Biomechanical Evaluation of Posterior Shoulder Instability with a Clinically Relevant Posterior Bone Loss Model

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INTRODUCTION:
Though recognized as a risk factor, posterior glenoid bone loss has only recently been characterized and is distinctly different than anterior glenoid bone loss patterns. Existing biomechanical studies are limited by employment of anterior glenoid bone loss models which are different in both orientation and morphology than posterior glenoid bone loss, and testing in a single neutral arm position thus not fully accounting for the contribution of capsuloligamentous structures in various at-risk arm positions. The purpose of this study was to evaluate the biomechanical effectiveness of a posterior labral repair in the setting of a clinically relevant bone loss model using 3-dimensional computed tomography modeling of patients with recurrent posterior shoulder instability in various at-risk arm positions.

METHODS:
Ten fresh-frozen cadaveric shoulders (mean age: 55.4 years, range: 39-65) were prepared by removing all tissue except the capsule and distal rotator cuff insertions. A joint coordinate frame was established, the specimens were potted, then mounted to a customized fixture on 6-degrees-of-freedom robotic arm. A posterior labral tear was created, then repaired with 3 horizontal mattress sutures and secured by drilling 6 transosseous holes along the peripheral glenoid face exiting the anterior glenoid neck. The sutures were secured for the labral repair states to the mounted fixture under maximal tension and released for the labral tear states and for creating the sequential bone loss models. Bone loss models were created based off a cohort of CT data on patients undergoing revision posterior labral repair surgery to develop 2 clinically relevant 3D models of glenoid bone loss: the first simulating the mean bone loss in this cohort and represented 7% or small bone loss; the second was the mean + 2SD representing 28% or large bone loss. The bone loss was created on each specimen with a 3mm round burr to match each respective 3D printed template (Figure 1). Each specimen was tested in 7 consecutive states: 1) native anatomy, 2) posterior labral tear (6-9 o’clock), 3) posterior labral repair, 4) mean posterior glenoid bone loss with labral tear, 5) mean posterior glenoid bone loss with labral repair, 6) large posterior glenoid bone loss with labral tear, and 7) large posterior glenoid bone loss with labral repair. Each state underwent 75N of posterior-inferior force and 75N of compression during the four tests at 60 and 90 degrees of flexion and 60 and 90 degrees of scaption. Posterior-inferior translation, lateral translation, and dislocation force were measured for each condition. Statistical analysis was performed using two-factor random-intercepts linear mixed-effects models.

RESULTS:
Compared to the labral tear state, significant increases in dislocation forces occurred with labral repair independent of bone loss state or arm position with values as follows: 14.8N (60° scaption), 12.2N (90° scaption), 11.1N (60° flexion), and 10.1N (90° flexion) with mean 12.1 ± 2.0N across all arm positions (figure 1). Dislocation force significantly decreased between no bone loss and small bone loss (mean 12.4 ± 0.7N) and between small bone loss and large bone loss (mean 11.8 ± 2.1N), regardless of labral state in all arm positions (Table 1). Posterior-inferior translation significantly decreased with labral repair compared to labral tear states independent of bone loss state in all arm positions (Figure 2). Lateral translation of the humeral head significant increased when the labrum was repaired independent of bone loss state in all arm positions except 90° scaption and decreased progressively in all bone loss states in all arm positions (table 1). In the native state, the shoulder significantly translated posterior-inferior in scaption at 60 and 90 elevation compared to flexion (p<0.017) and was most unstable in 60° scaption with 29.9 ± 6.1mm posterior-inferior translation.

DISCUSSION AND CONCLUSION: This is the first study to biomechanically evaluate posterior glenoid bone loss using a clinical model in various at-risk arm positions on a 6 degree-of-freedom robot and through a precise linear effects model has established values for the increase in dislocation force posterior labral repair provides regardless of bone loss. The most significant finding of the study is that independent of bone loss, labral repair reduced posterior dislocation forces by 12.1 ± 2.0N and significantly decreased posterior-inferior translation. With a mean decrease in dislocation force of 12.4 ± 0.7N with small (7%) bone loss, labral repair alone may be enough to restore shoulder stability in most individuals. However, significant increases in posterior bone loss may require bony augmentation for adequate stability based on individual factors such as age and activity level.
Table 1: Summary of statistically significant among modeled effects for labrum rate and bone loss rate. Separate linear mixed-effects models were constructed for each combination of shoulder position, elevation, and measurement. Numbers in the columns reflect the estimated effect of moving from State A to State B, as indicated in the column header. Arrows indicate an increasing effect in the presence of arrows, while down arrows indicate a decreasing effect. **g** represents not statistically significant.