CONGRUENT PATELLOFEMORAL INLAY RESURFACING

FROM FOCAL TO TOTAL PATELLOFEMORAL SURFACE RECONSTRUCTION

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Background: The complexity of patellofemoral articulation presents controversy and challenges in the treatment of isolated patellofemoral arthrosis and arthritis. Multiple procedures have been reported with variable success rates. The purpose of this review is to outline basic science and clinical experience of an inlay resurfacing technology used in the management of localized and diffuse patellofemoral degeneration.

Basic Science: Restoration of patellofemoral kinematics is crucial for the clinical treatment effect and its longevity. Eight fresh frozen knee specimens were evaluated in three conditions: Intact, defect and inlay resurfacing, were assessed for patellofemoral contact area, peak contact pressure, and peak force. Results from this study support the importance of a congruent defect fill in the patellofemoral joint. In the defect state, peak contact force increased from 13 to 18 N and peak contact pressure increased from 23 to 31 kg/cm². Edge loading and peak contact forces were highest in the periphery of the lesion. Following inlay resurfacing, peak contact force and pressure were restored to 88% and 90% when compared to the intact state. Contact area was restored to 85% of normal.

Clinical Experience: The patient benefits of inlay resurfacing continue to undergo clinical investigation. 20 patients were treated with focal patellofemoral HemiCAP® resurfacing and were prospectively evaluated with an average follow-up of three years showing excellent results across all KOOS subdomains. Symptoms improved from 16 to 26 (max 28), the pain score increased from 22 to 34 (max 36), function improved from 49 to 66 (max 68), sport from 6 to 18 (max 20) and quality of life from 4 to 12 (max 16). In a separate investigation, 22 cases were treated with patellofemoral HemiCapWave resurfacing for diffuse patellofemoral degeneration. The average prospective follow-up was 15 months. Early results showed clinically meaningful improvements despite the relative short follow-up.

Conclusion: Both basic science and clinical outcomes of patellofemoral inlay resurfacing have demonstrated encouraging results supporting the treatment concept. Intra-operative joint surface mapping and implantation of matching off-the-shelf components provide an anatomic fit in a challenging joint topography when tissue preservation is desired. Conservation of bone stock and healthy articular cartilage may reduce the impact on future surgery in patients with disease progression. Further follow-up and larger patient cohorts are required to identify individual performance criteria and long term clinical benefits of the procedure.

Level of Evidence: Review, Case Series, Level IV

Keywords: Patellofemoral Resurfacing, Arthroplasty, Knee Cartilage
Introduction

Isolated patellofemoral (PF) pain due to arthrosis and arthritis is frequently encountered in orthopaedic practice and affects approximately 9% of patients over 40 years of age (1). Complex joint biomechanics and surface geometry form a challenging environment to recreate a congruent and stable resurfacing construct in particular for active patients who failed conservative measures or biological treatment options and may need to undergo conventional arthroplasty in the future. Joint preservation and restoration of normal joint biomechanics play an important role in the management of patients suffering from isolated patellofemoral degeneration.

Etiological factors of the disease process can be attributed to trauma, degeneration, malalignment, or idiopathic conditions. Early disease stages are typically managed with conservative measures, including rest, taping, bracing, activity modification, medication, and physical therapy including stretching, strengthening exercises and gait training (2-10). Many patients with advanced degeneration will continue to be disabled and require surgical intervention to address their pathology. Treatment options cover a wide spectrum and depend on the underlying etiology, disease stage, patient age and functional expectations.

Procedures to correct patellofemoral pathomechanics include transposition or elevation of the tibial tubercle to shift contact stress and unload the patellofemoral joint (11) and lateral retinacular release (10) to re-balance patellar tracking and unload lateral capsular structures. Skeletal malalignment, in particular when rotational has been described as a major cause of patellofemoral instability, arthritis and pain and should be treated with de-rotational osteotomies (12). Chondral procedures include debridement for low grade focal defects (10,13), bone marrow-stimulating techniques such as microfracture (14-16), autologous chondrocyte implantation (17-20), osteochondral grafting (18,21) and allograft transplantation (22,23).

