A Review Paper

Humeral Resurfacing Arthroplasty: Rationale, Indications, Technique, and Results

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Abstract

Humeral head resurfacing arthroplasty has evolved into a reliable method of shoulder arthroplasty designed to restore the natural anatomy of an arthritic or damaged articular humeral surface. Recent implant changes have improved the ability of the surface replacement implants to recreate the humeral head surface and the initial implant fixation. Instrument changes have improved the ability to place the implant in the anatomical position that recreates an individual's humeral articular surface posterior offset, neck-shaft angle, and version. These implant and instrument changes have led to a more refined surgical technique that avoids the complications associated with use of stemmed implants. Minimal bone resection occurs in shoulder resurfacing arthroplasty—the result being bone stock preservation, which is important in active or young patients with shoulder arthritis. Cementless surface replacements have been shown to provide results comparable to those of stemmed implants similar in diagnosis and follow-up. In this article, I outline the current rationale for resurfacing arthroplasty implants and the indications for their use. I also present the surgical technique and review the results of proximal humeral resurfacing arthroplasty.

The concept of resurfacing arthroplasty as a treatment for painful humeral head articular cartilage conditions evolved from its application in arthritic hip joints. First-generation humeral resurfacing arthroplasty implants, which were based on extensive historical experience with hip resurfacing arthroplasty, lacked a central stem and relied on methylmethacrylate for fixation. Second-generation humeral arthroplasty implants were then developed, as better understanding of component fixation led to use of a central stem and application of an ingrowth contact surface to improve immediate and long-term component fixation.[1,2] Third-generation implants, which have been designed with anatomical head sizing based on the observation that humeral head height correlates with humeral head diameter (Figure 1),[3,4] achieve fixation at the time of implantation with unique undersurface designs and cruciate stem designs that provide immediate rotational stability. Theoretically, long-term fixation of third-generation implants has been improved by adding hydroxyapatite to the porous coating on the undersurface of the head and on the proximal portion of the stem and by increasing the contact area with the apical flat surface on the undersurface (Figure 2). In this article, I present the current rationale for using humeral head resurfacing arthroplasty implants, define their clinical indications, describe the surgical technique, and review the results.

The rationale for using humeral resurfacing arthroplasty includes preservation of humeral bone stock (Figure 3) and reduction in intraoperative occurrences such as humeral periprosthetic fracture and excessive blood loss. In the case of implant failure or development of glenoid arthrosis and the need for revision, a humeral resurfacing arthroplasty does not

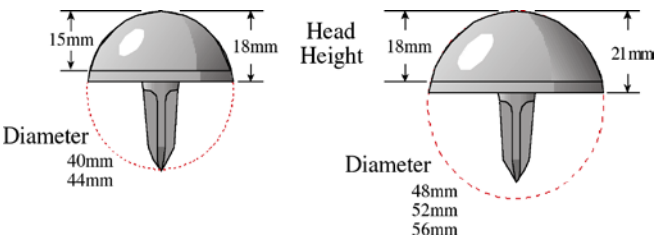

Figure 1. Anatomical sizing of a third-generation resurfacing implant (Global CAP Adjustable Prosthetic; DePuy, Johnson & Johnson, Warsaw, Ind). Illustrator, Steven B. Lippitt, MD.

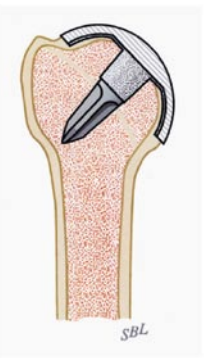

Figure 2. In the same resurfacing implant shown in Figure 1, the proximal humerus is reamed to fit the back of the implant, which has a flat, porous-coated surface for bone ingrowth. Illustrator, Steven B. Lippitt, MD.

