Arthrosurface Inlay Resurfacing: Indications, Surgical Technique, and Results

13

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13.1 Introduction

Cartilage lesions in the knee are common [1] and can be highly symptomatic [2-4]. The biological treatment spectrum offers a wide range of cartilage procedures that address these lesions from different perspectives: Palliative interventions (debridement) aim at lesion stabilization and the removal of mechanical symptoms. Reparative (marrow stimulation techniques), restorative (chondral, osteochondral transplantation), and reconstructive (allograft, prosthetics) procedures target defect filling and surface reconstructions, while corrective procedures (osteotomy) take aim at the underlying disease process. All but palliative and prosthetic reconstructive measures require prolonged rehabilitation to ensure adequate biological response, remodeling, and healing.

In individuals of advanced age, with longer-standing symptoms and a surgical history, the transition from biological procedures to joint arthroplasty is not well established because prosthetic design concepts of conventional joint replacement do not fulfill the requirements of early intervention; rather, they provide a solution for delayed treatment. The fundamental goal is to maximize implant longevity. Very good long-term results have been published [5-8], yet conventional arthroplasty is not without controversy: onlay surface replacements introduce a non-native joint surface geometry, which has implications for pain relief, functional outcomes, and implant survivorship. High-demand patients, such as younger, more active populations as well as heavy and morbidly obese patients, have inferior clinical outcomes combined with higher revision rates [7-10]. While the delay strategy may work on an individual basis, today many patients are seeking solutions that allow them to return to work and active lifestyles.

First-intervention metallic prosthetics should follow the treatment concepts of biological procedures: a minimally invasive approach, joint preservation through maintenance of healthy soft tissues and bone stock, and biomechanical stability combined with a new contoured joint surface that counteracts lesion propagation.

Since 2003, a knee resurfacing platform (Arthrosurface, Franklin, MA) has been developed that is consistent with the paradigm of joint preservation. Moreover, it allows the surgeon to address joint arthrosis with a contoured metallic implant that is thin, sized to the lesion, and specific to the joint surface of the patient. The 66 different sizes and shapes (47 different metallic ones for the knee and a corresponding set of 19 polyethylene component choices) provide the first step in arthroplasty under the continuum of care for joint arthrosis and arthritis (Fig. 13.1). All metallic components are made of a CoCr alloy and have Ti coverage where they interface with bone (screw fixation, undersurface of the articular component); the polyethylene components are ultra-high-molecular-weight polyethylene (UHMWPE) and are cemented into the prepared implant bed.

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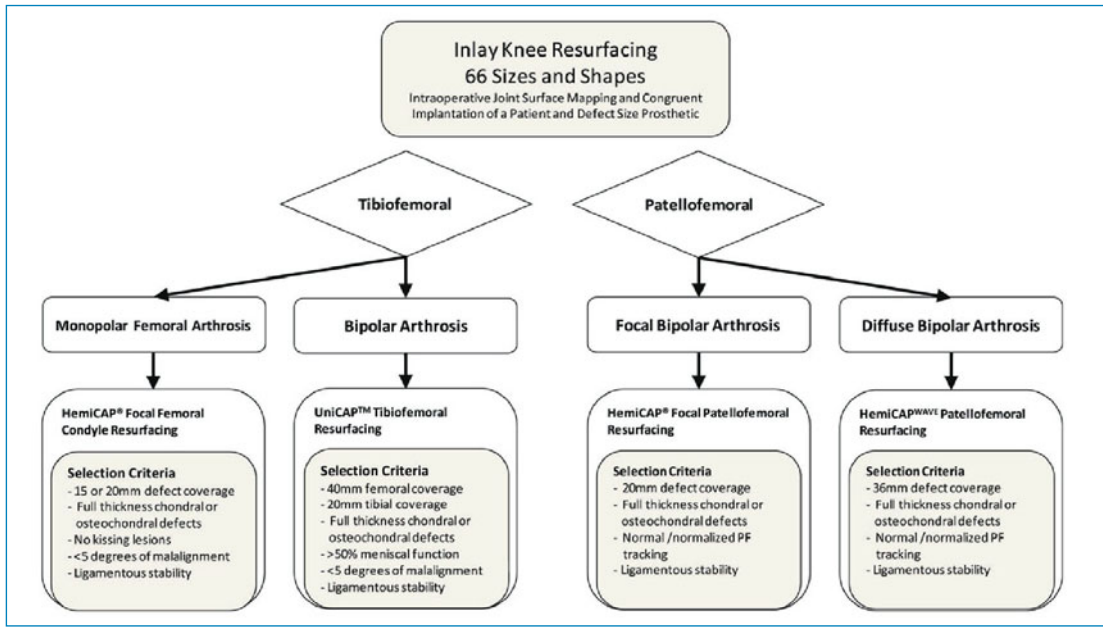

Fig. 13.1 Inlay knee resurfacing platform for tibiofemoral and patellofemoral mono- and bipolar arthrosis

Table 13.1 Technical pearls for inlay knee resurfacing

1.	Manage patient expectations and educate on early focal resurfacing vs. delayed total arthroplasty.
2.	Ensure adequate implant defect coverage.
3.	Recess implant components slightly below the articular surface (0.5–1.0 mm) to avoid damage to the opposing articular surfaces.
4.	Careful intraoperative mapping of the defect needs to be undertaken in order to match the prosthetic implant curvature to the native articular surface.
5.	Ensure uniform cement coverage surrounding components.
6.	Inlay components do not correct the mechanical tibiofemoral alignment.

