2015 Update: Stemless Shoulder Inlay Arthroplasty
Basic Science and Clinical Review

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Summary

Background: Stemmed arthroplasty and onlay resurfacing continue to be the mainstay in shoulder replacement; however, technical challenges to recreate the normal joint volume, prosthetic version, inclination, and soft tissue tension persist to varying degrees with these devices. HemiCAP inlay arthroplasty is a relatively novel concept that was introduced in 2003 and expanded from focal to hemi humeral head coverage, including inlay glenoid resurfacing. Aside from the inherent joint preservation aspect using a stemless design, inlay arthroplasty may be widely defined as a procedure that replaces the tissue volume that is removed during the preparation with a contoured and patient specific reconstruction. This review examines basic science and clinical results from various past and ongoing investigations.

Basic Science: Humeral head shape and glenohumeral kinematics play a critical role in hemi- and total shoulder arthroplasty and have implication for shoulder function, implant survival and glenohumeral preservation. Finite element analysis and glenohumeral contact mechanics have shown that the sphere model is an oversimplified representation of the humeral head surface. Non-spherical surface reconstruction showed a three-fold improvement in surface fit over the traditional sphere and inlay arthroplasty had a two-fold improvement in placing the geometric center of rotation closer to the normal position when compared to stemmed hemiarthroplasty. Basic science studies concluded that inlay arthroplasty may provide better function by restoring the glenohumeral biomechanics and the associated peri-articular muscle lever arms closer to the normal condition.

Clinical Experience: Results from inlay arthroplasty have been reported across a variety of indications ranging from focal chondral and osteochondral defects to traumatic bone defects in glenohumeral instability, avascular necrosis of the humeral head and glenohumeral arthritis. Pain and function parameters show substantial improvements; overall patient satisfaction demonstrates a high acceptance rate. Registry data further support these findings showing the lowest revision rate across all shoulder implant classes for inlay arthroplasty.

Conclusion: Compared to existing shoulder arthroplasty procedures, the HemiCAP® system avoids technical challenges restoring the humeral head surface with a low-profile inlay implant. Component shapes are based on scientific evidence to maximize the anatomic fit for each patient. Joint biomechanics are maintained, which may have positive effects on implant survivorship, patient recovery and function. Over 40 different shoulder component sizes and shapes provide a pathology specific surface restoration. Preservation of bone stock and healthy cartilage support the concept as a primary arthroplasty procedure.

Key Words: Shoulder inlay arthroplasty, resurfacing, glenohumeral biomechanics

Level of Evidence: Review
Introduction

The concept and development of shoulder arthroplasty dates back to the 1950s (1-3) and was born from the challenges associated with the management of acute four-part fractures of the proximal humerus. Stemmed hemiarthroplasty provided a new treatment solution that was later expanded to total shoulder arthroplasty with the development of glenoid components (4) targeting degenerative joint disease. In order to provide a less invasive bone sparing alternative, the concept of shoulder surface arthroplasty was introduced in the 1980s (5).

Many new techniques in soft tissue balancing and physiological joint stabilizations were introduced over the past 15 years, yet restoration of normal joint kinematics with an anatomic shoulder reconstruction remains challenging. Many studies have demonstrated satisfactory results in both hemi- and total shoulder arthroplasty (6-22); however humeral shaft related complications and glenoid component loosening have been the most frequently reported obstacles in conventional stemmed shoulder replacement (23-33).

Articular cartilage and bone stock preservation are gaining significant importance as procedure numbers increase worldwide and a younger patient population undergoes shoulder replacement. The younger, active patient is at the highest risk for possible future revision procedures. Shoulder hemiarthroplasty has seen a three-fold increase in the United States since the early 1990s. Total shoulder arthroplasty more than quadrupled between 1993 (6292) and 2008 (26773) (Figure 1) (34).