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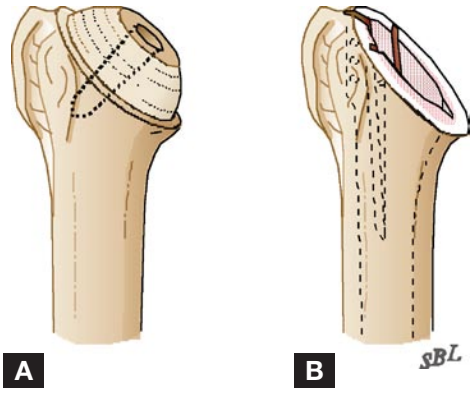

Figure 3. A rationale for resurfacing arthroplasty is bone preservation for later procedures, such as arthrodesis or revision. The figures here reveal the amount of proximal humerus resected during a resurfacing arthroplasty (A) and a hemiarthroplasty (B). Illustrator, Steven B. Lippitt, MD.

require removal of a cemented or ingrowth stem and therefore avoids humeral shaft fracture and catastrophic loss of humeral bone. Conversion to standard stemmed arthroplasty and placement of a glenoid component do not require specialized equipment or specialized techniques.[2] Arthrodesis as a salvage procedure following resurfacing arthroplasty may require less bone graft because of the preserved metaphyseal bone.

Accurate intraoperative articular surface positioning is also reliably obtained because of the absence of an intramedullary-based system. Systematic anatomical investigation of proximal humerus anatomy has revealed that normal anatomy values (eg, retroversion, head-shaft angle, center of rotation) vary from individual to individual.[3-6] These variations are difficult for an intramedullary-based system to encompass, and biomechanical studies of several intramedullary-based humeral head replacement systems have shown that replication of the normal articular surface cannot be achieved with these systems and that they displace the center of rotation superiorly and laterally, potentially causing late complications.[5,7] However neck-shaft angle and retroversion can be easily managed with a resurfacing arthroplasty by identifying the humeral anatomical neck and the center of the humeral head at time of surgery. Therefore, resurfacing arthroplasty of the humeral head provides a reliable technique for anatomically recreating a stable articulating surface, regardless of individual pathologic anatomy.[8]

Indications

Historically, humeral resurfacing arthroplasty was indicated for active younger patients with osteoarthritis and a concentric glenoid, for patients with rheumatoid arthritis, and for patients with avascular necrosis who had adequate supportive bone. These indications were expanded to include instability arthritis with a concentric glenoid or resurfaced glenoid, arthroscopy, arthropathy, posttraumatic arthritis or arthritis associated with a proximal humerus malunion, cuff-tear arthropathy with stable kinematics, and dialysis arthropathy. Numeric patient age is not relevant, but the quality of the proximal humerus is a significant factor, and the subchondral surface should support at least 60% of the resurfacing implant.[2,9,10] A humeral resurfacing arthroplasty requires an intact subscapularis tendon or pectoralis major transfer to provide anterior gleno-implant stability but may be performed in the presence of large rotator cuff tears if stable kinematics are present.[1] The resurfacing arthroplasty functions as a hemiarthroplasty, and therefore a congruent glenoid surface is also a requirement. Glenoid surface abnormalities (eg, eccentric wear, cystic bone changes, rim deficiencies) should be managed to produce a stable, congruent surface against which the resurfacing implant can articulate. However, glenoid resurfacing with an implant may be a problem because of limited exposure in a stiff shoulder joint and should be a consideration in any preoperative decision making.

Surgical Technique

Preoperative templating of a 30° external rotation anteroposterior plain film allows the surgeon to estimate the size of the implant that will be needed during surgery. At this time, the surgeon can also estimate head diameter and height and identify any degenerative anatomical humeral head changes that may influence intraoperative implant positioning or sizing. Head size will be verified intraoperatively by measuring the humeral head after peripheral osteophyte removal. An axillary lateral plain film or computed tomography scan is also required before surgery to identify nonconcentric glenoid wear.

Proximal humerus resurfacing can be performed with the patient given general anesthesia, regional anesthesia, or a combination of both. The patient should be placed in a supine, beach-chair position and lateral enough to allow the surgical arm to be fully extended. One of 2 different approaches is commonly used, depending on surgeon preference: either the superior (Mackenzie[11]) approach or the deltopectoral approach. The deltopectoral approach has been well described and has the advantages of preserving the deltoid origin, being extensile, and facilitating subscapularis lengthening.[12] The method of subscapularis release and repair depends on the degree of external rotation loss and may consist of an intratendinous incision and anatomical repair, a release of the subscapularis from the lesser tuberosity with a subperiosteal incision, a z-lengthening of the subscapularis and anterior capsule, or a lesser tuberosity osteotomy.