Basic science [11-14] and clinical outcomes [15-18] complement each other and support this platform for the treatment of chondral and osteochondral defects. Inlay resurfacing is not a replacement of existing cartilage repair procedures; rather, it is an extension of reconstructive methods with the support of individual patient management. The key aspects that should be considered when performing inlay resurfacing are listed in Table 13.1.

13.2 Monopolar Focal Femoral Condyle Inlay Resurfacing

Focal femoral condyle prosthetic resurfacing continues localized management of full-thickness chondral and osteochondral lesions and expands the range of precursor biological treatment options. Successor procedures such as unicondylar knee replacement provide a sound clinical exit strategy when larger surface reconstruction is warranted.

This interim treatment solution for patients between 40 and 60 years of age provides a biomechanically stable, congruent defect-filling designed to protect the remaining normal cartilage. It consists of two components, an articular component and a fixation component (Fig. 13.2), joined by a morse taper interlock. The cobalt chrome 15- or 20-mm articular components are both available in a variety of incremental offset convexities corresponding to the surface curvature of the patient's condyle.

Fig. 13.2 Examples of HemiCAP focal inlay resurfacing prosthetics: high-pitched screw fixation component and modular, contoured articular component

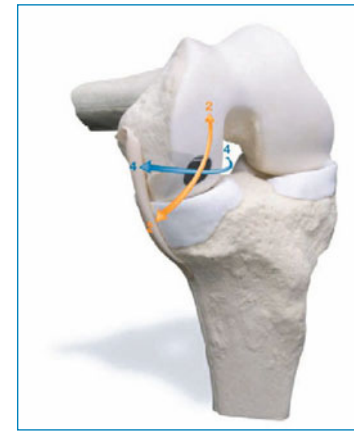

Fig. 13.3 Intraoperative 3-D surface mapping using the HemiCAP system

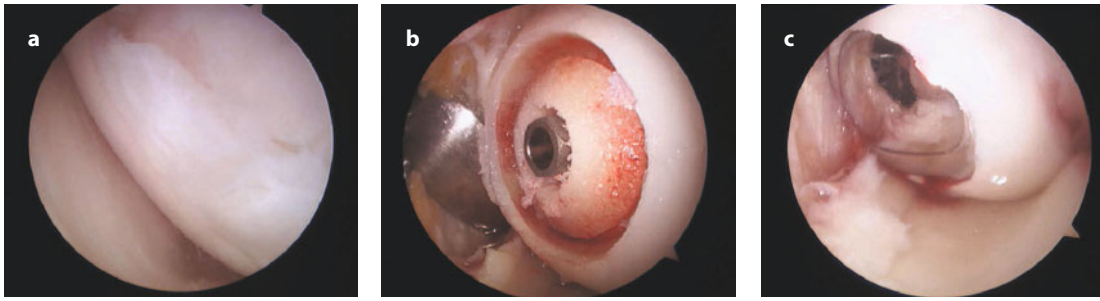

Fig. 13.4 Example of HemiCAP focal femoral condyle resurfacing after failed microfracture, medial femoral condyle. **a** Defect filling after prior microfracture, resulting in soft, fissured repair cartilage. **b** Implant bed with screw fixation in center. **c** HemiCAP focal resurfacing implant with slightly recessed implant margins

13.2.1 Surgical Technique

A small para-patellar incision is made over the defect through which the device is implanted on the medial or lateral femoral condyle. Using a drill guide and pin, the surgeon establishes a perpendicular working access to the joint surface and drives a cannulated step drill into the bone until the proximal shoulder of the drill is flush to the articulating surface. The fixation component is placed at the correct height under visual control and the patient-specific joint surface curvature is measured intraoperatively (Fig. 13.3). The implant socket is prepared using precision surface milling. A sizing trial allows for proper assessment of the cartilage–implant interface. The final articular component is aligned on the implant holder and inserted into the taper of the fixation component. Progressive tapping on the impactor engages the articular and fixation components. Final placement of the surface prosthetic is targeted slightly recessed (0.5–1.0 mm) to the surrounding articular cartilage to account for nearby cartilage thickness variations during weight-bearing, thereby avoiding any overloading or deleterious effects to the opposing side (Fig. 13.4).

