THE EFFECT OF ARM POSITION ON HILL-SACHS ENGAGEMENT: A FINITE ELEMENT STUDY

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INTRODUCTION

Bony lesions of the glenohumeral joint are important risk factors that often lead to recurrent anterior shoulder dislocation. A Hill-Sachs lesion is defined as bone loss from the posterior-superior aspect of the humeral head due to a compression fracture. There exists no clear information about the engagement of the lesion depending on its size and the position of the arm. This may be the reason that sometimes smaller humeral head lesions are left untreated. The aim of this study was to show the theoretical relationship between the engaging Hill-Sachs lesion and the shoulder’s anterior instability. This study examined the effects of different sizes of Hill-Sachs lesions at various humero-thoracic abduction and rotation angles of the arm. We hypothesized that the distance to dislocation will decrease with increasing size of the defect and also that the shoulder’s stability would decrease at a higher humero-thoracic abduction angle and greater degree of external rotation of the arm.

METHODS

A computer-based finite element approach was used to model the glenohumeral joint with an intact humerus and glenoid. A generic model was developed for cartilage and bones of the glenoid and humerus, using data available in the literature [4,5]. Bones were assumed to be rigid bodies, and cartilage was modeled with hyperelastic material properties having a Young's modulus (E) of 10 MPa and a Poisson’s ratio (ν) of 0.4 [6]. 3D hexahedral element mesh was used, with 7830 elements for humeral head, and 9280 elements for glenoid mesh. Then different sizes of Hill-Sachs lesions for the humeral head were created, similar to those of Kaar et al. [1]. Lesion sizes were $\frac{1}{8}$, $\frac{3}{8}$, $\frac{5}{8}$, and $\frac{7}{8}$ of the humeral head radius (R). The experiments were analyzed using static analysis with displacement control in the anterior inferior direction. A 50-N compressive load was simulated for an intact joint, and the translational distance to dislocation was analyzed. Tests were performed at two different thoracohumeral abduction angles (45° and 90°). At each thoracohumeral abduction angle, a range for arm rotation was chosen between 40° internal to 60° external rotation. For arm to abduct to a humero-thoracic angle of 90°, the glenohumeral joint was rotated 60°. Likewise, thoracohumeral abduction angles of 45° was calculated as the 30° glenohumeral joint rotation.

RESULTS

Figure 1: % Intact translation distance comparison for humeral defects in neutral position and humero-thoracic abduction angles of 45° and 90°.

The comparison of percent intact translational distance to dislocation results for four different sizes of Hill-Sachs lesions at neutral rotation with a previous study shows similar patterns [1](Fig. 1). Results showed that for defect size $\frac{5}{8}$R, the gradual decrease in distance to dislocation occurred...
after external rotation of 30°. But for defect size 7/8*R, the gradual decrease can be seen after 10° of external rotation (Fig. 2). The horizontal and vertical axis represents the angle of rotation of the arm (40° internal to 60° external rotation) and the distance to dislocation (in millimeters), respectively.

Figure 2: Distance to dislocation (in millimeters) at 45° thoracohumeral abduction.

At a higher abduction angle (90°), the defect size 3/8*R has a reduced distance to dislocation of 9.5 mm during external rotation of 60° (Fig. 3). A decrease in the distance to dislocation for defect sizes 3/8*R, 5/8*R, and 7/8*R occurs at 30° external rotation, 10° external rotation, and 20° internal rotation, respectively.

DISCUSSION

The results from this study were compared to those from the study by Kaar et al. for validation of the model [1]. Results comparison showed similar trend patterns for the reduction of distance to dislocation. The distance to dislocation was reduced to 10.43 mm from 13.73 mm for the largest humerus defect at 90° humero-thoracic abduction and 0° rotation. This signifies that the shoulder becomes unstable with an increase in abduction in the presence of a humeral head defect. Kaar et al. concluded that a defect size of 7/8*R needs to be treated surgically, with associated soft tissue repairs [1]. But at 45° humero-thoracic abduction, we found that during external rotation of the arm defect size 5/8*R and 7/8*R reduces stability rapidly. Whereas, at 90° humero-thoracic abduction, a humerus defect size of 3/8*R, and 5/8*R had reduced stability during external rotation. It was interesting to see that defect size 7/8*R is already engaged at neutral rotation and 90° humero-thoracic abduction, as the distance to dislocation reduced sharply after 20° of internal rotation.

This study predicted that even Hill-Sachs lesions of smaller size can significantly decrease shoulder stability at higher angles of humero-thoracic abduction. Furthermore, we saw the engagement of Hill-Sachs lesion with rotation of the arm. We found that in the presence of a humeral head lesion, shoulder stability decreases with increase in external rotation of the arm. One limitation of this study is that it was based on approximate geometry of the glenohumeral joint and absence of the joint capsule.

CONCLUSIONS

Instability of shoulder increases with increasing size of the humeral head lesions. Smaller size defects are more likely to engage with the arm in greater degrees of abduction and external rotation. These findings may have implication for planning surgical reconstruction for shoulder instability.

REFERENCES