A Theoretical Model of the Effect of Bone Defects on Anterior Shoulder Instability
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INTRODUCTION:
The presence of either a Hill-Sachs or a bony Bankart lesion has been indicated as a possible cause of subluxation and anterior shoulder dislocation. Anterior dislocation accounts for approximately 98% of all shoulder dislocations. Common treatments include soft tissue repair, bone grafting, and total shoulder replacement. It has been reported that there is a possibility of recurrent instability even after an arthroscopic or open procedure, with an incidence of 8-18%. Often, during the initial procedure, bony defects are left untreated due to a greater inclination towards soft tissue repair. Our aim was to investigate the influence of lesion size of isolated and combined Hill-Sachs and bony Bankart lesions on the shoulder’s stability. Previous studies have investigated effects solely due to isolated bone lesions on the shoulder’s instability. This computational study investigated the effect of both bony Bankart and Hill-Sachs lesions in the glenohumeral joint on the shoulder’s stability. We hypothesized that by increasing the size of isolated humeral and glenoid lesions, the stability of the joint would decrease. In addition, we expected that the presence of the glenoid and humeral head lesion together would demonstrate more instability than isolated lesions.

METHOD:
A computer-based finite element approach was used to model the glenohumeral joint with an intact humerus and glenoid. A sample-specific model was developed for cartilage and bone of the glenoid and humerus using data from previous studies. All experiments were analyzed using static analysis with displacement control. The two testing positions used for the experiments were abduction angles of 45° and 90° with neutral arm rotation. Simulations were run with a 50-N compressive load for the intact joint as well as for both isolated and combinations of lesions of the humeral head and glenoid. The sizes of lesions for humeral head and glenoid were similar to those created in studies by Kaar et al. and Itoi et al., respectively. These were \( R_h \), \( R_c \), \( R_h' \), and \( R_c' \) of the humeral head radius (Rh) and \( R_h'' \), \( R_c'' \), \( R_h''' \), and \( R_c''' \) times the radius of glenoid (Rg). Results from these studies were compared to results from the simulations to validate our model. For every simulation, the reaction force and translational distance to dislocation were recorded. The stability ratio was calculated as the ratio of the peak reaction force in the translation direction and the compressive load as shown in equation below.

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\text{Stability Ratio} = \frac{\text{Peak reaction force}}{\text{Compressive force}}
\] (1)

RESULTS:
At 90° abduction, the translational distance to dislocation for the isolated Hill-Sachs lesion was decreased from 14.0 mm to 9.9 mm, whereas for the isolated Bankart lesion, it decreased from 14.0 mm to 0.6 mm. At 45° abduction, the presence of an isolated Hill-Sachs lesion decreased the translational distance to dislocation to 13.6 mm; for an isolated glenoid defect, it decreased to 0.6 mm. For some combined lesions, the distance to dislocation decreased to 0.0 mm at both abduction angles (Fig. 1).

The stability ratio at 90° abduction decreased from 43% to 42% for isolated Hill-Sachs lesions but showed no effect at 45° abduction. At both 45° and 90° abduction angles, the stability ratio for the largest isolated glenoid lesions and some combined lesions decreased to 0%. Fig. 2 shows the stability ratio for combined lesions.

DISCUSSION:
The study showed that the bony Bankart lesion has a major impact on the instability of the glenohumeral joint. Stability of the joint decreased by a higher percentage for the isolated glenoid lesions than the isolated humeral lesions. The results were in consensus with those of past studies, which helped to validate the finite element model. The combination of the Hill-Sachs lesions with the Bankart lesions magnified the effects of instability in some cases, which supports our hypothesis. It was also found that an arm position at 45° abduction is more stable than at 90° abduction. One limitation of this study was that the labrum was not included in the model. Additionally, the effects of external and internal rotations were not considered.

SIGNIFICANCE:
This study proposed a theoretical model with clinical relevance which showed a direct correlation between the anterior stability of the glenohumeral joint and sizes of the lesions.

REFERENCES:

Figure 1. Translational distance to dislocation for combined defects at 45° (A) and 90° (B) abduction and neutral rotation of the arm.

Figure 2. Stability ratio for combined defects at 45° (A) and 90° (B) abduction and neutral rotation of the arm.