13.2.2 Results

Kirker-Head et al. reported on the biocompatibility of this implant in the caprine model [11]. A continuous trabecular and subchondral bone interface was observed surrounding both the screw and the resurfacing unit. Cartilage flow from the adjacent native tissue covered the implant-cartilage interface. Several clinical studies of

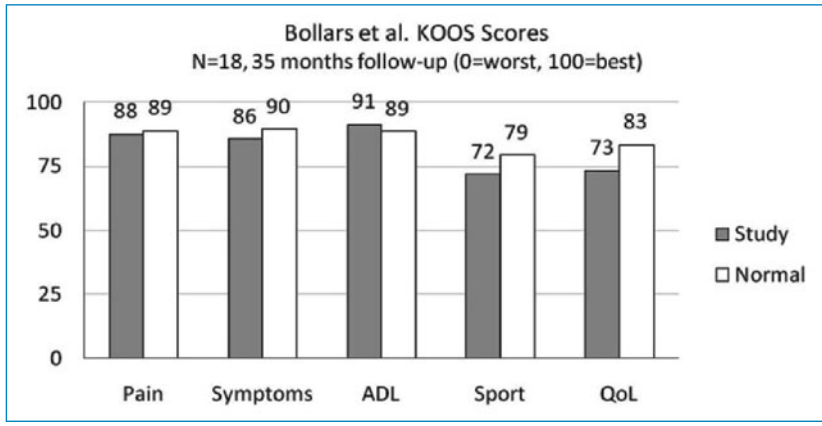

Fig. 13.5 35-month follow-up KOOS scores comparing focal femoral condyle resurfacing to normative, age-matched values (from [20])

the HemiCAP focal femoral condyle resurfacing prosthesis have been undertaken to date, showing encouraging results with a follow-up of up to 6 years.

Von Hasselbach and Witzel reported on 121 patients with a mean age 52.5 years in whom the HemiCAP resurfacing prosthesis was implanted, with a mean follow-up in this series of 14 months [19]. The follow-up Hospital for Special Surgery (HSS) score was high (95.3), with an increase of 12% from baseline. Second-look arthroscopies performed for non-device related indications showed no deleterious cartilage effects on opposing articular surfaces. Radiographs showed no peri-prosthetic radiolucency or implant subsidence.

Thirty-six patients in the prospective US phase II multicenter feasibility trial have completed their 2-year follow-up. Forty patients (26 males, 14 females), with an average age of 47 years, were treated with the device: 38 for isolated full-thickness defects of the medial femoral condyle and two for defects on the lateral side. Two patients were lost to follow-up, one died before the 2-year endpoint, and in one conversion to unicondylar knee replacement was necessary. The average preoperative WOMAC domains showed significant baseline pain (308) and functional deficiencies (999) that had improved remarkably by 3 months after the procedure (pain 68, function 246). The average results showed further improvement across all domains from 1 to 2 years postoperatively. The mean total WOMAC score was best at the 2-year follow-up time point and had improved from 1436 preoperatively to 341.

Bollars et al. studied 18 patients with an average age of 51 years in whom the study device was implanted and found excellent results at a follow-up of 35.3 months [16]. In these middle-aged patients, 83% had a normal or nearly normal IKDC score. Compared to normative age-matched scores, in the study patients there was a close match across all KOOS domains (Fig. 13.5).

Becher et al. studied 21 patients with a mean age of 54 years at the time of the initial focal resurfacing. The minimum follow-up was 5 years (range: 5–6 years) [15]. The authors demonstrated radiographic joint space preservation and statistically significant improvements across all KOOS score subdomains, Tegner score, and SF-36 score.

To date, examples from second-look arthroscopies have confirmed the preclinical results. The prosthetic appears to be well incorporated; the superficial cartilage layer from adjacent healthy margins covers the implant cartilage interface; and opposing tibial surfaces have not shown any apparent response to the contoured prosthetic.

13.3 Bipolar Tibiofemoral Inlay Resurfacing

Bipolar knee inlay resurfacing was introduced in 2008 to provide an option for patients with early tibiofemoral arthrosis (Fig. 13.6). It is minimally invasive, preserves the menisci and

Fig. 13.6 The UniCAP meniscal-sparing unicondylar system

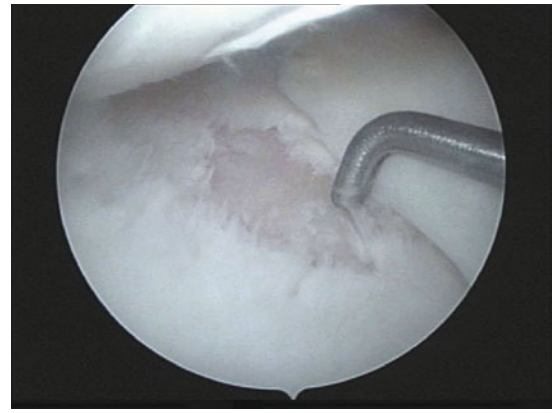

Fig. 13.7 Localized tibial defect

cruciate ligaments, and retains the bony architecture of the knee joint. Similar to the focal monopolar femoral condyle implants, the larger bipolar tibiofemoral implants come in a number of different surface convexities to allow for precise and contoured inlay resurfacing. Inherent to the technique, the tibiofemoral alignment cannot be changed with inlay implants. Therefore, the mechanical tibiofemoral axis has to be taken into consideration for indications and for surgical planning (Fig. 13.1).