After the subscapularis and capsule have been released, the humerus is delivered out of the wound using simultaneous adduction, external rotation, and extension of the arm—which requires a complete inferior capsular release from the humeral neck to its posterior interior attachment. With the humeral head delivered out of the wound, all humeral osteophytes are removed. This is a particularly important step, as the anatomical neck must be visualized to guide humeral preparation and determine the neck-shaft angle. A curved Crego or reverse Hohmann retractor is placed superiorly

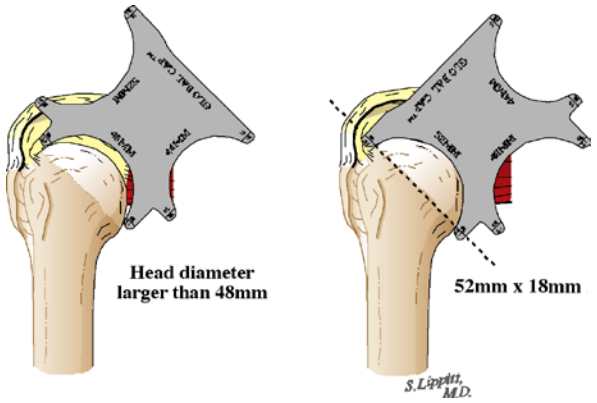

Figure 4. Humeral head sizing with a humeral head gauge. When the anteroposterior axis is smaller than the superoinferior axis, the smaller of the measurements is used. Illustrator, Steven B. Lippitt, MD.

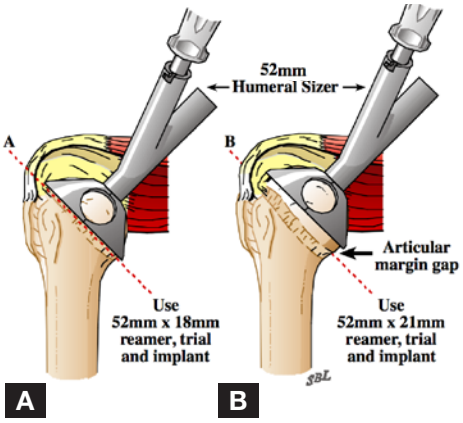

Figure 5. The humeral head sizer (A or B) that most closely approximates the head size should be selected. The deeper reamer (B) should be used if the sizer is more than 3mm short of the anatomical neck. Preoperative templating can assist in making this decision. Illustrator, Steven B. Lippitt, MD.

along the anatomical neck to protect and retract the long head of the biceps and posterosuperior rotator cuff. At this time, the biceps tendon may be tenodesed distally at its natural resting length. The anatomical neck should be identified and marked with electrocautery or a marking pen.

The head is sized with templating before surgery, and the size is confirmed intraoperatively using the humeral head sizer or the humeral head gauge (Figure 4). The preoperatively determined sizer is placed over the humeral articular surface, such that its superior rim is parallel with the superior articular cartilage line, and the plane of the head sizer rim is parallel with the plane of the anatomical neck of the native humerus (Figure 5). The appropriate head sizer is determined by identifying the articular margin of the humerus in relation to the inferior edge of the sizer, as the interior of the sizer represents the outermost diameter of the definitive implant.

Once head size is determined, component position can be obtained using the patient's natural anatomy. The varus-valgus inclination of the component is determined by placing the sizer in a position so that its anterior rim is parallel to the plane of the anatomical neck. In determining the component retroversion, the sizer is viewed from the superior position and is tilted so its superior rim parallels the articular cartilage from anterior to posterior. After both planes are determined, the threaded guide pin is drilled through the center of the cannulated sizer. The tip of the guide wire should penetrate the lateral cortex of the humerus. The head gauge is then used to confirm humeral head diameter and thickness. If the anteroposterior axis is smaller than the superoinferior axis, then the smaller of the measurements is used to select reamer size. Given the previously determined head size, humeral shaping is performed with an appropriately sized reamer (Figure 6A). The assembled reamer is passed over the guide wire onto the humeral head, and reaming is begun with force applied parallel to the guide wire. Reaming is done until bone chips are seen exiting from the most superior holes in the peripheral surface of the reamer (Figure 6B). Reaming depth can also be checked by observing the distance between the advancing reamer and the rotator cuff attachment site. The reaming process creates a shelf, equal in width to the thickness of the eventual implant at the base of the humeral head in the anatomical neck region. All remaining osteophytes are removed so that the implant forms a smooth transition to the peripheral rim of the humeral head. The trial is used to assess final implant size and fit. The appropriate cannulated trial implant is passed over the guide wire onto the reamed humeral surface. A check should be done to ensure uniform contact between the undersurface of the trial and the bone. The large viewing windows in this trial aid in this visualization. The cruciform shape of the implant stem improves the rotational stability of the implant. The cannulated cruciform stem punch is used to create a path for the implant stem in the unreamed cancellous bone in the base of the central hole and to ensure correct stem seating of the implant. The stem punch is passed over the guide pin and into the central hole in the humeral head, and then a mallet is used to hit the stem punch into the cancellous bone of the humerus.

