Resurfacing Arthroplasty of the Humerus: Indications, Surgical Technique, and Clinical Results

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ABSTRACT
Resurfacing arthroplasty of the shoulder is not a new concept in orthopedic surgery. Although only a few reports describe the indications, technique, and results, experience with these devices continues to grow. A specific advantage of resurfacing arthroplasty, the concept of a bone-preserving procedure, may prove to be particularly important in younger patients who require prosthetic arthroplasty surgery. The indications and surgical technique are illustrated in this review. Our early clinical results with 2 humeral resurfacing prostheses reflect those of other published reports; namely, favorable clinical outcomes can be expected.

Keywords: arthroplasty, resurfacing, arthritis

HISTORICAL PERSPECTIVE
Resurfacing arthroplasty is not a new concept in shoulder arthroplasty. There have been a few clinical series that describe the indications, surgical technique, clinical results.1–3 These clinical reports suggest that preservation of the humeral bone and avoidance of the use of a stemmed prosthesis can be successful in selected patients. There are also clear advantages, in some patients, for a resurfacing arthroplasty, being more bone conserving and not requiring an intramedullary stem for humeral head fixation. The clinical experience using surface arthroplasty has been very limited in the United States, but in the last 5 years, there has been an increased availability of this type of prosthetic option, making a discussion of the current clinical experience a timely review.

INDICATIONS AND REQUIREMENTS
The primary indication for use of a humeral resurfacing arthroplasty is significant shoulder pain that is refractory to nonoperative treatment that is associated with severe and complete or near-complete loss of articular cartilage on the humeral surface. In most cases, the indications for use of a resurfacing arthroplasty is the same as for standard total shoulder arthroplasty that is associated with advanced arthritis. The common clinical conditions that could be indicated for resurfacing arthroplasty are osteoarthritis, rheumatoid arthritis, posttraumatic arthritis, avascular necrosis, rotator cuff tear arthropathy, and postcapsulorrhaphy arthropathy. In resurfacing arthroplasty, there needs to be sufficient quantity and quality of bone in the epiphyseal portion of the humerus to allow for stable fixation of the implant. In some patients, resurfacing arthroplasty is not indicated because there is severe bone loss often associated with extensive avascular necrosis with head collapse, severe Hill-Sachs lesions with chronic locked dislocation, or severe humeral head collapse with some cases of rheumatoid or osteoarthritis (Fig. 1). In some cases of severe osteopenia associated with elderly patients with rotator cuff arthropathy, the bone quality may be insufficient to support the prosthesis. Bone loss is determined on preoperative radiographs or computed tomography scans, but in some cases that have moderate bone loss, the appropriateness of resurfacing arthroplasty can be determined intraoperatively after bone preparation (Fig. 2). In most prosthetic systems, conversion from a resurfacing prosthesis to a stemmed component is easily performed.

The use of a polyethylene prosthetic glenoid component is in some patients a desirable option in the
management of severe glenoid disease. In these cases, a resurfacing arthroplasty can limit glenoid exposure, making the proper placement of a pegged glenoid component difficult. This is particularly true in the heavy and muscular patient or the patient with significant scar or deformity associated with posttraumatic arthritis. In some cases of resurfacing arthroplasty, there is sufficient exposure to place a glenoid component. In these cases, a keeled polyethylene component may be considered as a preferred prosthetic option because it is easier to insert than a prosthetic design that has multiple pegs in more than one plane or axis. In most cases where the use of a polyethylene component is important to achieve optimal pain relief, using a stemmed component is preferable. Compared with hemiarthroplasty with a stemmed implant design, total shoulder arthroplasty has been shown to provide better pain relief and functional results in patients with osteoarthritis. In the circumstance where a hemiarthroplasty is preferred or a soft tissue interposition for glenoid resurfacing is indicated, a resurfacing humeral arthroplasty is an ideal indication.

The advantages of a resurfacing arthroplasty over a stemmed implant are clearly present when there is a proximal humeral malunion. This is particularly true when the positioning of the prosthesis can be modified to allow for resurfacing without osteotomy of the tuberosities as often seen with moderate surgical neck malunions (Fig. 3). With moderate varus malunion (20–30 degrees of malunion from normal), a resurfacing arthroplasty can avoid the need for a surgical neck osteotomy that would be required to properly place anatomically sized humeral stem.

**SURGICAL TECHNIQUE**

**Approach and Exposure of the Humerus**

A deltopectoral approach is most familiar to surgeons in North America, although the superior approach is advocated by Copeland for this procedure, and the reader is referred to the works of Levy and Copeland, Levy et al., and Mackenzie for the description of this approach for this prosthesis.