As part of a novel clinical treatment strategy in the management of pain and restoration of shoulder function, humeral head inlay resurfacing was introduced in 2003 (HemiCAP® Contoured Articular Shoulder Prosthesis, Arthrosurface Inc., Franklin, MA). Compared to onlay resurfacing arthroplasty, the inlay design introduced several advantages to the field of shoulder replacement: Various defect sizes can be treated based on intraoperative findings; healthy articular margins as well as underlying bone is preserved; the native contour is maintained and serves as a reference for a patient specific surface reconstruction. The anatomic joint reference during the procedure allows for a unique control of joint volume replacement: Therefore inlay arthroplasty may be generally defined as a procedure that replaces tissue volume with an equal amount of contoured resurfacing arthroplasty.

The goal of this review is to provide an update on inlay shoulder arthroplasty covering basic science and clinical outcomes from past and ongoing studies.
Prosthetic Design

The HemiCAP® Contoured Articular Shoulder System consists of three components: a fixation component, a modular humeral head component and an inlay glenoid resurfacing component. Fixation screw and humeral head components are connected via a morse taper interlock. The fixation component is a titanium alloy (Ti 6AL 4V) cancellous screw with full-length cannulation. The low-profile cobalt chrome (co-cr-mo alloy) articular component has a titanium plasma spray undercoating to promote bony ingrowth. The shoulder resurfacing system provides 43 different articular sizes and shapes across five different diameters accommodating a vast range of anatomical size variations in male and female humeral head dimensions. This allows for a patient and pathology specific humeral head surface reconstruction. Available diameter groups include 25mm, 30mm, 35mm, 40mm and full head OvO components which range in sizes from 48mm to 58mm (Figure 5).

In order to accommodate non-spherical surface dimensions at the outer margin of the humeral head articular surface, the three largest diameter groups include a selection of symmetric and asymmetrical articular components. Two UHMWPE inlay glenoid sizes are available: A 20mm circular component (Figure 7) and a double circle 20mm x 25mm.

Surgical Technique

Humeral Head

Most cases are performed through a standard deltopectoral approach in the beach chair position. This incision is utilitarian and can be converted to a larger approach if necessary. As an alternative, a posterior, or a deltoid split approach can be used to gain access to the humeral head. For standard procedures, the deltopectoral interval is developed and the cephalic vein identified. The deltoid and pectoralis major muscles are retracted and the conjoint tendon is developed and retracted medially while protecting the musculocutaneous nerve. The axillary nerve is isolated and protected. The subscapularis is incised one centimeter lateral to the musculotendinous junction and sutures are placed into the edge of the subscapularis and capsule to help retract and repair the tendon and ligaments at the conclusion of the procedure. The joint capsule is incised and released along the anatomic neck until sufficient exposure of the humeral head defect is achieved.

The glenoid is evaluated and any pathology is addressed as indicated. As an alternative, arthroscopic intervention can be used to treat concurrent pathologies at the beginning of the procedure.

Utilizing the drill guide, maximum coverage of the defect is verified and a guide pin is placed perpendicular to the joint surface and into the center of the defect. The cannulated instrumentation set ensures that the vertical axis is maintained throughout the procedure. After drilling a pilot hole, the
fixation component is inserted. A contact probe determines the radius of curvature in two planes (Figure 6). Offset increments in 0.5mm sizes allow for a precise fit to the existing articular surface. A matching reamer prepares the site for the prosthetic implantation. A sizing trial with corresponding diameter and offsets allows for final verification of proper fit. The selected articular component is oriented into the correct planes and impacted thereby engaging the morse taper interlock. The glenohumeral joint capsule and subscapularis are repaired and the incision is closed according to standard procedure.

**Stemless Total Shoulder**

Stemless total shoulder replacement using the described inlay components is similar in technique; however several steps are important to consider: Exposure to the glenohumeral joint should be adequately developed to ensure visualization of the humerus, glenoid, and to gain access to periprosthetic osteophytes which have to be removed when resurfacing the joint. Superior and medial reference points should be marked on the humeral head with a bovie during mapping to facilitate final implant orientation. After reaming the head, the clearance cut should be performed to maximize glenohumeral space. Prior to humeral component placement, attention is directed towards the preparation of the glenoid.

