INTRODUCTION: The complications following shoulder hemiarthroplasty have a strong correlation with the failure to properly restore the anatomic structure and the force system in the glenohumeral joint. The complications resulting from inadequate restoration of the force system may not appear to be seriously immediately following surgery, but they certainly lead to known sequelae including glenoid component loosening, decreased range of motion, pain, and stiffness. In addition, with the shoulder being the most mobile joint in the body, combined with a high variability in proximal shoulder anatomy, there are inherent limitations in current prosthesis design which add to the difficulty in restoring the glenohumeral joint force system. The objectives of this study were to quantify the glenohumeral joint forces and the glenoid contact pressures/areas before and after hemiarthroplasty in a cadaver model.

MATERIALS AND METHODS: Five fresh frozen cadaveric entire upper extremities without evidence of a rotator cuff tear or other joint disease were used (mean age 80.1 ± 2.3 years). The muscles of the anterior and middle portions of the deltoid and the rotator cuff were resected and the tendons were preserved while leaving the glenohumeral joint intact. The wrist and each of the digits were fixed in extension and the elbow was fixed in 90° of flexion with the use of stainless steel threaded pins. For biomechanical testing, a custom shoulder testing jig that permitted the measurement of glenohumeral joint forces and contact pressures while simulating individual shoulder muscle forces was used. For muscle force simulation, the action of the rotator cuff and the deltoid (anterior and middle portions) were loaded in a similar manner as previously described for glenohumeral abduction (1). The direction of each muscle force vector was defined as the line from the tendon insertion to the centroid of the muscle. An arthrotomy was made in the anterior capsule that was large enough to allow placement of the Fuji pressure sensitive film (Fuji Photo Film Co, Ltd, Japan). Three small uniform slits were made in the film to prevent folding or wrinkling during loading. The humeral head was manually distracted from the glenoid until loads were applied to the shoulder tendons(1). The glenohumeral contact pressures and areas were quantified using the HP scanner and NIH Image 1.52 (2). The joint force was measured with a 6-degree of freedom load cell (Assurance Technologies, Garner, NC). This force was resolved into three orthogonal components: 1) force perpendicular to the glenoid; 2) force directed anterior to the glenoid; and 3) force directed superior to the glenoid. After initial joint force measurements were made, the joint was unloaded, Fuji film was placed, and glenohumeral joint was loaded as previously described for two minutes (2). Biomechanical testing was performed at four glenohumeral positions. To simulate 90° of shoulder abduction, the scapula was abducted 30° and the glenohumeral joint was placed in an additional 60° of abduction. This testing position was chosen because anterior instability is common at 90° of shoulder abduction. The apprehension position was simulated by placing the shoulder into an additional 60° of shoulder abduction, the scapula was abducted 30° and external rotation. The Aequalis humeral component (Tornier Inc.) was then implanted through the anterior capsule arthrotomy under the guidance of the senior surgeon. All anatomic parameters were optimized for each specimen. Care was taken not to disturb the insertion of the subscapularis tendon on the humerus. Testing was then repeated at each of the four previously described shoulder positions. For statistical analysis, ANOVA was performed to compare the joint forces (of the three orthogonal axes) of before and after hemiarthroplasty. A p-value of 0.05 was used as the level of significance.

RESULTS: In all four positions there was a significant decrease in total contact area after prosthesis implantation (p<0.05)(Figure 2). This ranged from 27-40% (p<0.05). There was also a corresponding increase in total contact pressure, ranging from 27 – 55%, the highest of which were in the apprehension position (notably, prosthesis edge-loading was observed in these positions). The peak glenohumeral contact pressure after hemiarthroplasty at 90° abduction increased 33% and 66% in neutral and apprehension positions, respectively (p<0.05) (Figure 1). The glenohumeral joint force perpendicular to the glenoid showed no significant changes after hemiarthroplasty (p=0.05). The forces in the superior-inferior direction increased by as much as 26% in the 90° abduction and neutral position, and the anterior-posterior directed forces increased anteriorly by as much as 26% in the 90° abduction and apprehension positions (p<0.05) (Figure 2).

DISCUSSION: This study demonstrates significant changes in contact pressure and area following shoulder hemiarthroplasty. The most notable differences in contact pressure occurred in our defined “apprehension” position both qualitatively and quantitatively. Edge-loading of the beveled edge of the prosthesis on the glenoid surface in these positions created smaller contact areas and increased pressures. Full arm elevation involves external rotation to allow for the coronal-plane humeral arc of rotation to articulate with the smaller transverse arc of the glenoid. Our “apprehension” position represents an extreme of motion. Replacing the cut articular surface with a similarly sized prosthetic surface decreases the available range of humeral articulation. Thus, poor clinical outcome and a decrease in range of motion may be related to prosthesis design and abnormal shoulder biomechanics.

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REFERENCES: