

Biomechanical Impact of Glenoid Baseplate Central Fixation on Scapular Spine Stress in Reverse Shoulder Arthroplasty: A Finite Element Analysis

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INTRODUCTION: Periprosthetic scapular spine fractures remain a challenging complication following reverse total shoulder arthroplasty (rTSA), resulting in poor clinical outcomes and increased revision risk. While glenoid baseplate fixation is critical for implant stability, its influence on scapular stress propagation is not fully understood. The biomechanical impact of different central fixation mechanisms, such as central press-fit post versus central bicortical lag screw with varying exit paths, on scapular spine stress has not been evaluated. Our hypothesis was that bicortical screw fixation will have a different pattern of glenoid stress concentration compared to a central post.

METHODS:

Three finite element models of rTSA prostheses were developed using validated scapula geometry and a standardized glenoid baseplate with four bicortical peripheral screws. Abaqus (Dassault Systèmes, USA) was used for the analysis. The models differed only in their central glenoid baseplate fixation options which included: central press-fit post, central 6.5 mm bicortical lag screw exiting anterior to the glenoid vault, and central 6.5 mm bicortical lag exiting posterior to the glenoid vault. Physiologic loading conditions were applied based on in vivo data capturing composite joint reaction forces during three functional activities: combing hair overhead, lifting a coffee pot from belt height, and lifting a 10 kg object from the ground. These composite vectors accounted for deltoid, rotator cuff, and other muscle contributions during each task and were applied to the humeral head to replicate realistic load transmission through the glenoid into the scapula. Von Mises stress, principal stress, and strain values were calculated for each model, with isolated analysis and comparison performed across the Levy I, II, and III zones of the scapula. An independent t-test was conducted to compare the average values of all finite element nodes within each Levy zone between the bone cage and posterior lag screw models.

RESULTS:

The average von Mises stress, principal stress, and strain across all Levy zones (I, II, and III) were consistently higher in the central 6.5 mm bicortical lag screw constructs compared to the central press-fit post configuration. Among the constructs, the posteriorly exiting bicortical lag screw generated the highest mechanical load. The most pronounced difference occurred in Levy Zone III during simulated lifting of a 10 kg object from the ground, where the posterior screw model exhibited nearly double the stress and strain relative to the central post. Quantitative analysis of all elements within Levy Zone III revealed that the press-fit cage demonstrated a principal stress of 2382.55 ± 3342.39 Pa, von Mises stress of 4184.03 ± 3134.33 Pa, and strain of $1.22 \times 10^{-7} \pm 1.14 \times 10^{-7}$. In comparison, the posteriorly directed screw model showed markedly elevated values: principal stress of 4225.93 ± 5725.77 Pa, von Mises stress of 7512.85 ± 5816.77 Pa, and strain of $2.33 \times 10^{-7} \pm 1.98 \times 10^{-7}$. These differences were statistically significant ($p < 0.005$). Localized stress concentrations, as shown in Figure 1, were observed at the cortical exit sites of both central lag screw models, suggesting a potential stress-riser effect at these locations.

DISCUSSION AND CONCLUSION:

This finite element analysis investigation demonstrated that central screw fixation induces greater stress and strain across the scapular spine compared to central press-fit post under physiologic loading conditions. These findings provide a possible biomechanical contribution to the clinical association between lag screw trajectories and periprosthetic scapular spine fractures following rTSA. While central lag screws remain a widely used and effective option for glenoid baseplate fixation, this study underscores the importance of thoughtful trajectory selection, especially avoiding screw exits posteriorly near the scapular spine when possible. Central post fixation may offer a mechanical advantage in reducing stress propagation through vulnerable bone, particularly in patients with compromised bone quality and risk factors for fragility fractures. Finite element modeling can serve as a valuable tool in preoperative planning by providing insight into implant behavior under functional loading and informing construct selection in at-risk populations.

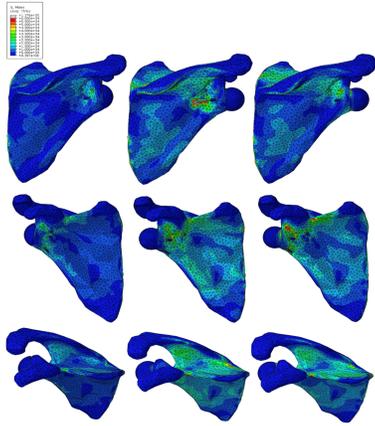


Figure 1. FEA results under the simulated loading condition of lifting a 10 kg object from the ground. Columns represent the three central fixation models: press-fit bone cage (left), posteriorly exiting bicortical lag screw (center), and anteriorly exiting bicortical lag screw (right). Rows display three orthogonal views of the scapula: posterior-anterior (top), anterior-posterior (middle), and superior-posterior (bottom). Von Mises stress distributions are shown, highlighting areas of peak loading and stress propagation across the scapular body.