**Glenoid**

The drill guide is positioned central to the inferior aspect of glenoid defect and the guide pin is advanced into the bone to the depth of the etch mark using a cannulated power drill. The inferior glenoid reamer is placed over the guide pin and advanced until the depth stop makes contact with the proximal end of the guide pin. With the inferior glenoid trial flush and slightly recessed to the remaining glenoid fossa, advance the Peg Drill to make bone cuts for the inferior peg of the glenoid component. The first three steps are repeated to establish the superior peg. Using the glenoid punch, small channels are created in the reamed socket for cement penetration into the bone. A small amount of low-viscosity bone cement is applied to the prepared glenoid surface and the glenoid component is placed into position under pressure until the bone cement has set (Figure 7).

**Basic Science**

*Finite Element Analysis of Stemless Fixation*

In order to better understand the stress distribution of resurfacing devices in underlying bone, three different designs (fluted, small thread, large thread) were placed into a 2”x2” block of trabecular bone using SolidWorks. The model was then processed through HyperMesh to create individual meshes for each component (bone, cap, stem). Mesh sizes were adjusted to appropriate sizes for each component. Bonded (tie) contact conditions were used for all components (bone to cap and stem represent complete
bone fixation to components). The bottom of the bone block was fixed and a static load of 1779 N was applied to the upper portion of the cap in a direction normal to the cap. The results showed very similar bulk responses when statically loaded at 1779N. Stress distribution is equivalent for all three designs in the bulk bone. However, the threaded devices better accommodate loads by distributing them through the bone, as opposed to concentrating them at the tip. There exists a small stress concentration at the end of the fluted device, while the threaded devices don’t have the area nor magnitude of this concentration. The major finding is that the stress fields induced by a titanium post with a small threadform are not statistically distinguishable from a smooth cobalt stem with flutes. Thus, it is concluded that load transfer from a humeral implant to the surrounding bone is unlikely to show clinical differences in a compressive loading scenario.

**Figure 2**: Finite Element Analysis of Fluted Resurfacing (A), Small Thread Resurfacing (B), and Large Thread Resurfacing (C). No statistically significant differences in stress fields were observed.

**Humeral Head Shape and Surface Reconstruction**

The true shape of the articular surface of the humeral head has undergone significant debate and investigation; however, many modern shoulder prostheses are based on the traditional sphere model. In an investigation on mathematical modeling of humeral head geometry on 54 humeri, Philips et al. (35) hypothesized that the simplified representation of the articular surface of the humeral head as a sphere may have negative repercussions related to natural joint mechanics and implant loading. The goal of this study was to investigate alternative models for the shape of the articular surface of the humeral head comparing the standard sphere, ellipsoid, and the previously unexplored ovoid. Structured light scanning was utilized to accurately and precisely measure the surface of both the cartilage covered articular surface of the humeral head and the underlying bony surface. The ovoid shape was found to most closely fit the articular surface, an improvement over the sphere by a factor of three. The ellipsoid shape fit the articular surface approximately two times better than the sphere model and was found to fit the surface in a fairly repeatable orientation. The authors conclude the non-spherical shape showed the best fit and may have clinical importance with implant designs which can
accommodate peripheral asymmetry and may possibly improve joint contact mechanics and joint rotation (35). Results from other device configurations confirm the benefits of asymmetrical arthroplasty: A recent study by Jun et al. (36) compared the native humeral head with spherical and non-spherical prosthetic configurations in a cadaver model under multiple positions with anatomic muscle loading. The custom, non-spherical prosthetic head more accurately replicated the native humeral head shape, rotational range of motion, and glenohumeral joint kinematics than a spherical head.

An ongoing study by Knight et al. (37) evaluated pre- and postoperative true AP radiographs in 56 shoulders from 50 patients who were treated with the HemiCAP OvO Implant. The radius of curvature (ROC) of the humeral head and neck-shaft angle of the humerus were determined to quantify the degree of humeral head deformity and to assess the restoration of the patients' anatomy. The difference between the implant and the predicted normal humeral head ROC did not significantly increase even with significant deformity of the humeral head (1.3mm vs. 0.1mm; p= 0.10). The study showed that total shoulder resurfacing using an ovoid humeral component effectively restores predicted normal humeral anatomy.