13.3.1 Indications

The target population consists of middle-aged patients who have failed previous conservative treatment and/or surgical interventions and have re-developed significant pain, causing limitations in function and in the activities of daily living and requiring surgery for mono-compartmental arthrosis.

Preoperative clinical examination should show a stable knee with less than 5° of mechanical malalignment, range of motion with a deficit of less than 10° of flexion or 5° of extension, satisfactory meniscal function, and a normal to slightly overweight body mass index (BMI <30). If a patient considered for resurfacing has factors just outside these parameters, for example malalignment or ligamentous instability, these should be dealt with prior to or in conjunction with the UniCAP procedure. When more than one risk factor is present, consideration needs to be given to the compounding effect when determining patient indications and expectations.

Contraindications for the procedure include metabolic disorders affecting implant fixation, bony deformation, mechanical malalignment affecting the ipsilateral compartment, high BMI >30, and widespread degeneration that cannot be covered by the prosthesis. Patients need to be carefully selected, on an individual basis (Fig. 13.1), taking into account both their expectations and the demands of their activities.

13.3.2 Surgical Technique

The patient is positioned and prepared for standard knee arthroscopy allowing for deep knee flexion during femoral preparation. The anterolateral portal is established first, as it improves visualization of the medial compartment (Fig. 13.7). Once the proper indication is confirmed, a full-length anteromedial skin incision is placed vertically 1 cm medial to the patella tendon and extending proximally from the mid-pole of the patella down to 1 cm distal to the joint line. Capsular integrity is maintained by limiting the capsulotomy to the anteromedial portal for the arthroscopic tibial preparation. The full-length skin incision is made initially in order to aid in tissue dissection and avoid challenges associated with extravasation

during arthroscopy. Extending the skin incision distally below the joint line facilitates exposure and avoids posterior pin deviation and skin interference during reaming of the posterior femoral implant bed. Once concomitant findings have been addressed, attention is directed towards the tibial defect.

13.3.2.1 Arthroscopic Tibial Resurfacing

Normal knee kinematics include a tibial rollback phenomenon during knee flexion whereby access to the tibial plateau can become challenging. Consequently, arthroscopically assisted tibial preparation greatly facilitates visualization and work flow.

With the knee in 20–30° of flexion and valgus stress, the tibial templates are trialed through the anteromedial incision until the underside curvature matches the plateau surface with full contact in all planes. An overly anterior or posterior placement of the tibial component should be avoided and a bony rim (≥ 5mm) maintained around the implant. This will protect tibial plateau stability and minimize the risk of reaming through the anterior cortex.

The tibial drill guide is attached and aligned front to back with the tibial plateau.

A small incision is made over the proximal anteromedial tibia, ensuring that the distal bullet is fully engaged into the cortical bone and that the tibial template is parallel to the tibial plateau. A drill pin is placed through the center of the tibial template, defining the axis of the tibial tunnel. Care must be taken to maintain the proper axis without excessive torque, to avoid pin deviation. The tibial pilot drill is advanced over the drill pin into the center of the tibial defect and then removed. The introducer, driver, and blade stop are assembled and advanced into the prepared tunnel until the tip of the introducer is flush with the tibial plateau. The introducer and driver are then removed, leaving the blade stop set at the appropriate depth for reaming the tibial implant. A blade drive shaft is moved through the tunnel and connected to the tibial cutting blade, which is introduced through the anteromedial portal.

A high speed drill is used with an initial counterclockwise rotation to ensure an even cutting engagement into the plateau. Preparation of the tibial implant bed through clockwise rotation is completed when the cutting blade reaches the proximal end of the blade stop. A congruent, slightly recessed fit of the tibial component is verified with the appropriate sizing trial while the tibial cutter remains in place. Proud margins are lowered by adjusting the blade stop clockwise with a wrench: a 90° turn lowers the blade stop and implant floor by 1 mm after re-reaming. Before the final tibial implant is placed, attention is directed to the preparation of the femoral component.

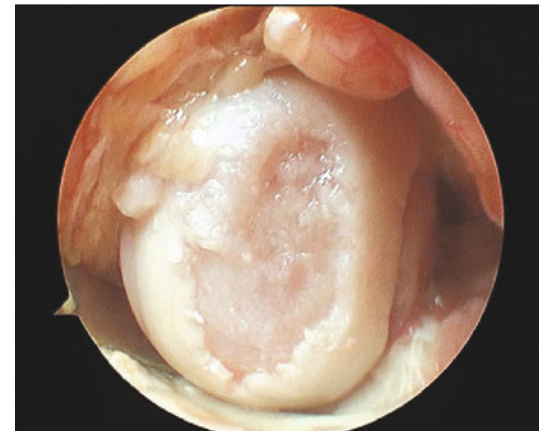

Fig. 13.8 Degenerative defect of the medial femoral condyle

13.3.2.2 Femoral Resurfacing

The femoral drill guide is placed over the defect (Fig. 13.8) with four points of contact to establish a perpendicular working axis to the joint surface. Adequate defect coverage is confirmed and a threaded pin is advanced into the bone. The femoral centering shaft is driven over the pin until the laser mark line is flush with the original articular surface. The 40-mm contact probe is placed over the femoral centering shaft to map the anterior-posterior (AP) curvature; medial-lateral (ML) mapping is repeated with the 20-mm contact probe. The average medial-lateral offset will determine the appropriate central femoral reamer, which is advanced over the centering shaft until it contacts the stop. All instruments are removed and the appropriate guide block is selected based on the average anterior-posterior offsets. The