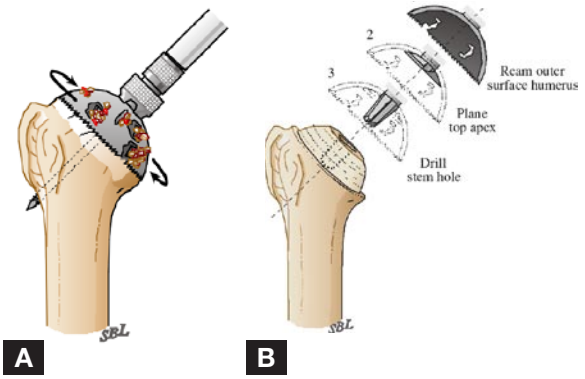

Figure 6. The humeral reamer is passed over the guide wire, and reaming progresses until the humerus has been reshaped. Illustrator, Steven B. Lippitt, MD.

Table I. Results of Proximal Humerus Resurfacing Arthroplasty*

Prosthesis	Diagnosis	Mean Follow-Up (mo)	Type	Postoperative Constant Score	Elevation Change (°)	Revision(s)
Copeland[9]	OA	78	39 TSA	61.9	68-128	4
			30 HA	58.1	64-124	0
Copeland[10]	RA	90	42 TSA	53.4	47-104	2
			33 HA	47.9	50-101	1
Copeland[13]	OA	34.8	20 HA	52	73-120	0
	RA	32.6	26 HA	48	56-97	0
Durom[1]	RA	45.1	45 HA	66.1 intact cuff		0
				56.9 massive tear		0

*OA indicates osteoarthritis; RA, rheumatoid arthritis; TSA, total shoulder arthroplasty; HA, hemiarthroplasty.

Regardless of whether a glenoid component is used in combination with this implant, soft-tissue releases are required to maximize postoperative range of motion (ROM). A ring retractor may be used to retract the humeral head posteriorly. However, extreme care must be taken so the retractor does not damage the reamed humeral surface, and the humeral head trial may be reinserted to help protect the reamed bone. Circumferential release of the glenohumeral joint capsule may then be accomplished. In cases in which the anteroinferior capsule is pathologically thickened, it can be excised. The glenoid needs to be visualized in its entirety (and incongruities or deficiencies noted), and glenoid resurfacing procedures may also be performed if necessary. After appropriate soft-tissue releases have been performed and the glenoid is evaluated, soft-tissue balancing should be assessed. The humeral head trial is reinserted, and the humerus is reduced into the glenoid fossa. As a general rule, with the humerus in neutral rotation and the arm in 0° to 20° of scapular plane abduction, a posteriorly directed subluxating force should cause posterior translation of 50% of the humeral head. In addition, the subscapularis should be long enough to reattach to its insertion site, allowing the arm to go to at least 30° of external rotation. The humeral head is exposed so that the entire prepared surface of the humerus can be seen. The humeral trial is removed. The stem of the humeral head implant is placed into the central hole with the cruciform flanges aligned in the appropriate cruciate path. The head impactor tool and the mallet are used to seat the implant completely. That the implant has been fully seated should be verified. There should be no gap from the periphery of the implant and the reamed margin of the humerus. The humerus should be reduced into the glenoid fossa, and the desired degree of laxity should be verified in the shoulder.

The subscapularis is repaired according to the method of detachment. After subscapularis closure, passive external rotation with the arm at the side should be at least 30°. The deltopectoral interval should be closed. In a routine fashion, the subcutaneous tissue and skin are closed. Plain films should be obtained to verify implant positioning and seating (Figure 7).

Postoperative Rehabilitation

Pendulum and passive ROM exercises should begin within 24 hours of surgery. There are no limits to passive ROM exercises, except that external rotation should not exceed the safe zone of rotation observed at surgery after subscapularis closure. A sling may be used for comfort and protection. An overhead pulley is added at 4 to 6 weeks. Passive stretching and strengthening exercises of the rotator cuff and deltoid and scapular muscles should commence at 6 weeks after surgery. These exercises are progressed as tolerated over the next 3 to 6 months. Complete recovery from surgery occurs by 9 to 12 months.