Historical reports on treatment of advanced PF arthritis describe isolated prosthetic resurfacing of the patella (24,25) and patellectomy (26). Both have been widely replaced with more recent designs of patellofemoral arthroplasty (7-9,27-29) and total knee replacement (30-32).

The basis for many original PF implant designs has been the trochlear footprint of existing total knee designs with modified instrumentation to create a PF system. Many traditional PF implants share the same features as their respective total knee systems: onlay design, forged or cast materials, large medial/lateral surface areas, limited sizes, singular trochlear geometries and a jig based instrumentation.

Prosthetic Design

The HemiCAP® patellofemoral resurfacing system combines intra-operative, three-dimensional joint surface mapping with implantation of matching, off-the-shelf, contoured articular inlay components. The implant is composed of a titanium bone-anchoring fixation stud (Figure 1B) and a large variety of articular cobalt chrome components with varying offsets for trochlear resurfacing (Figure 1C,1D). The 20 mm diameter provides anatomic surface reconstruction for localized defects of the distal trochlea. The 20 mm UHMWPE polyethylene patellar component is available in two different contour configurations (Figure 1E,1F) and varying offsets for congruent resurfacing.

The larger patellofemoral HemiCAP Wave System provides full trochlear surface coverage and has a corresponding set of patella implants (UHMWPE).

All HemiCAP Wave trochlear components are machined from solid CoCr mono block in order to keep implant thickness to a minimum (about 4-5mm) and maximize tissue preservation (Figure 2 A-G). The Arthrosurface Patellofemoral System avoids the introduction of non-native surface geometries by using an inlay design, asymmetric, laterally flanged and anatomically correct C-shaped sulcus for the
larger Wave components, a large variety of convexities, thinly machined trochlear components, all of which are implanted using precision milling guides. There are 21 trochlear shapes and 13 different patellas in order to provide a patient- and defect-size specific fit.

Figure 1:
A. HemiCAP™ resurfacing prosthesis: Articular component connected via morse taper to the fixation component
B. Titanium fixation stud (Ti-6Al-4V)
C. Example of trochlea resurfacing component with deep offsets (Co-Cr-Mo); undersurface coating: CP-Ti
D. Example of WAVE trochlea resurfacing component with shallow offsets (Co-Cr-Mo); undersurface coating: CP-Ti
E. Example of patella component with anatomical ridge (UHMWPE)
F. Example of patella component in contoured, round shape (UHMWPE)

Figure 2 from top to bottom:
A. CoCr monoblock
B. Machining process
C. Surface coverage
D. Implant profile
E. Implant bed
F. Inlay resurfacing
G. Arthroscopic view
Patient Selection, Indications, and Contraindications

In order to effectively identify patients suitable for patellofemoral resurfacing, assessment of the kinematic chain during the entire range of knee function is necessary. Patella alignment, signs of tilt and subluxation, crepitus and functional status of the extensor mechanism under load have to be taken into consideration. Preoperative physical examination, radiographs, and MRI provide guidance towards the underlying disorder and source of pain with functional limitations. The patellofemoral resurfacing system is intended for patients who have not responded to conservative treatment measures, or previous surgical procedures and demonstrate arthrosis or arthritis of the patellofemoral joint. Patients are required to have normal patella tracking, which can be also addressed surgically during the resurfacing procedure. In addition, patients should demonstrate ligamentous stability and adequate range of motion. The patient age range is typically between 40 and 65 years (+/- 5 years). The implant surface dimensions must cover the entire lesion. Strict adherence to these selection criteria is critical for optimized outcomes.

