**Orthopaedic Research Lab, Columbia University, New York, NY.**

**48th Annual Meeting of the Orthopaedic Research Society**

**Paper No: 0282**

**BIOMECHANICAL EVALUATION OF A NOVEL GLENOID DESIGN IN TOTAL SHOULDER ARTHROPLASTY**

**INTRODUCTION:** Glenoid component loosening is the most common complication of total shoulder arthroplasty (TSA) [9]. Loosening is thought to occur with eccentric loading of the glenoid rim which can occur when the humeral component translates on a conforming glenoid. Non-conforming joints allow humeral translation on the glenoid without rim loading, but at the expense of increased contact area. Previous studies have quantified the effect of joint conformity on humeral head kinematics and force-displacement relationships [1-4,6] but have not studied articular contact patterns. The objectives of this study are to compare glenohumeral joint (GHJ) mechanics before and after TSA, and to evaluate the performance of three glenoid components: (1) non-conforming (NC), (2) conforming (CF), and (3) a novel design featuring a variable radius of curvature across its articular surface.

**METHODS:** Specimen preparation: Six normal fresh-frozen cadaveric shoulders (mean age 52, range 34-67) were thawed, dissected, and instrumented for mechanical testing on a custom apparatus [8]. Rotator cuff and deltoid muscle forces were simulated, and the weight of the arm and scapulothoracic motion were also modeled. Two sets of precision triaxial each were affixed to both the scapula and distal humerus for kinematic analyses and for articular surface registration [8]. Prior to testing, the joint capsule was transsected and repaired using a novel technique which facilitated the replacement of multiple glenoid prostheses while restoring capsular tension throughout all testing configurations. Test protocol: Seven test positions were selected: (i) scapular plane arm elevations of 30, 90, 120, and 150° in starting (i.e. external) rotation [5,7] for “centered” loading, and (ii) two rotations at 90° elevation representing “subluxed” (i.e., potential rim loading) positions: horizontal extension in starting rotation, internal rotation in the scapular plane, and horizontal (i.e., forward) flexion with internal rotation. The repaired natural joint (RNJ) was tested first, followed by blinded, randomized testing of the three glenoid designs (CF, NC, and the new design). GHJ replacement was performed using standard sized Co-Cr-alloy humeral heads and keeled UHMWPE glenoids. For a humeral head component with radius of curvature R₀, the CF glenoid had radius R₀ and the NC glenoid radius was (R₀+3). The new design featured a conforming center and non-conforming periphery. The set of muscle forces used to actively position the RNJ was maintained for the three prosthetic configurations. At each kinematic position studied, the trial locations were obtained using a 3-D coordinate measuring machine (CMM). Following testing of the RNJ, stereophotogrammetry was performed on the glenoid and humeral head cartilage surfaces for contact and kinematic analyses [5,7]. After testing each glenoid component, its surface was digitized with the CMM to obtain its orientation relative to the humeral head. The prosthetic humeral head and its reference triads were digitized at the conclusion of all kinematic testing. Data analysis: Accurate geometric (b-spline) models of the natural and prosthetic joint surfaces were created, and a series of non-linear optimization techniques were employed for surface registration with experimental data. Joint contact was computed using the proximity technique [7], while joint reaction forces were calculated in accordance with free-body analysis of external forces acting on the humerus. The reference point for kinematic and contact results was the center of curvature of the glenoid, located at the origin of its anatomic axes. Statistical analyses were conducted using a generalized linear model ANOVA with repeated measures and post-hoc tests. Data was analyzed separately for the four scapular plane (SCP) elevations, the three positions of subluxation (SLX), and for all seven positions (full range).

**RESULTS:** Joint reaction forces: In all three anatomic directions, no significant differences (p>0.05) were detected among glenoids when analyzing SCP elevations. For SLX positions, the anterior-posterior (A-P) resultant force was significantly (p=0.037) greater for the NC glenoids (52±23 N) compared with the RNJ (55±18 N). Kinematics: The center of curvature of the humeral head was consistently more superior in the prostheses compared to the RNJ both during SCP (3.9±3.9 vs. 2.3±2.6 mm, p=0.038) and SLX (3.8±3.8 vs. 1.6±2.8 mm, p=0.016) motions. CF glenoids subluxed posteriorly relative to the remaining glenoids during SCP abduction (p<0.01).

Medial-lateral (M-L) and superior-inferior (S-I) ranges of translation tended to be smaller for SLX motions compared to SCP elevations. Meanwhile, A-P ranges of translation were very similar (p=0.5) for all glenoids for the SCP, SLX, and full ranges (Fig. 1). Contact centroids: Contact for all glenoids was consistently located superior to the component’s center of curvature for all seven test positions (1.5-12.8 mm for RNJ, 4.6-12.2 mm for implants). Following kinematic trends, contact was more posterior for CF glenoids during elevations (p=0.02) and rotations (p=0.3). The S-I range of centroid translation was greater for the RNJ than for implants (SLX, p=0.11; SCP, p=0.052; full range, p=0.053), whereas in the A-P direction the NC joints exhibited the largest ranges among all glenoids (SLX, p=0.2; SCP, p=0.61; full range, p=0.37).

Figure 1: Range of anterior-posterior humeral head translation for scapular plane elevations (SCP), subluxation rotations (SLX), and all test positions

**DISCUSSION:** Despite clinical speculation that component conformity in TSA strongly influences implant performance and survival, few significant (p<0.05) differences were found among the three glenoid designs under the imposed test conditions, including out-of-plane positions that were originally thought to result in larger joint translations and to promote eccentric glenoid loading. In response to uniform muscle loads, statistically significant differences in calculated resultant forces were found only with forward flexion, where the NC design experienced greater posterior loads than the RNJ (p=0.037). Geometrically, the new glenoid design featured conforming and non-conforming regions, and in general its response was intermediate to those of the two other designs. The range of humeral head translation, a measure of joint stability, tended to be largest for the NC and smallest for CF glenoids (Fig. 1). In flexion, the contact centroid for CF joints was the most posterior (nearly 8 mm from the joint center, p>0.3) among all four glenoids, but interestingly, this trend was more pronounced for SCP motions (p=0.02). Articular contact tended to be focused more superiority during all motions but was more centered in the A-P direction, particularly for SCP elevations. In all test positions, the center of curvature of the native humeral head generally remained closer to the A-P and S-I mid-line of the joint compared to the implants; however, its contact centroid exhibited large ranges of translation in the S-I (12.4±4.3 mm across all 7 positions, highest among all glenoids) and A-P (8.8±2.6 mm) directions. Differences between natural and prosthetic joints may be related to the greater compliance of articular cartilage compared to polyethylene. The results obtained from this experimental model incorporating muscle and capsular loads emphasize the importance of soft-tissue balancing in total shoulder arthroplasty.