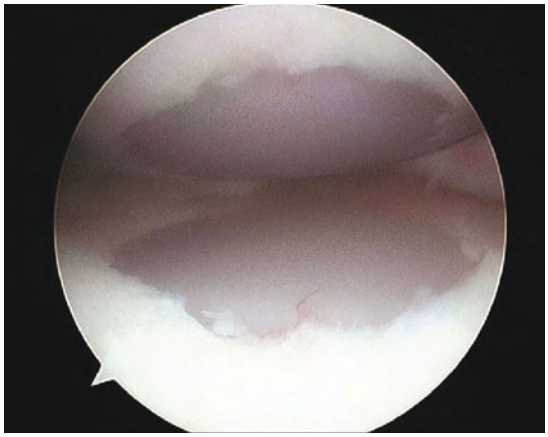

Fig. 13.9 Final tibiofemoral inlay resurfacing components

guide block is attached to the femoral drill guide and realigned on the distal femur under four points of contact to ensure accurate guide pin placement. Pin sleeves are inserted into the guide block. Both the anterior pin and subsequently the posterior short threaded pin are advanced into the bone to the level of the laser mark line. The guide block and pin sleeves are removed and proper pin alignment is confirmed. Analogous to the central reamer, the posterior implant bed is reamed based on the average medial-lateral offsets, followed by the anterior implant bed. Both reamers have a pin stop that is visible through the slotted window in the reamer shaft. Slightly recessed implant margins are confirmed with the corresponding femoral sizing trial. The femoral pilot drill is advanced through the sizing trial handle to the level of the laser mark line and left in place. The handle is removed and the femoral step drill is advanced over the femoral pilot drill down to the stop in the slotted window. The pilot hole is tapped and the fixation component is inserted into the sizing trial handle and advanced into the bone with the hex driver.

The final tibial implant is cemented first, before the final femoral component is implanted. The tibial component is inserted into the implant bed and both suture and suture retriever are passed through the tibial tunnel exiting on the distal drill hole. A slotted driver is used to adjust the final axial rotation of the tibial poly implant. A cement injector is advanced through the distal tibial tunnel. The tibial implant bed and tunnel are cemented under pressure, ensuring an even fixation and support column for the tibial component. A small amount of bone cement is applied to the underside of the femoral articular component and impacted engaging the morse taper between the components (Fig. 13.9).

13.3.3 Rehabilitation

Peri-operative narcotics and intra-articular local anesthetics can be used for immediate postoperative pain control [21, 22]. Cold compresses are helpful in reducing pain and swelling in the first 48 h following the procedure.

Weight-bearing as tolerated is encouraged for 2–6 weeks while slowly weaning off crutches. Range of motion exercises are started immediately, either through home exercise or formal physical therapy. A continuous passive motion machine several times a day for the first 2 weeks can also be used but is not required. Strengthening begins as soon as pain and swelling will allow. Patients should not return to sporting or other high-demand activities until a full range of motion is achieved, with no pain or swelling evident.

13.3.4 Results

Miniaci et al. presented the findings of their prospective series at the 2011 ISAKOS meeting [23]. Thirty-eight patients with a mean age of 48 years underwent surgery performed on an outpatient basis. The average follow-up was 19 months (range: 12–27 months). KOOS subcomponent scores showed statistically significant improvement on pain, symptoms, activities, and sports (Fig. 13.10). The average VAS pain score was reduced from 6.9 to 2.7 at the last follow-up. Postoperative range of motion returned to normal in 89% of the knees within the first 6 weeks postoperatively. No loosening or mechanical failure was observed during follow-up. Radiographically, there was no case of implant subsidence, prosthetic disengagement, or periprosthetic cyst formation.

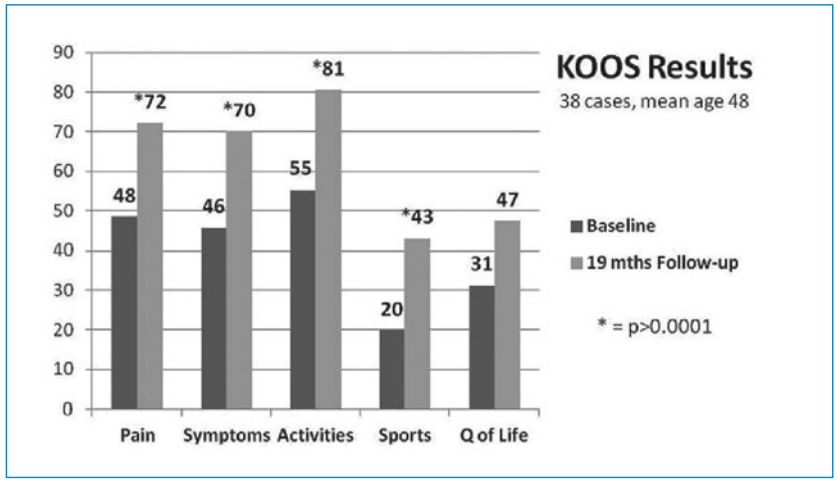

Fig. 13.10 Prospective KOOS component score improvement at 19 months follow-up after tibiofemoral UniCAP resurfacing

