Glenohumeral Pressure With Surface Replacement Arthroplasty Versus Hemiarthroplasty

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abstract

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It is not known whether significant differences in the glenohumeral center of pressure and contact pressure exist between surface replacement arthroplasty and hemiarthroplasty compared with the native joint. Twelve fresh-frozen cadaveric shoulders were dissected free of soft tissue, and the joint capsule was removed. The scapula was potted with the glenoid parallel to the ground. A pressure-sensitive sensor was placed in the glenohumeral joint, and each specimen was tested in sequence: intact, surface replacement, and hemiarthroplasty. Loading was done with a 440-N compression load at 0.5 Hz with the shoulder in 4 different positions. The center of pressure and contact pressure were measured at each position. The glenohumeral contact pressure with surface replacement was not different from intact pressure in 2 arm positions. Pressure with hemiarthroplasty was significantly different compared with the intact shoulder at all 4 arm positions and compared with the surface replacement group at 2 arm positions (P≤.05). Change in the anterior-posterior center of pressure from intact was significantly smaller with surface replacement compared with hemiarthroplasty with the humerus at 0° flexion/0° abduction and at 0° flexion/90° abduction (1.11±0.89 mm vs 2.38±1.62 mm, P=.02, and 0.68±0.50 mm vs 2.37±2.0 mm, P=.01, respectively). Change in the superior-inferior center of pressure was significantly smaller with surface replacement vs hemiarthroplasty at 0° flexion/0° abduction and at 90° flexion/90° abduction (0.98±1.16 mm vs 2.33±1.38 mm, P=.02, and 1.50±1.28 mm vs 2.90±1.92 mm, P=.04, respectively). Compared with hemiarthroplasty, surface replacement arthroplasty more closely replicated the contact pressure and center of pressure in the intact glenohumeral joint.

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Surface replacement arthroplasty was developed as a potentially bone-preserving procedure with special application in patients with viable humeral head bone stock. Early clinical results are similar to those with hemiarthroplasty. This method does not require humeral osteotomy and therefore allows the surgeon to maintain native version, head height, offset, and neck shaft angle. A less invasive procedure is desirable, especially in patients who have viable humeral head bone stock, such as those with avascular necrosis, osteochondral defects, and isolated humeral head osteoarthritis.

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The goal of this cadaveric study was to compare the glenohumeral contact pressure and center of pressure at typical clinical arm positions using surface replacement arthroplasty and hemiarthroplasty. The authors hypothesized that surface replacement arthroplasty would more closely approximate the contact pressure and center of pressure in the native joint.

**Materials and Methods**

Twelve fresh-frozen human cadaver shoulders were used. The average age was 74.8 years (range, 56-86 years), and 11 were male and 1 was female. A previously published testing model was followed. All 12 shoulders were dissected free of soft tissue, and the capsule was removed to expose the humerus and glenoid. Soft tissue was removed as a potential variable because the goal was to isolate the biomechanics of the glenohumeral joint. The anterior-posterior and superior-inferior diameters of the glenoid with intact labrum were measured with a digital caliper. The glenoid was potted in plaster of Paris with the glenoid oriented parallel to the ground to ensure that all loads across the joint would be compressive. Two 0.045-in (1.1-mm) Kirschner wires were placed through the glenoid neck and the body of the scapula to help maintain a parallel orientation.

The humeral shaft was potted in plaster of Paris and placed in a custom fixture that was mounted on an MTS servohydraulic load frame (MTS Systems, Eden Prairie, Minnesota) (**Figure**). The fixture was allowed to translate in 2 directions to maximize anatomic loading on the glenoid. The exposed length of the proximal part of the shaft was 5 cm from the greater tuberosity to minimize diaphyseal bending moments and interference by the testing apparatus during range of motion. The neutral axis was defined by placing the bicipital groove anteriorly and rotating the humerus externally 10° with a goniometer with no abduction or flexion.