**Glenohumeral Joint Biomechanics**

Hammond et al. compared HemiCAP® resurfacing to standard stemmed hemiarthroplasty for functional glenohumeral positions. A custom shoulder testing system allowed for individual peri-articular muscle loading. The articular surface of the normal humeral head, resurfacing and hemiarthroplasty was digitized using a Microscribe 3DLX. A mathematical model was used to calculate the geometric center of the humeral head and the total distance from the normal geometric center was calculated in each setting. Glenohumeral contact area and pressure was assessed using Tekscan sensors. Functional testing was conducted at 20, 40, and 60 degrees of abduction, neutral and 30 degrees of internal and external rotation. Results demonstrated that humeral head resurfacing had a two-fold improvement in placing the geometric center of rotation closer to the normal position when compared to hemiarthroplasty (Figure 4). Anatomic resurfacing may provide better function by restoring the glenohumeral biomechanics and the associated peri-articular muscle lever arms closer to the normal condition. In addition, resurfacing may also better limit eccentric glenoid wear because the glenohumeral joint biomechanics and the moment arms of the rotator cuff and the deltoid muscle are restored more closely to those of the intact condition (38).

In a recent study, Gagliano et al. (39) compared onlay and inlay glenoid prosthetic designs with respect to their biomechanical loading characteristics, and differences in gross loosening in 8 matched pair cadaveric shoulders. Using TekScan data capture, they found that contact area decreased and pressure increased after TSA. Resultant force values significantly increased in the onlay component compared to the native glenoid, whereas force decreased in the inlay component compared to the native glenoid. During fatigue testing, all onlay glenoid components showed evidence of gross loosening at a mean of 1126 cycles whereas none of the inlay glenoid components showed gross loosening out to 4000 cycles. The authors concluded that inlay glenoid prosthetic design exhibits superior biomechanical characteristics, consistent with greater stability and far superior resistance to gross loosening during fatigue testing, when compared to a traditional onlay glenoid prosthetic design.
Clinical Experience

2014 Australian Arthroplasty Registry (40)

Stemless Inlay Arthroplasty (HemiCAP®, Arthrosurface, Franklin, MA) demonstrated the lowest revision rate among all shoulder implant classes in the 2014 report with 0.5 revisions per 100 observed implant years. Of particular interest is the treatment of patients under the age of 65 years where joint preservation is especially important. Registry results in this younger age demographic treated for OA with primary arthroplasty showed a 5 - 6 times higher revision rate using stemmed Total Shoulder Replacement (TSR), stemmed Hemi Shoulder Replacement, or Hemi Onlay Resurfacing when compared to HemiCAP Inlay Arthroplasty (Figure 8). Reverse Total Shoulder Arthroplasty had revision rates that were 2 – 4 times higher than HemiCAP.

![Figure 8: 2014 Australian Arthroplasty Registry: Revision Rates by Shoulder Classes and Patient Age](image)

Summary from Clinical Investigations

HemiCAP® inlay arthroplasty has been reported in the literature for a variety of indications supporting the treatment concept and benefits of the procedure: Avascular necrosis (41,42), osteoarthritis (43,59), focal chondral and osteochondral defects (44-47), Hill-Sachs Reverse Hill-Sachs (44, 47-56), shoulder resurfacing in chondrolysis (57) and surface reconstruction following fracture malunion have been described (58).

A number of articles reported on the use of inlay arthroplasty for the treatment of Hill-Sachs and Reverse Hill-Sachs lesions (Table 1). Combined results from two investigational sites showed successful surface reconstruction in 44 patients treated for bony Hill-Sachs defects (Bateman/Morton, Miniaci, Kodali et al. – ongoing investigations). One in 44 patients had an epilepsy related secondary instability event; all others showed no signs of recurrent instability at a mean follow-up of two years.
Table 1. HemiCAP® Inlay Arthroplasty for Instability Related Humeral Head Bony Defects

<table>
<thead>
<tr>
<th>Number of Patients</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kösters C, Schliemann B, Raschke M. Endoprothetik nach Trauma. Trauma Berufskrankh 2010;12:47–52</td>
</tr>
<tr>
<td>24</td>
<td>Bateman/Morton, Central Coast NSW, Australia</td>
</tr>
<tr>
<td>53</td>
<td>TOTAL</td>
</tr>
</tbody>
</table>