Fig. 13.11 Trochlear component of the focal HemiCAP patellofemoral resurfacing implant

13.4 Focal Bipolar Patellofemoral Inlay Resurfacing

The HemiCAP focal patellofemoral resurfacing prosthesis (Fig. 13.11) provides an extension of reconstructive procedures in patients with focal bipolar lesions in which patellofemoral arthroplasty would be too invasive.

Patellar and trochlear components are matched intraoperatively to the native geometry [14] and allow for congruent surface reconstruction in patients with focal traumatic or degenerative disease and failed prior biological procedures. A detailed description of the surgical technique was previously published [14,18]. The authors reported that the procedure allowed for restoration or maintenance of normal biomechanics while minimizing the amount of bony resection.

Patellofemoral (PF) kinematics were evaluated following inlay resurfacing of the trochlea on eight fresh-frozen cadaveric knee specimens using a real-time pressure sensor pad (Tekscan, Boston, MA) [17]. Each specimen was tested in three different conditions, intact, defect, and inlay resurfacing, which were assessed for PF 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 from 23 to 31 kg/cm^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% compared to the intact state while contact area was restored to 85% of normal. Results from this investigation support the importance of a congruent defect-filling in the patellofemoral joint. The authors concluded that, despite the inherent challenges, limited trochlear resurfacing achieved anatomic re-approximation of the PF surface and knee contact pressures. Clinical studies are ongoing, evaluating 2- to 5-year results.

13.5 HemiCAP^{Wave} Resurfacing Arthroplasty

Due to the complex surface morphology of the PF joint and the high transarticular pressures,

Fig. 13.12 HemiCAP^{Wave} trochlear component

biological treatment options have not achieved consistent results. Onlay versus inlay PF arthroplasty continues to be a source of controversy, despite the advantages of native joint surface geometry with inlays. In order to achieve successful outcomes with any type of PF arthroplasty, the underlying pathology has to be carefully assessed and should be taken into account in the treatment plan. The goal remains to avoid overstuffing the PF joint and to re-establish normal PF tracking in a smooth and congruent central compartment.

The HemiCAP^{Wave} resurfacing provides a thin, anatomical implant with a lateral flange and no overstuffing, due to congruent inlay implantation with curvatures measured specifically for each patient (Fig. 13.12). Despite its relatively recent introduction, the technique has gained rapid acceptance among knee surgeons treating patients with PF disease. Ongoing studies continue to evaluate the clinical benefits and the durability of the procedure.

13.5.1 Surgical Technique

13.5.1.1 Trochlear Resurfacing

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

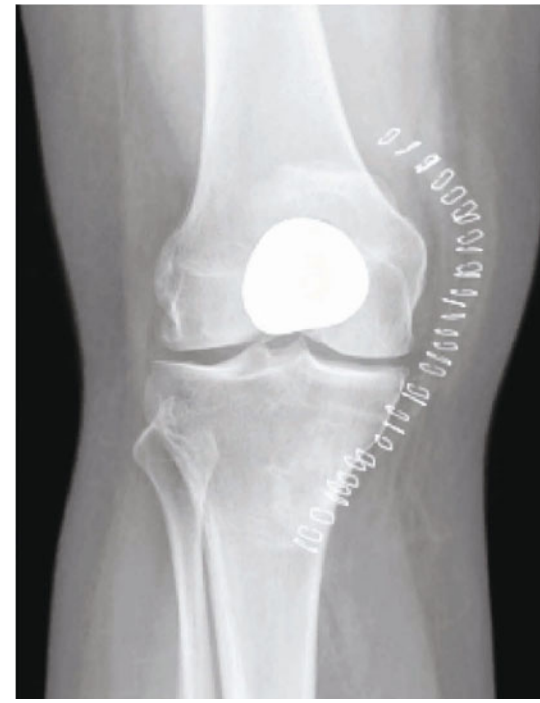

Fig. 13.13 Postoperative AP radiograph following HemiCAP^{Wave} resurfacing

is flush with the medial and lateral facets. The results of superior/inferior mapping determine the appropriate guide block, which is secured in the trochlear groove. A set of guide block reamers prepares the implant bed. The fit of the congruent inlay to the surrounding articular surface is confirmed with a sizing trial. A step drill prepares the pilot hole for the insertion of the tapered screw fixation. The femoral resurfacing component is aligned on the implant holder and inserted into the prepared socket. The fixation and articular components are connected with the aid of the impactor, and the prosthetic is firmly seated in the trochlea (Fig. 13.13).