A dynamic pressure-sensitive sensor that was 0.1 mm thick (I-scan 5051; Tekscan, South Boston, Massachusetts) was used to measure changes in the position of the center of pressure and the magnitude of glenohumeral contact pressure. Before placement of the sensor, 3 reference points were labeled with permanent marker on the labrum: superior, inferior, and closest point to the center of the coracoid. These reference points allowed interpretation of data based on consistent orientation across specimens. The sensor was placed between the humerus and the glenoid and glued into position with cyanoacrylate. For each specimen, pressure was applied to the sensor with a blunt object at each labeled reference point after each loading stage. Pressure data from the reference points were used to normalize sensor orientation consistently across specimens to assess the shift in the center of pressure. The sensor remained in place for all testing of each specimen.

Once the intact specimen was tested, the humeral head was prepared for the surface replacement arthroplasty group and was subsequently tested. Bone preparation was initiated by debridement of osteophytes to appropriately identify the anatomic neck. A centralizer/sizer instrument was used to find the center of the anatomic humeral head and to determine the correct implant size that best fit the specimen. The humeral head was shaped to the proper roundness corresponding to the selected centralizer/sizer using a humeral head shaper. The humeral head was then broached to the appropriate head size. After trial implants were fitted, the selected...
humeral prosthesis (Ascension Orthopaedics, Austin, Texas) was impacted until it was flush against the bone. This prosthesis is a distal geometric stem and is stable without cementing once implanted.

The surface replacement implant was then removed, and the hemiarthroplasty neck template was fixed to ensure the proper humeral anatomic neck cut along the rotator cuff insertion. The cut was made with an oscillating saw, and the metal template was removed. The stemmed hemiarthroplasty (Ascension Orthopaedics) was fit according to the anatomic dimensions of the specimen. The head neck angle of the implant was fixed at 135°. The specimen was then tested on the load frame.

The MTS machine was used to apply a compressive load of 440 N at 0.5 Hz for 20 cycles to simulate in vivo gleno-humeral loading conditions during range of motion of the shoulder during activities of daily living.11 The joint was tested in the intact state and then with surface replacement followed by hemiarthroplasty.

Test positions of the humerus relative to the glenoid were 0° elevation/0° abduction (N-N), 0° forward elevation/90° abduction (N-90), 90° forward elevation/90° external rotation (90-90), and 90° forward elevation/0° abduction (90-N). These were considered typical arm positions that would allow an overview of joint biomechanics in the clinical setting.

Mean contact pressure was measured. Movement of the center of pressure after each treatment was measured relative to the center of pressure in the intact state in that specimen. Contact pressure was defined as the pressure applied to the glenoid by the humeral head, and the center of pressure was defined as the center point among all points of pressure recorded by the electronic sensor as the humeral head contacted the glenoid. The center of pressure in intact, surface replacement, and hemiarthroplasty specimens was determined based on pressure measurements obtained during testing with I-scan software. Movement of the center of pressure was measured in millimeters in the anterior-posterior and superior-inferior planes.

Power analysis showed that 10 specimens in each group would provide 80% power to detect a 10% difference in pressure if such a difference existed with a .05 significance level. Data were compared with analysis of variance. If analysis of variance showed a significant difference, a post hoc Scheffé test was used to identify differences. P≤.05 was considered statistically significant.

**RESULTS**

Glenohumeral contact pressure in the hemiarthroplasty group was significantly lower than in the native shoulder at all arm positions and significantly lower than with surface replacement in 2 of 4 arm positions (Table 1). This finding indicated that hemiarthroplasty was associated with a significant change in contact characteristics compared with the intact joint. In the surface replacement group, no difference was seen in contact pressure compared with the native shoulder with the arm at the N-90 and 90-90 positions, indicating that surface replacement was not associated with a significant change in contact characteristics compared with the native joint. Contact pressure in the surface replacement group was significantly lower than in the native shoulder at the N-N and 90-N positions.

Compared with the native shoulder, the surface replacement arthroplasty group showed significantly less anterior-posterior movement of the center of pressure than the hemiarthroplasty group at the N-N and N-90 positions (Table 2). This finding indicated that surface replacement arthroplasty was associated with significantly less change from the intact center of pressure compared with hemiarthroplasty. No difference was seen between the groups with the shoulder at the 90-90 and 90-N positions. In the coronal plane, significantly less movement of the center of pressure was seen with surface replacement compared with hemiarthroplasty at the N-N and 90-90 positions.

