The Effect of Anterior Glenoid Cartilage Defects on Anterior Glenohumeral Stability: A Biomechanical Study

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INTRODUCTION:

The prevalence of anterior glenoid cartilage defects in the absence of osseous defects is reported up to 57% in anterior shoulder instability cases. The curvature of the glenoid cartilage deepens the glenoid concavity and therefore augments shoulder stability. Clinically, the presence of a glenoid cartilage defect is associated with an increased risk for instability recurrence. Even in the absence of instability recurrence, the loss of stability may increase translation of the humeral head relative to the glenoid and thus contribute to glenohumeral osteoarthritis (OA). Osteoarthritis occurs in up to 60% of cases after glenohumeral instability with long-term follow-up. Small cartilage defects may thus increase translation and contribute to OA progression. However, little is known regarding the effect of cartilage defects upon shoulder stability. While it is well-known that a glenoid osseous defect of >25% glenoid width critically destabilizes the shoulder, it is unclear whether glenoid cartilage defects contribute to the shoulder stability, and if so at what size defect the shoulder is critically destabilized. The purpose of this study is to determine the effect of incremental cartilage defect sizes on the anterior shoulder stability.

METHODS:

This was a controlled laboratory study testing 12 fresh-frozen shoulders. All soft tissue was removed from the scapula and humerus, except for the glenoid labrum and articular cartilage. All specimens were free of macroscopic and radiographic evidence of glenohumeral osteoarthritis or prior surgery.

Each cadaver underwent a computed tomographic (CT) scan. From these images, 3D models of both the humerus and scapula were created. The models were used to create 3D printed negative molds to align the bones to the testing system in the predefined orientations. On the humeral side, specimen-specific fixtures aligned the humerus in 45° abduction and neutral rotation relative to the scapula. The humerus was attached to a cantilever arm to allow the application of a vertical 50 N compressive force using static weights. On the scapular side a plane was fit to the mean surface of cavity of the glenoid fossa on the 3D model. Specimen-specific scapula alignment fixtures were designed to hold the scapular body medial to the glenoid vault to maintain a horizontal orientation of this plane. The scapula fixture was mounted on linear rails to allow anterior humeral translation, as well as a plate to provide fixed rotation in 15° increments about the scapular axis. The linear stage was then connected via a low-stretch cable to a hydraulic testing machine.

The stability ratio was tested sequentially with intact cartilage and defects of width 3, 6, and 9 mm. For each condition, the stability ratio was determined in three directions: anterior, anterosuperior, and anteroinferior. Anterior was defined as perpendicular to the long axis of the glenoid (0°), anterosuperior was defined as +30° superior to anterior, and anteroinferior was defined as -45° inferior to anterior. During testing, the scapula was translated 10 mm posterior relative to the humeral head, from a centered position on the glenoid at 2 mm/sec. From each test, the peak translation force was determined based upon the force curves, and the stability ratio was defined as the peak translation force divided by 50N compression force.

RESULTS:

In the anterior direction, the stability ratio decreased between intact cartilage (0.36±0.07) and all defects 3-mm or larger (0.32±0.08, $p<0.023$, Figure 1) In the anteroinferior direction, the stability ratio decreased between intact cartilage (0.52±0.07) and all defects 3-mm or larger (0.47±0.07, $P<0.006$). In the anterosuperior direction, the stability ratio decreased between intact cartilage (0.36±0.04) and all defects larger than 6-mm (0.32±0.04, $P<0.006$). A 3-mm cartilage defect was equivalent to 10% of the glenoid width and 7% of the glenoid length. There were strong negative correlations between the glenoid cartilage defect size and the stability ratio in the anterior direction, the anteroinferior direction and the anterosuperior direction ($r= -0.79$, -0.63, and -0.58, respectively, $P\leq0.001$, Figure 2). There were strong negative correlations between the ratio of glenoid cartilage defect size to the glenoid width and the stability ratio in all directions ($r= -0.81$, -0.63, and -0.61, respectively, $P\leq0.001$).

DISCUSSION AND CONCLUSION:

The present study showed that even a small glenoid cartilage defect of 3 mm, which equates to 10% of the glenoid width and 7% of the glenoid length, significantly reduced glenohumeral stability in the anterior and anteroinferior directions. The width of the glenoid cartilage defect was inversely correlated with the stability ratio, suggesting that larger defects results in larger decreases in stability. Thus, to fully restore glenohumeral stability, in addition to labral repair, it may be necessary to reconstruct cartilage defects even as small as 3 mm. These results indicate that the prior suggestion that removing 2-5 mm of cartilage at the anterior glenoid margin to promote labral healing may actually promote instability recurrence.

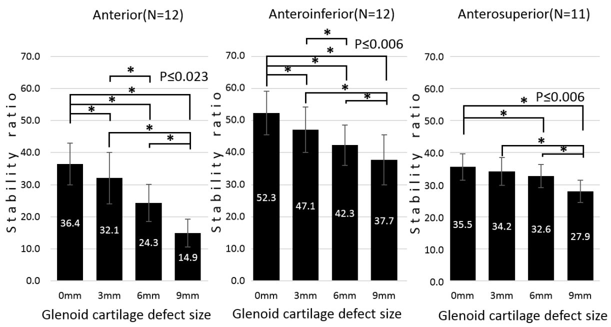

Figure 1. The relationship between the glenoid cartilage defect size and the stability ratio.

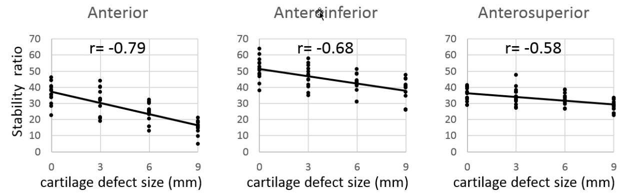

Figure 2. The relationship between the glenoid cartilage defect size and glenoid the stability ratio.