30° thru 135°. Pain limited the patient from doing a one-leg step up without an assistive device. Marked pain was noted with patellofemoral compression. The Q angle was 10°, and the patient had symmetric quad atrophy compared with other lower extremity muscle groups. The knee was stable, and she had no increase in pain with patellar lateral apprehension testing. The medial and lateral compartments were unremarkable, and the knee was stable without effusion. Preoperative radiographs showed advanced isolated patellofemoral arthrosis with lateral patellar subluxation.

Index procedure
The patient underwent right knee arthroscopy with intra-articular debridement, arthroscopic lateral release, open patellofemoral HemiCAP resurfacing, and medial retinacular plication. There was minimal blood loss, and the surgery was conducted on an outpatient basis. The patient was noted to have 110° of flexion the first postoperative week, with 135° degrees after the third postoperative week. At last follow-up, 3 months after the procedure, the patient reported “great

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<th>Preoperative assessment</th>
<th>Last follow-up assessment</th>
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<td>R 34.3</td>
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<td></td>
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<td>Fulkerson knee score</td>
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<td></td>
<td>R 70</td>
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<td></td>
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<td>Tegner</td>
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<td></td>
<td>R 5</td>
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Fig. 8. (A) Case 1, Merchant preoperative x-ray. (B) Case 1, Merchant postoperative x-ray after patellar and trochlear HemiCAP resurfacing with lateral release and medial retinacular plication. (Note: improved patellofemoral tracking alignment).
pain relief and near-normal range of motion” (Table 2).

Currently the patient is pending contralateral surgery as she waits to accumulate time off from work to accommodate the procedure and postoperative recovery (Fig. 12).

Discussion

Many investigators have stressed the importance of prosthetic design factors to improve outcomes of isolated patellofemoral arthroplasty [3,14,15,29–31]. A wider selection available on the market today and improved prosthetic geometry have led to increased interest in unicompartmental arthroplasty of the patellofemoral joint. In conventional onlay patellofemoral arthroplasty, the implant geometry typically dictates the new joint surface, imparting nonnative geometry. Therefore, HemiCAP inlay resurfacing may have significant intrinsic advantages in patients with patellofemoral defects surrounded by relatively healthy articular cartilage margins and proper, or improved, extensor mechanism alignment.

Three-dimensional intraoperative mapping of the joint curvatures, preparation of a shallow implant bed, and placement of matching contoured articular inlay components provide preservation of healthy articular cartilage and valuable bone stock, avoid the risk of overstuffing the joint, and may keep the biomechanics of the patellofemoral joint unaltered. Soft tissues and extensor mechanism maintain their original tension, which may aid in postoperative recovery and strengthening. Prosthetic stability and fixation are embedded into the overall joint surface, providing a theoretic advantage for implant stability in comparison with exposed onlay prosthetic devices.

Bone cuts, as typically performed during conventional patellofemoral arthroplasty, are avoided using the described technique. This is

| Table 2 |
| Case 2: outcomes measures for right knee with 3 months of follow-up |

<table>
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<th>Preoperative assessment</th>
<th>Last follow-up assessment</th>
<th>Percent improvement</th>
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<td>Tegner</td>
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<td>2</td>
<td>100</td>
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not only important in the context of minimal impact on joint biomechanics but also in the background of future revision surgery, should the need arise.

In particular, younger and active patients with isolated patellofemoral degeneration may benefit the most from a cartilage and bone stock-preserving procedure. At the same time, older patients with more compromised or fragile health may derive a medical advantage from focal resurfacing through minimized surgical dissection, shorter procedure time, and a reduction in potential blood loss.

Primary implant stability is provided through the fixation stud anchored into the distal trochlea, connected with an articular component via taper interlock, which is seated in a precisionreamed shallow implant bed. Because of the similarities in implant design and material with undersurface titanium coverage and titanium fixation component, a comparison to the goat study of Kirker-Head and colleagues [23] for focal femoral resurfacing may be suitable. The investigators have shown secondary stability with new trabecular bone abutted to the underside of the articular component and around the fixation stud without any evidence of a residual adverse inflammatory reaction to the implant or any indication of subchondral cyst formation in the medullary tissue surrounding the prosthesis.

High loads and complex patellofemoral joint surface geometry are challenging for biologic resurfacing methods. Therefore, patients who have not responded to such treatment options, or are not amenable because of advanced age or postimplantation requirements with prolonged protected physical therapy, may benefit from a stable prosthetic inlay construct with immediate primary fixation that allows for accelerated rehabilitation.

Patellofemoral malalignment reduces the contact area between patella and trochlea, thus, reducing the load-bearing surface over which forces from the extensor mechanism are transmitted to the femur [32].

Although overall patellofemoral joint reactive forces remain the same, the reduced contact area leads to focally elevated joint stresses [33–37]. Correction of malalignment in combination with a load-sharing congruent inlay resurfacing may help in normalizing patellofemoral joint kinematics and will have advantages for implant survivorship.

Becher and colleagues [27] found no significant differences in peak contact pressure for flush HemiCAP implantation in the femoral condyle when compared with the normal, untreated joint. Future basic science investigations will need to establish scientific evidence for patellofemoral joint kinematics after HemiCAP resurfacing.

The HemiCAP patellofemoral resurfacing procedure is highly reproducible and therefore has a short learning curve. Nevertheless, poor patient selection, technical errors, residual soft tissue imbalance, and continuation of patellofemoral or tibiofemoral degeneration may have a negative impact on clinical outcomes.

Intermediate and long-term clinical outcomes are required to show the benefits of this technology and allow for comparison with other patellofemoral treatment options including conventional arthroplasty. Future increase in prosthetic surface coverage will make the HemiCAP patellofemoral resurfacing technology accessible to a wider range of patients with more diffuse and degenerative cartilage defects of the patellofemoral joint.

Summary

Distal patellofemoral inlay resurfacing with the HemiCAP technology is a novel treatment option. It is indicated for patients with relatively localized defects or degeneration limited to the distal femoral trochlear and patellar. The native joint surface geometry is intraoperatively mapped for
inset surface components with matching offsets. The trochlear and patellar prostheses are implanted congruent to the surrounding articular surface, conveying intrinsic stability. Proper patellofemoral tracking must be present or should be addressed in concurrent procedures. This patellofemoral resurfacing system may provide advantages for joint preservation, biomechanics, and component fixation when compared with traditional onlay arthroplasty. This initial report outlines theoretic concepts and surgical technique and provides case reports.

References