**DISCUSSION**

These data show that in a biomechanical model, the glenohumeral joint contact pressure and center of pressure were closer to those in the intact joint after surface replacement arthroplasty than with hemiarthroplasty. Contact pressure with surface
replacement was not different from that with the intact joint in 2 of 4 arm positions, whereas significantly different contact pressure compared with the intact joint was found in all arm positions after hemiarthroplasty. Both procedures affected native joint biomechanics, but movement of the center of pressure with surface replacement was significantly lower than that with hemiarthroplasty at 2 of 4 arm positions in both planes measured. These findings suggested that the glenohumeral center of pressure and contact pressure may be preserved more closely with surface replacement arthroplasty than with hemiarthroplasty. Although this was a biomechanical study, recreating glenohumeral contact pressure to that of the native shoulder may decrease eccentric glenoid load and limit further erosion and degeneration.

Surface replacement arthroplasty is an attractive option for patients with isolated humeral head defects because the native shoulder anatomy is maintained. Early clinical results were similar to those with hemiarthroplasty. Levy and Copeland found outcomes similar to those of previous hemiarthroplasty findings in their study of 5- and 10-year results of surface replacement in patients with osteoarthritis and rheumatoid arthritis. In a series of 36 patients younger than 55 years, Bailie et al showed improvement from preoperative American Shoulder and Elbow Surgeons scale scores in 35 of 36 patients at an average of 38 months and concluded that surface replacement is effective in younger, active patients.

The current findings support those of a previous cadaveric study of glenohumeral biomechanics in which Hammond et al found that surface replacement more closely replicated the kinematics of the native glenohumeral joint compared with hemiarthroplasty. In their study, the humeral head shifted significantly more from the geographic center of the glenoid with hemiarthroplasty compared with surface replacement, and the apex of the humeral head showed a significant superior shift after hemiarthroplasty. They reported a shift in the center of rotation from the calculated geometric center of the intact specimen of 4.7±0.3 mm with hemiarthroplasty and 2.2±0.3 mm with surface replacement. This degree of difference from the intact shoulder for the 2 procedures was similar to that found in the change in the center of pressure in the current study. The previous study found no significant difference in contact area or peak pressure between the 2 procedures.

The current study had several limitations. Given the experimental set-up, the authors were able to quantify shoulder kinematics only in distinct snapshots in time. A biomechanical model with cadavers cannot fully recreate clinical loading of the glenohumeral joint, but the authors’ loading model was consistent and represents clinical loading conditions during activities of daily living. Procedures were determined sequentially for each specimen, with the potential for change in the specimen with successive loading. However, testing the procedures on the same specimen allowed the authors to avoid variability from 1 specimen to another.

<table>
<thead>
<tr>
<th>Movement of Center of Pressure From Intact Position</th>
<th>Surface Replacement (n=12)</th>
<th>Hemiarthroplasty (n=12)</th>
<th>P</th>
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<tbody>
<tr>
<td>Anterior-posterior plane</td>
<td>N-N, mm, mean±SD</td>
<td>1.1±0.9</td>
<td>2.4±1.6</td>
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<td>N-90, mm, mean±SD</td>
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<td>90-N, mm, mean±SD</td>
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<td>Superior-inferior plane</td>
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<td>2.3±1.4</td>
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<td>1.5±1.1</td>
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Abbreviations: N-N, 0° elevation/0° abduction; N-90, 0° forward elevation/90° abduction; 90-90, 90° forward elevation/90° external rotation; 90-N, 90° forward elevation/0° abduction; SD, standard deviation. *P≤.05.

### Conclusion
Surface replacement arthroplasty is a bone-preserving procedure with application in patients with viable humeral head bone stock, such as those with avascular necrosis, osteochondral defects, and isolated humeral head osteoarthritis. Clinical studies have shown good results compared with hemiarthroplasty, but biomechanical assessment of the center of pressure and contact pressure has not been done. The current biomechanical data suggest that surface replacement arthroplasty more closely maintains native joint kinematics compared with hemiarthroplasty and should be further investigated as an alternative to hemiarthroplasty.

### References