12 shoulders in 11 patients (9 females, 2 males) with a mean age of 56 years (range 17 – 75 yrs) were treated for osteonecrosis of the humeral head (5 with Creuss stage III – crescent sign and 6 with stage IV – loss of spherical shape; 1 was stage V – DJD). The average procedure time for inlay arthroplasty was 41 minutes (range 23 – 62min). All were treated on an outpatient basis. No transfusions or other complications were recorded. At a mean of follow-up of 30 months (range 21 – 57 months), the VAS pain score had improved from 75 to 16, WOOS scores were improved from 1421 to 471 and preoperative range of motion for forward flexion improved from 94 degrees to 142, external rotation from 28 to 46 degrees. All patients were satisfied with the result. Radiographic review of the HemiCAP implants showed no signs of loosening, osteolysis, implant separation or migration, glenoid erosion, or joint space narrowing (41).

In a recently published study by Sweet et al. (59), 19 patients (20 shoulders) were evaluated for pain and function. Sixteen shoulders were diagnosed with osteoarthritis while 4 shoulders had osteonecrosis. At a mean followup of 32.7 months (17-66) the ASES, SST, Range of motion and VAS pain scores all improved significantly from preoperative levels (p>0.001). 90% of the patients were satisfied with their outcome and 75% assessed their shoulders as good to excellent at final follow-up. Postoperative radiographs showed no evidence of periprosthetic fracture, component loosening, osteolysis, or device failure.

Summary data from five ongoing investigations across the US shows substantial improvement on pain and function scores in patients treated with the HemiCAP device at an average follow-up of 37.4 months (range 3-98) (Table 2,3). Despite the variability in cohort sizes, endpoints, and follow-up interval, core outcomes results provide supporting evidence for the procedure.
Table 2: Functional Outcome Scores

<table>
<thead>
<tr>
<th>Series</th>
<th>Cohort Size</th>
<th>Average Follow-up (months)</th>
<th>Function Scale</th>
<th>Function Baseline</th>
<th>Function Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49</td>
<td>31.5 (12-72)</td>
<td>ASES Constant WOOS</td>
<td>n/a n/a n/a</td>
<td>74.8 72.4 76.4</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>30.0 (24-39)</td>
<td>WOOS ASES Constant</td>
<td>29.2 27.9 26.9</td>
<td>82.9 75.4 72.6</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>36.4 (25-56)</td>
<td>Re-dislocation PENN Total PENN Function</td>
<td>n/a</td>
<td>No repeat dislocation Improved by 36.4 improved by 20.6</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>61.4 (12-98)</td>
<td>Constant SST</td>
<td>38.4 3.7</td>
<td>81.1 7.4</td>
</tr>
<tr>
<td>5</td>
<td>47</td>
<td>27.6 (3-72)</td>
<td>ASES SST Constant SANE</td>
<td>40.7 3.2 39.6 13.1</td>
<td>78.4 9.1 79.6 78.3</td>
</tr>
<tr>
<td>Total</td>
<td>167</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

100=Best Possible, 0=Worst Possible: ASES, Constant, WOOS
12=Best Possible, 0=Worst Possible: SST
60-Best Possible, 0=Worst: PENN Function; study only reported improvement, not raw scores

Table 3: Pain Outcome Scores

<table>
<thead>
<tr>
<th>Series</th>
<th>Cohort Size</th>
<th>Follow-up (months)</th>
<th>Pain</th>
<th>Pain Baseline</th>
<th>Pain Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>30 (24-39)</td>
<td>VAS</td>
<td>7.8</td>
<td>1.9</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>31.5 (12-72)</td>
<td>VAS</td>
<td>n/a</td>
<td>1.4</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>36.4 (25-56)</td>
<td>PENN</td>
<td>n/a</td>
<td>Improved by 11.3</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>61.4 (12-98)</td>
<td>VAS</td>
<td>7.6</td>
<td>3.7</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>27.2(8-72)</td>
<td>VAS</td>
<td>6.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Total</td>
<td>119</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0=Best Possible, 10=Worst Possible: VAS
PENN Pain Subscale: 0-30; study only reported improvement, not raw scores