After initial exposure, the rotator cuff is evaluated to determine its integrity. If the cuff is intact, then the subscapularis tendon is divided in its mid substance and separated from the underlying capsule (Fig. 4). The subscapularis must be completely separated from the underlying capsule and released from the base of the coracoid (releasing the coracohumeral ligament). The capsule needs to be completely incised from the inferior humeral neck to at least the posterior-inferior corner of the humeral neck. It is the senior author’s (J.P.I.) personal preference to excise the anterior and anterior inferior capsule by also releasing the capsule from the anterior and inferior rim of the glenoid. To do this safely, the axillary nerve needs to be localized and retracted (Fig. 5). Sufficient exposure can also be achieved by releasing the capsule from both the humeral and glenoid rim insertions.

When the subscapularis and capsule are released as described, the humeral head can be dislocated by external rotation, adduction, and extension of the humerus. To facilitate this exposure, proper selection and placement of the retractors is necessary. One retractor should be placed between the superior portion of the humeral head and the deltoid retracting it posteriorly. The humeral head is

![FIGURE 1. Severe proximal bone loss associated with humeral dysplasia results in insufficient bone for fixation of a resurfacing prosthesis.](image1)

![FIGURE 2. Assessment of bone mass intraoperatively after bone preparation for humeral resurfacing.](image2)
levered away from the glenoid, and the pectoralis is retracted medially by use of 2 Darrach retractors between the medial part of the humeral head and the glenoid (Fig. 6).

The anatomical neck of the humerus needs to be precisely defined, which requires complete removal of the peripheral osteophytes around the entire humeral head (Fig. 7). The entire insertion of the superior and posterior portions of the rotator cuff should be identified.

**Sizing and Preparation of the Humerus**

**DePuy CAP.** Intraoperative sizing and preparation of the humerus at this point is dependent upon the details of the particular prosthetic system being used. For the DePuy CAP system (DePuy, Warsaw, Ind), there is a series of hemispherical sizer tools that also allow for proper positioning of the guide pin, thereby determining the final placement of the prosthesis with respect to version and inclination (Fig. 8). Having a full 360-degree exposure of the humerus and full definition of the anatomical neck is necessary to determine proper sizing and position of the humeral component.

After placement of the guide pin, the reamer is selected to correspond with the determined head size (radius of curvature and head thickness). The reamer should be used to a depth that does not compromise the rotator cuff insertion superiorly and posteriorly, provide the maximal contact surface area of the reamed surface of the humerus and the undersurface of the humeral prosthesis, and preserve the dense compact cancellous or subchondral bone of the humeral head (Fig. 9). Preservation...
of the rotator cuff insertion is best achieved by selecting the proper head size (thickness) and placing the prosthesis in the correct version and inclination. Preservation of the dense bone of the proximal humerus and optimization of contact require clinical judgment to cease reaming. When there are larger focal areas of bone loss and there is otherwise good contact in at least the other 75% of the surface area of the reamer undersurface, then it would be advisable to stop the reaming to maximize the denser bone of the remaining humeral surface. The DePuy CAP prosthesis has a flat surface at the apex of the undersurface of the prosthesis as well as on the reamer (Fig. 10). This feature allows for improved contact at the apex of the prosthesis with less depth of reaming. This flat surface of the prosthesis takes into consideration the common feature of humeral head flattening with bone loss at the apex of the humeral head often seen in osteoarthritis.

Placement of the trial component and removal of the guide pin allow for trial reduction to check for stability and range of motion of the component within the natural glenoid. As with all unconstrained arthroplasty cases, proper stability of the humeral component requires the surgeon to balance the soft tissue both anteriorly and posteriorly while preserving the subchondral bone.
posteriorly as well as obtaining a smooth concentric concave surface of the glenoid that is in anatomical version. In cases where there is excessive tightening or laxity of the posterior capsule, the correction requires release or imbrication of the posterior capsule, respectively. When there is abnormal glenoid version or asymmetric glenoid wear, then reaming the ‘high side’ of the glenoid with a convex reamer or a handheld burr is required (Fig. 11). With balanced soft tissues and corrected glenoid fossa abnormalities, the humeral head should be able to posteriorly translate approximately 50% of the humeral head diameter and inferiorly translate approximately 25% of the humeral head diameter. The arm should have the ability to externally rotate to at least 40 degrees when the subscapularis is brought back to its anatomical position. When the shoulder is at 90 degrees of abduction and 90 degrees of external rotation, the humeral head should still be reduced and within the glenoid fossa. Stability is also judged by the ability of the humeral head to be maintained within the glenoid fossa with full forward elevation and full internal to external rotation.