At the current time, advanced tibiofemoral degeneration and arthritis is considered a contraindication for isolated patellofemoral arthroplasty by many authors since tibiofemoral defects are not addressed by the implant (7-9,27-29). Specific contraindications for patellofemoral resurfacing include widespread degeneration which cannot be effectively covered by the implant, malalignment that is not addressed concurrently, chronic patella subluxation with associated bony deformations and other conditions with advanced bone loss, or poor implant fixation including late stage osteoporosis, metabolic or inflammatory disorders.

Surgical Technique

Focal Trochlear Resurfacing

As a first step, standard arthroscopy allows for joint inspection, confirmation of proper indication and treatment of concomitant findings. Surgical exposures to the patellofemoral joint may include a standard midline, a medial para-patellar incision or sub-vastus and a lateral mini-arthrotomy. Visualization of the distal trochlea and effective eversion of the patella to 90 degrees are established.

The fully cannulated instrument set provides stepwise preparation of a shallow implant bed and final delivery of the components. The HemiCAP® drill guide is firmly seated over the defect in the intercondylar groove to achieve a four point contact (Figure 3). This establishes perpendicular access to the joint surface upon which all consecutive steps are built. A guide pin is placed into the center of the defect over which a step drill is advanced. Standard tapping prepares the tunnel for insertion of the screw fixation to a controlled depth. The navigational properties of the fixation stud are employed through insertion of a centering shaft into the morse taper head. This serves as the normal axis for offset measurements in the superior/inferior and medial/lateral dimension with a contact probe. A corresponding surface reamer prepares the implant bed. A matching sizing trial confirms a congruent fit to the surrounding articular surface. Prior to placement of the final trochlea component, patella resurfacing is undertaken and both components are then seated in their implant beds (Figure 4).
**HemiCAP\textsuperscript{Wave} Resurfacing Arthroplasty**

With the knee in extension, the offset drill guide is used to establish a perpendicular working axis to the central trochlear surface. A guide pin is advanced into the bone to accommodate the contact probe for surface mapping and measurement of superior/inferior and medial/lateral offsets. The latter determines the corresponding central reamer which is advanced until the outer edge mark is flush with the medial and lateral facets. Superior/inferior mapping results determine the appropriate guide block which is secured in the trochlear groove. A set of guide block reamers prepare the implant bed. A sizing trial confirms congruent inlay fit to the surrounding articular surface. A step drill prepares the pilot hole for insertion of the tapered screw fixation. The femoral resurfacing component is aligned on the implant holder and inserted into the prepared socket. Using the impactor, fixation and articular components are connected and the prosthetic is firmly seated in the trochlea.

**Patella Resurfacing**

An alignment guide provides target placement for the patella component while observing range of motion. The drill guide is placed over the marked location on the patella and a guide pin is inserted to establish a normal working axis. A cannulated drill is advanced over the guide pin to form a pilot hole into which the patella centering shaft is placed with a power drill. The contact probe provides patellar offset measurements and a corresponding reamer prepares the implant bed. A sizing trial confirms again a congruent fit to the implant cartilage interface and proper component alignment is marked at the 12 and 6 o’clock positions. Two different contour configurations can be trialed to ensure optimal tracking. The inlay patella component benefits from cement application onto the implant rather than cement placement into the socket. This ensures even cement distribution surrounding the patella component. The final patella component is aligned and cemented into the implant bed.

**Rehabilitation**

A standard postoperative protocol with rest, ice, compression and elevation is used to control postoperative pain and swelling. The implant bed and fixation stud provide primary stability. Patients are therefore encouraged to undergo accelerated mobilization with early weight-bearing as tolerated supported by initial use of a walker or crutches. Range of motion exercises and muscle strength activity can be started immediately.

**Basic Science**

Patellofemoral kinematics was evaluated following inlay resurfacing of the trochlea on eight fresh frozen cadaveric knee specimens using a real time pressure sensor pad (Tekscan Inc, Boston, MA)(30).

Each specimen was tested in three different conditions: Intact, defect and inlay resurfacing which were assessed for patellofemoral contact area, peak contact pressure, and peak force. In the defect state, peak contact force increased from 13 to 18 N and peak contact pressure increased from 23 to 31 kg/cm\textsuperscript{2}. Edge-loading and peak contact forces
were highest in the periphery of the lesion. Following resurfacing, peak contact force and pressure were restored to 88% and 90% when compared to the intact state. Contact area was restored to 85% of normal (Figure 7, 8). Results from this investigation support the importance of a congruent defect fill in the patellofemoral joint and the authors concluded that despite the inherent challenges, limited trochlear resurfacing provides a unique and favorable alternative to prior implant designs by providing anatomic re-approximation of the patellofemoral surface and knee contact pressures.

Clinical Experience

Focal Patellofemoral Inlay Resurfacing

The patient benefits of inlay resurfacing continue to undergo clinical investigation. Van der Merwe et al.REF presented their results from 20 patients at the International Patellofemoral Study Group. At an average follow-up of three years, prospective data showed excellent results across all KOOS subdomains (Figure 9). Symptoms improved from 16 to 26 (max 28), the pain score increased from 22 to 34 (max 36), function improved from 49 to 66 (max 68), sport from 6 to 18 (max 20) and quality of life from 4 to 12 (max 16).
Case Report

A 42 year old male patient (avid runner) presented with stiffness and swelling following sporting activities. He was able to walk, however running was too painful. Physical examination showed patellofemoral crepitus, a small effusion, flexion was limited to 110 degrees, and the knee was ligamentously stable and had normal patella tracking. The patient had a history of Osgood Schlatter disease as a child and sustained a traumatic soccer injury two years prior to presentation. The pre-operative MRI demonstrated a full thickness defect of the distal trochlea and lower grade degeneration of the patella (Figure 10). The patient was initially taken to the operative room for arthroscopic debridement and microfracture of the Grade IV defect in the central intercondylar groove (Figure 11,12). An extensive rehabilitation program was initiated postoperatively without any complications. One year later, the patient was not satisfied with the treatment outcome and unable to run or resume recreational soccer. Repeat arthroscopy demonstrated a macroscopically healed trochlear defect (Figure 13) with mechanical failure, leaving a 17x22mm defect (Figure 14). The patella demonstrated Grade I changes (7x12mm). Unipolar trochlear HemiCAP® resurfacing was undertaken (Figure 15) and the patient was pain-free three months following the procedure. At that time, he returned to running followed by recreational soccer at four months after surgery. Last follow-up at 19 months demonstrated a satisfied patient with no pain, swelling, locking, or giving way, full range of motion, and normal patella tracking. The patient continues to run and play soccer.

Figure 10: Initial pre-operative MRI with full thickness defect of the trochlea and lower grade patella degeneration

Figure 11: Full thickness defect of the distal trochlea

Figure 12: Microfracture of the trochlear defect

Figure 13: 12 month follow-up arthroscopy: Macroscopic healing of the trochlear defect

Figure 14: 12 month follow-up arthroscopy: Mechanical failure of the trochlear defect

Figure 15: Postoperative Merchant and lateral view following PF resurfacing
HemiCAP\textsuperscript{Wave} Resurfacing Arthroplasty

The larger HemiCAP\textsuperscript{Wave} implants were introduced to US and International markets in 2008. To date, early results from prospective investigations are emerging. Twenty-two cases (mean age of 43.1 ± 13.7) were treated for diffuse patellofemoral degeneration. At a mean follow-up of 15 months, preliminary results show clinically meaningful improvements. Kujala and IKDC Scores demonstrate positive trends in the reduction of anterior knee pain and improvement of knee function (Figure 16,17).

