Increased Deltoid and Acromial Stress with Glenoid Lateralization and Onlay Humeral Stem Constructs in Reverse Shoulder Arthroplasty

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INTRODUCTION: Traditional (Grammont) reverse shoulder arthroplasty (RSA) designs medialized and distalized the center of rotation of the reconstructed glenohumeral joint[1]. More contemporary RSA design constructs have focused on increased glenoid lateralization to allow for improvements in impingement-free range of motion. Humeral component designs now feature both inlay and onlay constructs that effect both distalization and lateralization of the humerus. While these options may allow surgeons to influence range of motion and functional outcome following RSA, the effects of combined glenoid and humeral lateralization and distalization on acromial and deltoid stresses are poorly understood. The purpose of this study was to evaluate the changes in deltoid and acromial stress with variations in glenoid lateralization, and inlay versus onlay humeral component designs in RSA.

METHODS: A previously validated finite element (FE) model of RSA[2] was modified to incorporate a reverse shoulder arthroplasty system with both inlay and onlay configurations (Figure 1A). Inclusion of tensioned deltoid and subscapularis muscles is a key feature of the FE model. A 36 mm glenosphere was utilized for all configurations. Variations in total glenoid lateralization from 3 to 9 mm were evaluated. The acromion was assigned representative scapula-specific cortical and trabecular bone material properties[3]. Deltoid and acromial stresses were determined following virtual implantation of the glenoid and humeral components, as well as with simulation of external rotation from neutral to 50°. The torque required to externally rotate the humerus prior to impingement and any corresponding post-impingement subluxation were evaluated for each implant configuration.

RESULTS: Glenoid lateralization resulted in progressive strain of the deltoid after virtual implantation of RSA components (15% increase in deltoid stress over baseline for most lateralized case – Figure 2). Deltoid stress increased 7% when glenoid lateralization was increased from 3 mm to 6 mm and an additional 7.5% when glenoid lateralization increased from 6 mm to 9 mm. Deltoid stress increased further with distalization and lateralization of the humerus using the onlay construct due to stretching along the muscle axis. For example, at 9 mm of glenoid lateralization, deltoid stress increased 60% when the stem configuration was changed from an inlay to an onlay construct. Acromial stress correspondingly increased up to 37% with glenoid lateralization, and up to 117% with humerus distalization and lateralization (Figures 1B and 2). The construct with 9 mm of glenoid lateralization and an onlay stem design required the largest torque to externally rotate the humerus due to maximal tensioning of the subscapularis tendon compared to the other configurations. For each level of glenoid lateralization tested, the addition of an onlay stem increased the required torque to externally rotate the reconstructed glenohumeral joint. Additionally, the use of an onlay stem decreased the impingement-related subluxation at terminal external rotation for all levels of glenoid lateralization modeled except for 9 mm of glenoid lateralization, which alone eliminated the incidence of impingement.

DISCUSSION AND CONCLUSION:

Increased lateralization of the glenoid component resulted in increased levels of deltoid and acromial stress in RSA. For a given amount of glenoid component lateralization, the utilization of an inlay stem decreased acromial and deltoid stress as compared to onlay stem constructs. Increased soft tissue tension from glenoid lateralization and humeral distalization was observed to increase torque requirements for external rotation. However, it was also observed to decrease subluxation associated with impingement during maximal external rotation. This data allows surgeons to better understand the interactions of glenoid lateralization and humeral distalization as well as lateralization in the setting of contemporary RSA systems. An appreciation of these factors will assist surgeons' component selection when contemplating glenoid component lateralization and/or humeral distalization in RSA. Future investigation will further define these relationships and add to the understanding of how implant options effect the mechanics of RSA. Hopefully such efforts will lead to optimization of implant selection and improvement in design which will improve patient outcomes.

References: [1] Boileau et al. (2005), *J Shoulder Elbow Surg* 14(1 Suppl S):147S-161S. [2] Johnson et al. (2021), *Semin Arthroplasty: JSES* 31(1):36-44; [3] Chae et al. (2016), *J Orthop Res* 34(6):1061-8.

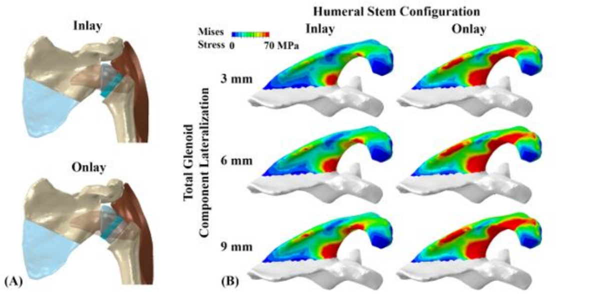

Figure 1. (A) RSA models incorporating the inlay and onlay constructs. Both models are shown with combinations of a standard baseplate and lateralized glenosphere providing 3 mm of total glenoid lateralization. The subscapularis tendon is shown transparent for clarity. (B) Scapular spine and acromial stress distributions at implantation shown for constructs incorporating inlay and onlay stems and progressive amounts (3 mm to 9 mm) of glenoid component lateralization.

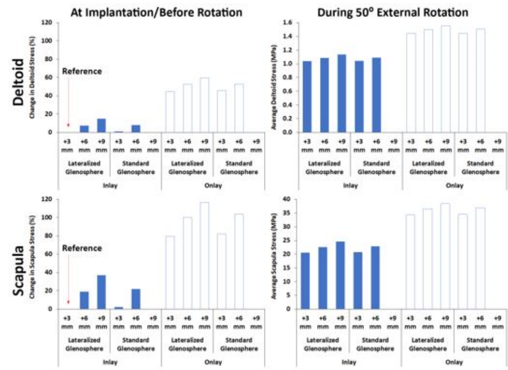

Figure 2. Variations in deltoid (top row) and scapula (bottom row) stresses at implantation (left column) and during rotation (right column) with total glenoid lateralization from 3 mm to 9 mm and inlay versus onlay humeral stem designs.