**HemiCAP Resurfacing Arthroplasty.** In cases where focal chondral defects are encountered, the HemiCAP prosthesis (Arthrosurface, Franklin, Mass) aims to resurface the specific region of pathology. Using a taper post fixation component that mates with the articular resurfacing component, the construct is seated level to the remaining viable articular cartilage. (Fig. 12) Therefore, in cases of a limited chondral defect, the pathological portion alone can be resurfaced, leaving intact the surrounding healthy cartilage. In cases where more diffuse arthritis is present, a larger 40-mm HemiCAP can be used to provide wide coverage of the articular surface, leaving the peripheral few millimeters of native cartilage intact.

Implantation of this prosthesis is divided into 2 general steps: (1) placement of the taper post in the central region of the cartilage defect of the humeral head and (2) choosing the correct size of the articular resurfacing component and securely fixing it to the taper post. The taper post, a headless titanium alloy cannulated screw, is placed over a guide pin in the central region of the chondral defect, perpendicular to the articular surface. The taper post is seated just below the level of the normal cartilage to allow the subsequent articular resurfacing component to sit flush with the cartilage. A defect area measuring guide is advanced over the guide pin next. Both the superior/inferior and anterior/posterior

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**FIGURE 10.** The DePuy CAP reamer yields a flat portion on the humerus apex corresponding to the flat portion on the undersurface of the final prosthesis.

**FIGURE 11.** Abnormal glenoid version or asymmetric glenoid wear should be corrected by reaming the ‘high side’ of the glenoid with a convex reamer or a handheld burr. In this case, excellent glenoid exposure is possible after full capsular release.

**FIGURE 12.** The HemiCAP device uses a taper post fixation element that mates with the articular resurfacing component to sit level with the remaining articular surface.
dimensions of the defect are recorded. As chondral lesions are located closer to the periphery, they are found to be in a zone that demonstrates less sphericity on the normal humeral head. Therefore, truly anatomically designed resurfacing implants need to incorporate the options of asymmetric sizing. This feature is integrated into the HemiCAP resurfacing system. By using the measurements of the chondral lesion, an asymmetric implant may be selected to match an asymmetric defect (Fig. 13).

With the resurfacing component selected, the friable edges of the chondral lesion are debrided, leaving a clean and stable cartilage margin. The trial resurfacing component is placed on the taper post to ensure proper coverage of the defect and, importantly, correct height of the component such that it rests level with the remaining normal articular cartilage. The final resurfacing cap is then fixed to the taper post using a Morse taper interface. The final construct should demonstrate coverage of the articular lesion, placement level with the remaining viable cartilage, and a smooth transition from the normal articular cartilage to the resurfacing component with a matched contour. A construct that is inappropriately placed proud to the native chondral surface will lead to increased contact pressures between the implant and the glenoid cartilage, with resultant premature degeneration of the glenoid articular surface. Conversely, animal studies have demonstrated that implants that are slightly recessed allow some cartilage cold flow over the edges and fill the small recess gap with resultant reduced contact pressures. Therefore, sitting the implant slightly recessed is preferable to sitting the implant slightly prominent.

Assessment of glenoid pathology as well as soft tissue balancing of the reduced glenohumeral joint is executed in the same manner as with other humeral resurfacing designs (see above).

**Glenoid Exposure**

Glenoid exposure is more difficult with resurfacing arthroplasty than when performing a stemmed humeral component where the humeral head is cut at the anatomical neck. Optimal glenoid exposure is required to (1) inspect and assess the degree of glenoid disease, (2) contour the fossa concavity or orientation, and (3) resurface the glenoid with either soft tissue interposition or a prosthetic component. The degree of glenoid exposure required for each of these objectives requires an increasing degree of visualization of the glenoid and, as such, different technical steps to optimize exposure. In most cases, it is difficult, if not impossible, to get proper exposure of the glenoid for placement of a pegged glenoid component particularly when the pegs are in a multiplanar orientation. In the authors’ opinion, the best indication for use of a resurfacing humeral implant is when a prosthetic glenoid component is not desired or required.

Regardless of the specific needs of an individual patient to use glenoid resurfacing, complete release of the anterior and inferior capsules to the inferior pouch at the 6-o’clock position along the humeral insertion is necessary (Fig. 5). Complete release requires either complete excision of the capsule or release of both the humeral and glenoid attachments of the anterior and inferior capsules.