13.5.1.2 Patellar Resurfacing

An alignment guide provides target placement for the patellar component while the surgeon monitors the 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 patellar 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 is again used to confirm a congruent fit with the implant cartilage interface. 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 patellar component benefits from cement application onto the implant rather than cement placement into the socket. This ensures even cement distribution surrounding the patellar component. The final patellar component is aligned and cemented into the implant bed.

13.6 Discussion

Total knee arthroplasty (TKA) is an excellent choice in end-stage knee arthritis. However, less invasive procedures are gaining widespread acceptance, as evidenced by the rapid increase over the past decade in the number of unicompartmental knee arthroplasties (UKAs) performed each year. Riddle et al. [24] reported an average increase in UKAs of 32.5% from 1998 to 2005, while TKAs had increased by only 9.4%. Yet, UKAs only account for 8% of all knee arthroplasty procedures. The use of UKAs in the younger population is a matter of debate as the revision rate is reportedly twice as high as in TKAs [4, 25, 26]. In a study by Furnes et al. [25], the proportion of patients ≤ 60 years of age receiving a UKA was 29%; the 7-year implant survival rate was 75.7% compared to 86% for patients between the ages of 61 and 69 and 91.3% for those > 70 years of age. While a good option for older (>65 years), less active patients, those under 65 and those with an active lifestyle would benefit from a less invasive procedure that would retain UKA or TKA as a primary exit strategy.

The availability of custom-fitting implants specific to the defect size and contoured to fit the native surface geometry of the patient has opened new treatment strategies, thus avoiding an interruption or delay during the transition from biologic to metallic joint resurfacing. Inlay resurfacing has several biomechanical and clinical advantages: Important structures for normal knee kinematics, such as menisci, cruciate ligaments, and the native joint contour, are preserved. Transarticular pressure profiles are normalized, thus keeping the soft-tissue tension unaltered [12-14]. As a result, overstuffing is avoided and pain relief as well as functional outcomes are accordingly improved. Healthy articular surfaces are preserved and share the weight-bearing load with the implant contour, which has positive implications for implant survivorship. The cartilage loss in limited arthrosis is addressed with a new, contoured prosthetic surface that is secured within the implant bone bed and anchored with a high-pitched screw fixation, in turn reducing the risk of lesion propagation through the offloading effect at the defect perimeter.

This concept has been validated in several basic science studies. Kirker-Head et al. [11] assessed the functional and biological responses of focal femoral condyle resurfacing. One year after implantation, the histological data confirmed the biocompatibility of the device and its incorporation into the femoral condyle. Becher et al. evaluated transarticular tibiofemoral pressure profiles in a variety of settings and reported the biomechanical safety of the device [12, 13]. Provencher et al. studied PF kinematics after limited trochlear resurfacing and concluded that the prosthesis provides a unique and favorable alternative to earlier implant designs by re-establishing anatomic PF surface and knee contact pressures [14].

13.7 Conclusions

The introduction of small knee implants over the past decade has stimulated the discussion on the continuum of care for knee arthrosis and arthritis. Established biological procedures for focal cartilage repair have been expanded through new reconstructive procedures utilizing patient-specific prosthetic inlays that simultaneously address the pathology and preserve healthy tissues. These treatment strategies follow surgeon-driven joint preservation goals that are consistent with localized repair in early-intervention cartilage repair. The 2- to 5-year clinical results support

HemiCAP resurfacing as a viable treatment option, although larger patient series with long-term follow-up are needed to establish the full spectrum of clinical performance criteria and related outcomes.

References

1. Curl WW, Krome J, Gordon SE, Rushing J, Smith BP, Poehling G (1997) Cartilage Injuries: A Review of 31,516 Knee Arthroscopies. Arthroscopy 13:456-60
2. Wluka A, E, Ding, Jones G, Cicuttini FM (2005) The clinical correlates of articular cartilage defects in symptomatic knee osteoarthritis: a prospective study. Rheumatol 44:1311-1316
3. Davis-Tuck ML, Wluka AE, Wang Y et al (2008) The natural history of cartilage defects in people with knee osteoarthritis. Osteoarthritis Cartilage 16:337-342
4. Heir S, Nerhus TK, Røtterud JH, Løken S, Ekeland A, Engebretsen L, Arøen, A (2010) Focal Cartilage Defects in the Knee Impair Quality of Life as Much as Severe Osteoarthritis A Comparison of Knee Injury and Osteoarthritis Outcome Score in 4 Patient Categories Scheduled for Knee Surgery. Am J Sports Med 38(2):**231-237**
5. Lastad Lygre SH, Espehaug B, Havelin LI, Furnes O, Vollset SE (2010) Pain and function in patients after primary unicompartmental and total knee arthroplasty. J Bone Joint Surg 92A(18):2890-2897
6. Loughead JM, Malhan K, Mitchell SY, Pinder IM, McCaskie AW, Deehan DJ, Lingard EA (2008) Outcome following knee arthroplasty beyond 15 years. Knee 15(2):85-90
7. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS (2003) Factors Affecting the Durability of Primary Total Knee Prostheses. J Bone Joint Surg 85A: 259-265
8. Rand JA, Ilstrup DM (1991) Survivorship analysis of total knee arthroplasty. Cumulative rates of survival of 9200 total knee arthroplasties. J Bone Joint Surg 73A:397-409
9. Amin AK, Clayton R, Patton JT, Gaston M, Cook RE, Brenkel IJ (2012) Total knee replacement in morbildly obese patients: results of a prospective, mathed study. J Bone Joint Surg 94-B:Supp 6 in press
10. Julin J, Jämsen E, Puolakka T, Konttinen YT, Moilanen T (2010)Younger age increases the risk of early prosthesis failure following primary total knee replacement for osteoarthritis; a follow-up study of 32,019 total knee replacements in the Finnish Arthroplasty Register. Acta Orthopaed 81 (4):413-419
11. Kirker-Head CA, Van Sickle DC, Ek SW, McCool JC (2006) Safety of, and biological and functional response to, a novel metallic implant for the management of focal full- thickness cartilage defects: Preliminary assessment in an animal model out to 1 year. J Orthop Res 24(5):1095-1108
12. Becher C, Huber R, Thermann H, Paessler HH, Skrbensky G (2008) Effects of a contoured articular prosthetic device on tibiofemoral peak contact pressure: a biomechanical study. Knee Surg Sports Traumatol Arthrosc 16(1):56-63
13. Becher C, Huber R, Thermann H, Ezechieli L, Ostermeier S, Wellmann M, von Skrbensky (2011) Effects of a surface matching articular resurfacing device on tibiofemoral contact pressure: results from continuous dynamic flexion-extension cycles. Arch Orthop Trauma Surg 131:413-419
14. Provencher M, Ghodadra N, Verma N, Cole BJ, Zaire S, Shewman E, Bach B (2009) Patellofemoral Kinematics After Limited Resurfacing of the Trochlea. J Knee Surg 22:310-316
15. Becher C, Kalbe C, Thermann H, Paessler HH, Laprell H, Kaiser T, Fechner A, Bartsch S, Windhagen H, Ostermeier S (2011) Minimum 5 – year results of focal articular prosthetic resurfacing for the treatment of full-thickness articular cartilage defects in the knee. Arch Orthop Trauma Surg 131:1135-1143
16. Bollars P, Bosquet M, Vandekerckhove B, Hardeman F, Bellemans J (2012) Prosthetic inlay resurfacing for the treatment of focal, full thickness cartilage defects of the femoral condyle: a bridge between biologics and conventional arthroplasty. Knee Surg Sports Traumatol Arthros 20(9):1753-9
17. Davidson PA, Rivenburgh D (2008) Focal anatomic patellofemoral inlay resurfacing: theoretic basis, surgical technique, and case reports. Orthop Clin North Am 39(3):337-46
18. Cannon A, Stolley M, Wolf B, Amendola A (2008) Patellofemoral resurfacing arthroplasty: Literature review and description of a novel technique. Iowa Orthop J 28:42-8
19. von Hasselbach C, Witzel U (2007) Biomechanics and clinical results of focal HemiCAP® resurfacing in the femoral condyle. Poster Presentation. German Congress for Orthopaedics and Traumatology, Berlin
20. Paradowski et al (2006) Knee complaints vary with age and gender in the adult population: population-based reference based data for the knee injury and osteoarthritis outcome score (KOOS). BMC Musculoskelet Disord 7:38–45
21. Weiss JM, Noble PC, Conditt MA, Kohl HW, Roberts S, Cook KF, Gordon MJ, Mathis KB (2002) What Functional Activities Are Important to Patients With Knee Replacements? Clin Ortho Rel Res 404:172-188
22. Chirwa SS et al (1989) Intra-articular bupivacaine (Marcaine) after arthroscopic meniscectomy: a randomized double blind controlled study. Arthroscopy 5:33-35
23. Miniaci A, Arneja S, Jones M (2011) Clinical results of a novel knee resurfacing arthroplasty for focal osteoarthritis of the knee. ISAKOS
24. Riddle DL, Jiranek WA, McGlynn FJ (2008) Yearly incidence of Unicompartmental Knee Arthoplasty in the United States. J Arthroplasty 23(3):408-412

25. Furnes O, Espehaug B, Lie SA, Vollset SE, Engesaeter LB, Havelin LI (2007) Failure mechanisms after unicompartmental and tricompartmental primary knee replacement with cement. J Bone Joint Surg Am 89:519-25
26. Koskinen E, Eskelinen A, Paavolainen P, Pulkkinen P, Remes V (2008) Comparison of survival and cost-effectiveness between unicondylar arthroplasty and total knee arthroplasty in patients with primary osteoarthritis: a follow-up study of 50,493 knee replacements from the Finnish Arthroplasty Register. Acta Orthop 79:499-507