Results

Reported clinical outcomes of second-generation humeral head surface replacement implants have compared favorably with those of stemmed implants.[2] Rates of revision for implant loosening and intraoperative or postoperative complications have been very low.[1,2,9,10,13] Review of the reported outcomes (Table I) reveals the clinical results of 2 different second-generation implants.[1,9,10,13] The patients with osteoarthritis improved to a mean age-adjusted Constant Score of 94%, and roughly 90% of these patients reported the shoulder to be much better. Only 1 resurfacing implant required revision. Further analysis of these reported results revealed that only 2 of the 7 revised failed resurfacing implants had primary loosening; the remaining revisions were done to correct a failed glenoid implant. Patients with rheumatoid arthritis also improved significantly, with

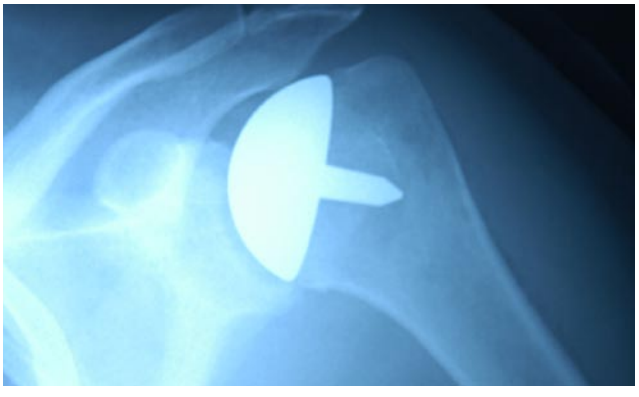

Figure 7. Final plain films should show anatomical resurfacing of the proximal humerus.

Table II. East Bay Shoulder Clinic Third-Generation Humeral Resurfacing Arthroplasty*

Diagnosis	Patients (n)	Mean Follow-Up (mo)	Mean Age (y)	Forward Flexion (°)	External Rotation Pre/Post (°)	VAS Pain Score Pre/Post (°)	Satisfaction (%)
OA	3	16	51	95/145	-20/35	8.1/.9	100
RA	1	13	43	70/140	20/35	7.0/.5	100
ISA	8	13	43	70/140	-30/35	8.4/1.3	87
CTA	7	12	67	60/110	80/30	8.5/1.5	71

*OA indicates osteoarthritis; RA, rheumatoid arthritis; ISA, instability surgery arthritis; CTA, cuff-tear arthritis; VAS, visual analog scale.

Constant Scores and forward flexion being affected by the integrity of the rotator cuff tendon. All patients with rheumatoid arthritis had significantly improved pain and satisfactory limited goal outcomes if cuff-deficient. Short-term clinical outcome data for third-generation humeral resurfacing implants have not been published yet, but the short-term experience has been encouraging (Table II).

Conclusions

The reported results of resurfacing arthroplasty in patients with osteoarthritis and rheumatoid arthritis are equivalent to results of hemiarthroplasty,[2] but several advantages may become clinically relevant with long-term analysis. An individual's proximal humeral anatomy is preserved, with no systematic alterations in lateral offset, neck-shaft angle, or retroversion.[8] Resurfacing arthroplasty of the humeral head does not require a humeral osteotomy and therefore avoids the potential technical errors in version, head height, offset, and neck-shaft angle. Intramedullary stems may also be placed in a varus or anterior canal position, and perforation or intraoperative fracture may occur. Removal of stemmed implants remains a problem, with associated tuberosity and shaft fractures leading to implant instability, eventual proximal humerus bone loss, and poor shoulder function. Clearly, humeral resurfacing arthroplasty offers many advantages over stemmed implants.

Recent development of a newer third-generation implant should lead to improved humeral head resurfacing clinical outcomes because of several implant and technique changes—specifically, the increase in anatomical implant sizes and the improved implant-to-bone interface that results from the redesigned reaming instrumentation and implant undersurface. The surgical technique has been simplified through instrumentation changes and application of the current understanding of proximal humerus anatomy to obtain individualized humeral head resurfacing implant positioning.

Author's Disclosure Statement

The author wishes to note that he is a consultant for DePuy Orthopaedics, Inc., and receives royalty payments for some of the DePuy products.

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