Several humeral head retractors can be used for exposure of the glenoid, and there is not one retractor that may be ideally suited for every patient. When using any of these retractors, care must be given to protect the reamed surface of the humeral head. Humeral

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**FIGURE 13.** A, Radiograph demonstrating a humeral head defect with relative preservation of the glenohumeral joint space. B, The large humeral head chondral defect is illustrated. C, After guide pin placement in the central portion of the defect, the articular surface is reamed to the subchondral bone. D, Sizing of the defect allows selection of the final implant that covers the area and recreates the proper surface contours. E, The surrounding healthy cartilage is left intact. F, Postoperative radiograph illustrating the HemiCAP implant filling the defect while recreating the normal humeral contours.
head preparation may be performed subsequent to glenoid preparation to afford some protection to the proximal humerus during retraction. However, even in this setting, compromise of the subchondral and cancellous bone may occur in the presence of overly vigorous retraction. In many cases, the trial humeral head component needs to be left in place so that the retractor does not crush the head. This leads to a more difficult exposure of the glenoid. So, if there is preservation of the subchondral bone or very dense cancellous bone, then removal of the trial prosthetic component and then gentle use of the retractor may give improved visualization of the glenoid. Alternatively, the use of a modified laminar spreader placed between the humeral head and the glenoid can provide sufficient space for contouring the glenoid or placement of a soft tissue interposition graft over the glenoid (Fig. 14).

**Wound Closure**

The subscapularis is reattached in an anatomical fashion, and the technique used is based upon the method that was used for tendon detachment. When the tendon is removed from the lesser tuberosity, it is placed back to the tuberosity with either suture anchors or through bone tunnels. Bone tunnels are placed from the tendon footprint and tied over a bone bridge in the groove of the biceps tendon. Placement of bone sutures in the biceps tendon groove is facilitated by the practice that removes the long head of the biceps tendon from the bicipital groove along with the intra-articular section. The remaining portion distal to the bicipital groove is tenodesed distally to local soft tissues (pectoralis major tendon). Some prefer, however, to preserve a normally appearing biceps tendon, especially in younger, more active patients.

Subscapularis repair after transtendonous tenotomy is carried out with a series of nonabsorbable sutures, making sure to obtain a secure and robust repair.

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**CLINICAL RESULTS**

**DePuy CAP and Biomet Copeland II**

Short-term clinical results at our institution with a proximal humerus resurfacing prosthesis suggest that the results are equivalent to that of a traditional stemmed total shoulder arthroplasty using an ultrahigh–molecular weight polyethylene glenoid component. The clinical outcomes of 16 patients (12 men) with mean follow-up of 19 months (range, 12–38 months) were reviewed. Mean age was 45 years (range, 16–77 years). Surgical indications included osteoarthritis in 11, avascular necrosis in 3, rheumatoid arthritis in 1 and posttraumatic arthritis in 1. The DePuy CAP prosthesis was used in 13 patients and the Biomet Copeland II prosthesis (Biomet, Warsaw, Ind) in 3. Glenoid resurfacing with soft tissue interposition (meniscus allograft or autologous capsule) was performed in 7 patients. With short-term follow-up, the results compare favorably to a group of 76 patients (mean age, 67 years) with stemmed total shoulder arthroplasty when assessed using a validated shoulder outcome score (University of Pennsylvania score) (Fig. 15). Further investigation will be needed to delineate the long-term outcomes of soft tissue interposition arthroplasty and its role in resurfacing arthroplasty of the humerus.

**HemiCAP Resurfacing Arthroplasty**

Similarly, only short-term clinical results are available for the HemiCAP resurfacing arthroplasty for the shoulder. To date, 62 patients at 6 institutions have undergone humeral resurfacing with the HemiCAP prosthesis and have a mean follow-up of 8 months (range, 3–24 months). Their mean age was 60 years (range, 25–84 years) and presented with various indications for resurfacing (osteoarthritis, 45; avascular necrosis, 8; focal chondral defects, 4; cuff tear arthropathy, 4; rheumatoid arthritis, 1). In 26 patients, concomitant procedures were

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**FIGURE 14.** Use of a modified laminar spreader placed between the humeral head and the glenoid can provide sufficient space for glenoid contouring or placement of a soft tissue interposition graft.
performed (rotator cuff repair, 13; subacromial decompression, 12). American Shoulder and Elbow Surgeons scores improved significantly from 38 to 70, and Constant scores improved significantly from 55 to 78 (Fig. 16). Only one patient failed to improve clinically. This patient had continued pain at most recent follow-up and is believed to be because of advanced osteoarthritic changes of the glenoid observed during the index procedure. Although the overall clinical follow-up is short in this group, no evidence of implant interface radiolucencies, osteolysis, or loss of fixation has been observed.

Clinical Results Reported in the Literature
Levy and Copeland first reported on the second-generation Copeland resurfacing arthroplasty (Biomet), which has hydroxyapatite (HA) coating on the undersurface of the implant. This prosthesis had improved results than with previous non–HA-coated devices. One hundred three Mark-2 prostheses were inserted into 94 patients. The indications for the treatment were osteoarthritis, rheumatoid arthritis, avascular necrosis, instability arthropathy, posttraumatic arthropathy, and cuff arthropathy. The mean follow-up was for 6.8 years (range, 5–10 years). The best results were achieved in primary osteoarthritis, with Constant scores of 94% for total shoulder replacement and 74% for hemiarthroplasty. The poorest results were seen in patients with cuff tear arthropathy and posttraumatic arthropathy with adjusted Constant scores of 61% and 63%, respectively. Most patients (94%) considered their shoulder to be much better or better than before the operation. Of the 88 humeral implants available for radiological review, 61 (69%) showed no evidence of radiolucency.

Levy and Copeland later reported on 39 total shoulder arthroplasties and 30 hemiarthroplasties using a resurfacing humeral prosthesis for treatment of osteoarthritis.

FIGURE 15. Minimum 1-year follow-up in 16 patients (mean age, 45 years) using the DePuy CAP and Biomet Copeland II humeral arthroplasty compare favorably with a group of 76 patients (mean age, 67 years) with stemmed total shoulder arthroplasty when assessed using a validated shoulder outcome score (University of Pennsylvania score).

FIGURE 16. Mean 8-month follow-up (range, 3–24 months) in 62 patients using the HemiCAP humeral arthroplasty demonstrates significant improvements in both American Shoulder and Elbow Surgeons (ASES) and Constant scores.
in patients with an mean age of 75 years. The mean follow-up was 7.6 years (range, 4–13 years) for total shoulder replacement and 4.4 years (range, 2–6.5 years) for hemiarthroplasty. The Constant scores improved from an age-adjusted Constant score of 34% (20 points) to 94% (61.9 points) for total shoulder replacement and from an age-adjusted Constant score 40% (25.3 points) to 91% (58.1 points) for hemiarthroplasty. Active elevation improved by a mean of 59.9 degrees to a mean of 128 degrees for total shoulder replacement and to a mean of 124 degrees for hemiarthroplasty. Of the patients, 90% considered the shoulder to be much better or better as a result of the operation. Radiographically, 1 humeral implant and 3 glenoid implants had evidence of loosening. Four revisions were performed in the total shoulder replacement group. No revision surgery was needed in the hemiarthroplasty group. The results of this series are at least comparable to those reported for stemmed prostheses and with a comparable length of follow-up.

Levy et al^11 reported on 75 surface replacement arthroplasty (33 hemiarthroplasties and 42 total shoulder arthroplasties) for the treatment of rheumatoid arthritis with a mean follow-up of 6.5 years. The mean Constant score was 47.9 points (age- and sex-adjusted score, 71%) in the hemiarthroplasty group and 53.4 points (age- and sex-adjusted score, 76%) in the total shoulder replacement group. The mean range of active flexion improved from 50 to 101 degrees in the hemiarthroplasty group and from 47 to 104 degrees in the total shoulder replacement group. Seventy-two of the 75 shoulders were considered by the patients to be much better or better at the time of the review. Of the 68 humeral implants that were evaluated radiographically, 56 (82%) showed no lucencies, 11 (16%) showed localized lucencies of less than 1 mm in width, and 1 (1.5%) was definitely loose. No lucencies were observed adjacent to the HA-coated implants.

**SUMMARY**

The results available for resurfacing arthroplasty of the humerus indicate that favorable clinical outcomes can be expected. The purported advantages of a humeral resurfacing design over a traditional stemmed humeral component include preservation of humeral bone stock and avoidance of stem-related complications (eg, periprosthetic fractures). Newer resurfacing designs offer the potential advantage of selectively targeting the region of the diseased articular cartilage while preserving areas that are yet unaffected. Furthermore, anatomical reconstruction provided by novel aspherical designs results in less glenohumeral joint stresses with the potential of better function. Long-term clinical outcomes are still needed, however.

The role of glenoid soft tissue interposition arthroplasty with concomitant humeral prosthetic resurfacing has yet to be fully elucidated. Although early experience has demonstrated encouraging results, the durability of the interposed soft tissue has yet to be defined adequately. Nevertheless, in carefully selected patients, this option may prove to be useful when a traditional stemmed humeral component and prosthetic glenoid would necessitate reduction of glenohumeral bone stock. This is particularly germane in younger patients with severe glenohumeral arthritis needing arthroplasty in whom future revision arthroplasty may be required.

**REFERENCES**