Discussion

Surgical management of patellofemoral arthrosis and arthritis in middle aged patients remains challenging due to high articular loads and limited biologic treatment options in this patient population. At the same time conventional knee arthroplasty should be delayed to avoid early revisions, in particular in patients with mono-compartmental degeneration. Many treatment options exist to address cartilage defects, yet the role of debridement is limited to small, low grade patellofemoral lesions and microfracture is typically reserved for younger patients. Martin and Buckwalter reported an age-related decline in chondrocyte synthesis, mitotic activity, and responsiveness to anabolic cytokines and mechanical stimuli, which may add to the explanation of an age-related increase in the prevalence of osteoarthritis and decrease in cartilage repair efficacy (39). Autologous chondrocyte implantation and osteochondral grafting may have similar limitations especially when confronted with a complex surface geometry.

Assessment of proper patellofemoral joint kinematics and restoration of abnormal patella tracking remains crucial for all treatment options currently used for management of patellofemoral arthrosis.

Isolated patellofemoral arthroplasty is intended for advanced mono-compartmental degeneration. The history dates back to the 1950s with McKeever’s initial report on patella resurfacing (25). Bipolar resurfacing of the patellofemoral joint was introduced in the 1970s, however, the data was less encouraging (40). Consecutive design changes and introduction of various patellofemoral arthroplasty prostheses resulted in good to excellent results in the majority of patients (7,8,26,41,42). Patellofemoral arthroplasty allows for preservation of healthy medial and lateral compartments. Nevertheless, total knee
arthroplasty has been reported for isolated patellofemoral arthritis (31-33), which may be a valid solution for older patients but cannot be recommended for the active middle-aged patient population (33). These patients would benefit most from joint conserving alternatives to maintain an active lifestyle and preserve valuable bone stock for possible arthroplasty in the future.

Drawbacks for long-term survivorship of patellofemoral arthroplasty are progression of tibiofemoral degeneration and implant loosening (9,27). Caution is therefore indicated in patients with primary osteoarthritis and initial manifestation in the patellofemoral joint. Argenson et al. reported aseptic loosening in 11 of 66 patients with long-term follow-up (9). High loads across the patellofemoral joint and exposure of onlay prosthetic designs may play a role in implant survivorship.

Most patellofemoral prostheses currently available on the market target diffuse degeneration, whereas the HemiCAP® patellofemoral system includes implant diameters for both localized and diffuse defects and may have several advantages over conventional patellofemoral arthroplasty procedures:

Congruent inlay components may have positive implications for implant stability, post-operative recovery, and joint preservation. Approximately 30% of the adult US population has a BMI of greater than 30 kg/m² (defined as obese) (43) creating increased demands on weight-bearing joints. Inlay resurfacing may provide a long-term survival advantage in particular in patients with proper joint kinematics, as trans-articular contact pressure is shared with the surrounding tissue and not concentrated on the prosthesis alone.

The shallow implant bed and small footprint of the fixation stud pose little or no limitations in future conventional arthroplasty for patients who may undergo disease progression. HemiCAP® resurfacing of the patellofemoral joint indicates promising results in middle-aged patients who have failed prior biologic treatment options, or are unlikely to achieve a successful outcome with conventional cartilage procedures. Patient selection and proper joint mechanics play an important role for successful treatment outcomes.

The surgical technique achieves reproducible results through control and reference steps throughout the course of implantation and allows for an individual, anatomic reconstruction of a challenging joint geometry. Soft tissue tension and extensor mechanism are kept unaltered which may be beneficial in particular for patients with a traumatic etiology and otherwise normal patellofemoral kinematics.

Combination implantation of various inlay implants may provide a future alternative to total knee arthroplasty in this relatively young patient population. Further follow-up is required to correlate the degree of patellofemoral degeneration with uni- versus bipolar- patellofemoral resurfacing and assessment of concomitant procedures. Long-term follow-up should negate the effect of peri-operative morbidity. In addition, patient subjective outcomes and further basic science studies are necessary to establish the medium and long-term benefits of this procedure in the management of symptomatic patellofemoral lesions.
References


