**Version Correction Affects Glenoid Fixation in Total Shoulder Arthroplasty on Biconcave Glenoids**

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**Disclosure:** Xiang Chen (N), Andreas Kontaxis, PhD (N), Jonathan Glenday (N), Akhil Reddy (N), Daniel Choi (N), Timothy Wright, PhD (1; Exactech, Mathys, Lima; 4; Exactech, Orthobond; 5; Stryker.), Lawrence Gulotta, MD (2; Biomet. 3B; Biomet.)

**Introduction:**

The Biconcave or B2 type of primary shoulder osteoarthritis (OA) promotes pathological alterations to shoulder biomechanics through the formation of a highly retroverted neoglouenoid cavity. These morphological changes compromise the stability of the shoulder creating high posterior glenoid wear and humeral head migration. During Total Shoulder Arthroplasty (TSA) in B2 shoulders, surgeons often ream the glenoid eccentrically in order to correct glenoid version and restore glenohumeral stability. However, clinical follow ups have shown that TSA on B2 glenoids is associated with a higher risk of early to mid-term glenoid component loosening when compared to other types of shoulder OA. Causes for this increased risk were hypothesized to be related to the high posterior glenohumeral load and the quality of periprosthetic bone stock, both of which are influenced by intraoperative version correction during TSA. No clear guideline exists for the optimal degree of version correction that centralizes glenohumeral contact concurrently ensuring long term component fixation in B2 glenoids. To understand how the eccentric reaming and version correction of the glenoid component can affect the loads and the primary fixation in TSA, subject-specific musculoskeletal and finite element (FE) models were developed in order to investigate stresses and bone load transfer during simulated activities of daily living (ADL).

**Methods:**

Subject-specific musculoskeletal and FE models were created from CT scans (n=3) of patients with B2 primary shoulder OA that had glenoid version larger than 15°. 3D models of commercially available 4-peg all-polyethylene TSA glenoids (Biomet, Warsaw, IN, USA) was used for the virtual implantation. For each specimen the glenoid cup was fixed into four positions, simulating different degree of eccentric reaming and version corrections of 0°, 5°, 10°, and 15° relative to each native glenoid version (12 bone-implant models in total). The scapula for each model was virtually reamed until the back surface of the glenoid component was in full contact with bone. A 1 mm thick cement mantle was included. The polyethylene cement component and the cement mantle were modeled as elastic materials. The bone material properties were determined using the grayscale values from each CT scan (Young’s modulus range = 0.003 to 17,161 MPa). The models incorporated a fully bonded bone-cement interface and a frictional implant-cement interface. ASTM F2028-14 Testing for glenoid component distraction and compression was simulated in a preliminary FE study, and micromotion values were compared with initial compression and distraction data of a similar 4-pegged glenoid component to determine a friction coefficient of 1.5.

A computational musculoskeletal shoulder model was used to calculate the peak glenohumeral contact load during a simulated ‘reaching an object at the head height’ activity. The model was customized to describe each specimen and each version correction. Those peak loads were applied to the custom FE models, which were constrained at the medial scapula border and the acromioclavicular joint. Stresses and load transfer through the bone-cement-implant system were calculated and compared across the 4 version corrections among 3 subjects. Possibilities of polyethylene material failure in the glenoid component were assessed using von Mises failure criteria. Critical cement volume was defined as the percentage of the cement mantle that showed principal stresses exceeding the fatigue strength of cement. For each subject, critical cement volumes at higher angles of version correction were normalized to the critical cement volume at 0° version correction. Load carried by peri-prosthetic bone was calculated for all bone-implant models.

**Results:**

Through the magnitude of peak contact load remained relatively unchanged for each subject across different version corrections (subject A: 502.3 ± 2.49 N; subject B: 590.5 ± 12.76 N; subject C: 469.5 ± 22.14 N), contact loads were centralized progressively as the degree of version correction increased (Fig. 1). At native B2 retroversion (0° version correction), 2 out of 3 subjects had regions in their glenoid component where localized stresses exceeded the failure threshold for polyethylene (Fig. 1). Critical cement volume varied across degrees of version correction among subjects. Compared to B2 retroversion, critical cement volume was increased at 10° and 15° version corrections for 2 out of 3 subjects (Fig. 2). On average, percentage of load carried by peri-prosthetic bone decreased as degrees of version correction increased (Fig. 3).

**Discussion:**

Version correction mitigates the risk of edge loading and polyethylene failure during the simulated ADL after TSA. However, the degree of version correction should be chosen with care. Risk for cement failure may vary with glenoid retroversion on a subject-specific basis. Meanwhile, excessive version correction could increase the risk for stress shielding in peri-prosthetic bone stock and may promote unfavorable bone remodeling.

**Significance:**

This study utilized a multi-objective modeling approach to evaluate TSA fixation simulating clinically important conditions. The comprehensive approach adopted in this study provided in depth information concerning the effectiveness and the risk of a common surgical procedure.

**References:**


**Figure 1.** Peak glenohumeral contact loads was progressively centralized as version correction (VC) increased in all 3 subjects. Von Mises stress in glenoid component is shown for subject A. ○, 0° VC; □, 5° VC; Δ, 10° VC; X, 15° VC.

**Figure 2.** 2 out of 3 subjects showed higher critical cement volume at 10° and 15° version corrections compared to 0° version correction. Absolute maximum principal stress in cement was shown for subject A.

**Figure 3.** Percentage of load carried by peri-prosthetic bone decreased as degrees of version correction increased. The difference was more profound in regions closer to bone-cement interface.

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