Radiographic Fixation

In a recent review, radiographs from 98 shoulders from two centers were reviewed by an independent radiologist. Anonymized DICOM images were assessed comparing first postoperative radiographs to last follow-up. Outcomes parameters were progressive subsidence or tilt, disengagement, and periprosthetic radiolucency. Periprosthetic Radiolucency was defined according to Sanchez (62) and Sperling (63): “At risk" for clinical loosening was defined when a radiolucent line of 2 mm or greater in width is present in 3 or more zones or tilt or subsidence is identified. The average radiographic follow-up was 37 months (range: 11-97 months). Comparative analysis showed no subsidence, tilt, or disengagement of the fixation component from the articular component in any shoulder. Zone specific analysis of periprosthetic radiolucency did not find any patient that qualified for the above mentioned at risk determination.
A radiographic review from several publications has shown similar results with the HemiCAP prosthesis. Athiviraham et al. (60) reported one year post resurfacing results of a patient with full range of motion, return of strength and no sign of radiographic loosening of the humeral implant. Scalise et al. reported on 62 patients and although the overall clinical follow-up was short (8 months), no evidence of implant interface radiolucencies, osteolysis, or loss of fixation were observed (46). In another study, serial radiographs of 12 shoulders in 11 patients showed no evidence of component loosening, including radiographic lines around the fixation component, osteolysis, or device migration (41). There also were no cases of heterotopic ossification or visibly progressive glenohumeral joint space narrowing. The authors reported that the contour of the implant matched that of the native surrounding geometry, showing restoration of the humeral head congruity. Other studies (42,47-49,58,61) have shown no evidence of radiolucencies implant loosening or osteolysis.

Discussion
HemiCAP® inlay arthroplasty has found increased acceptance into the mainstream treatment algorithm of shoulder arthroplasty. Key advantages over conventional stemmed arthroplasty are based on newer surgeon-driven clinical strategies of removing less bone stock, leaving functional structures intact and preserving articular cartilage. The patient’s unique joint geometry guides convexity matching and avoids the placement of nonnative curvatures into the joint. Glenohumeral biomechanics are maintained since joint height, inclination angle, and version are unchanged and alterations to the soft tissue tension are avoided. Humeral shaft and tuberosity related complications are prevented, since they are not involved in the site preparation and delivery of the prosthesis.

Previous studies have confirmed that the greatest physiological motion is achieved with a prosthesis that most closely restores the original geometry of the articular surfaces (64-67). This would maintain the joint motion, keep the centre of rotation intact and restore the proper tension on the overlying soft tissues. Studies have also confirmed that any change in the anatomy however small, would have important biomechanical consequences e.g. a 5mm increase in the thickness of the humeral head can greatly reduce the range of motion and increases the translation of the humeral head onto the glenoid surfaces (65, 66). Conversely any small decrease in the thickness of the humeral head can shorten the motion of the glenohumeral joint by as much as 24 degrees (67). Büchler and Farron described the importance of anatomic reconstruction to restore the physiological motions and original forces in the muscles and limit eccentric loading of the glenoid (68). This eccentric load may explain the report from Parsons et al. who found evidence of glenoid wear in all study patients using conventional hemiarthroplasty at a mean follow-up of 43 months post implantation (69).

Precise anatomic reconstruction of the humeral head with the HemiCAP device may reduce the effects on the opposing side and may delay long-term degenerative changes to the glenoid. Many studies have described the complexity and variability of the humeral head geometry (70-73). The central articulating portion changes from a spherical humeral surface to an aspherical shape towards the periphery. With increasing HemiCAP diameters, the variety of spherical and aspherical implant offsets provides a close match to the native joint anatomy.

Conclusion
Based on these considerations, the combined benefits of the HemiCAP® system may have three important implications: Restoring the geometric center of rotation closer to normal than hemiarthroplasty may provide faster recovery for patients, better functional results and longer lasting treatment effects for inlay resurfacing by keeping the muscle moment arms closer to normal and avoiding eccentric loading on the glenohumeral joint. Basic science and clinical evidence are complementing each other in support of a complex and highly accurate shoulder resurfacing system. The large number of sizes and shapes is unique and provides a compelling argument for its use in primary arthroplasty.
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