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Iliac bone grafting of the intact glenoid improves shoulder stability with optimal graft positioning

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Background: Bone grafting procedures are increasingly popular for the treatment of anterior shoulder instability. In patients with a high risk of recurrence, open coracoid transplantation is preferred but can be technically demanding. Free bone graft glenoid augmentation may be an alternative strategy for high-risk patients without significant glenoid bone loss. This biomechanical cadaveric study assessed the stabilizing effect of free iliac crest bone grafting of the intact glenoid and the importance of sagittal graft position.
Methods: Eight fresh frozen cadaveric shoulders were tested. The bone graft was fixed on the glenoid neck at 3 sagittal positions (50%, 75%, and 100% below the glenoid equator). Displacement and reaction force were monitored with a custom device while translating the humeral head over the glenoid surface in both anterior and anteroinferior direction.
Results: Peak force (PF) increased significantly from the standard labral repair to the grafted conditions in both anterior (14.7 ± 5.5 N vs 27.3 ± 6.9 N) and anteroinferior translation (22.0 ± 5.3 N vs 29.3 ± 6.9 N). PF was significantly higher for the grafts at the 50% and 75% positions compared with the grafts 100% below the equator with anterior translation. Anteroinferior translation resulted in significantly higher values for the 100% and 75% positions compared with the 50% position.
Conclusions: This biomechanical study confirms improved anterior glenohumeral stability after iliac crest bone graft augmentation of the anterior glenoid. The results also demonstrate the importance of bone graft position in the sagittal plane, with the ideal position determined by the direction of dislocation.

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Risk factors for recurrence of shoulder instability after standard arthroscopic Bankart repair have become more defined recently.[3,24,45] Patient characteristics, such as age and physical activity, and pathoanatomic lesions, such as Hill-Sachs lesions, glenoid bone loss, and joint hyperlaxity, are associated with a higher risk of recurrence after standard capsulolabral repair.[3] This has led to an increased interest in bone block procedures, such as the Bristow-Latarjet procedure,[19,23] for the treatment of high-risk patients with important anterior glenoid bone loss.[8,57] Furthermore, various authors have suggested expanding the indication to patients presenting without significant bone loss such as high-risk contact athletes and patients with engaging Hill-Sachs lesions, anterior labral periosteal sleeve avulsions, or joint hyperlaxity.[1,3,12,29]

Reports of high complication rates, however,[11,16,58] have pushed recent research towards less complex or invasive alternatives to the classic Bristow-Latarjet procedure. Arthroscopic glenoid augmentations using a free iliac crest autograft or a tibial or glenoid osteochondral allograft have already been described as a successful treatment option for high-risk patients.[17,28,31,33,39,46] However, biomechanical data on the effect of these procedures are sparse, particularly concerning patients without significant glenoid bone loss.

This biomechanical cadaver study had 2 purposes: first, to evaluate the effect of standard labral repair compared with free bone graft augmentation of the glenoid; and second, to investigate the influence of sagittal graft position on stability.

Materials and methods

Eight fresh frozen cadaveric shoulders (4 right and 4 left shoulders) from 4 male and 4 female donors, and 3 pairs of fresh frozen iliac crests from 3 male donors were obtained from our institutional anatomic bequest program. The mean age at the time of death was 66.5 years (range, 54-87 years) for the shoulder donors and 55.4 years (range, 51-61 years) for the iliac crest donors. We excluded specimens from donors with a history of shoulder instability and specimens with radiologic or clinical evidence of previous surgical treatment, advanced degenerative, traumatic, or neoplastic disease.

Shoulders were thawed overnight before removing all soft tissues, with the exception of labrum and articular cartilage, as has been described before.[18,22,53] Removal of the capsule and glenohumeral ligaments was not deemed to compromise the integrity of the experiment because of their minimal role in midrange instability. Rotator cuff action was simulated during all experimental procedures using compressive force on custom testing apparatus.[7,43] The glenoids and humeri were potted in Smooth-Cast 65D polyurethane resin (Smooth-on Inc, Easton, PA, USA) to allow fixation onto a custom testing apparatus, as described previously.[18,22,53] Briefly, the testing device consisted of a load cell mounted on a programmable stepper motor-controlled *x*-*y* table driving motion in the superior-inferior (*y*-axis) and anterior-posterior (*x*-axis) direction. The humerus was mounted in the scapular plane to a sliding stage connected to a pneumatic cylinder at 60° of abduction and neutral rotation. This allowed free translation of the humerus in the mediolateral (*z*-axis) direction while a constant (50 N) compressive force was applied. The specimen was sprayed with saline every 10 to 15 minutes during testing. Experiments were conducted at room temperature (24°C). Bovine serum was applied to lubricate the articular surfaces.

The reference position was determined by translating the glenoid underneath the humeral head surface until the humerus was seated at the most medial point.[22] From the reference position, the glenoid was first translated posteriorly, resulting in anterior humeral translation, until dislocation occurred. Afterwards, the glenoid was translated from same reference position in a posterosuperior direction along a line bisecting the *x*-axis and *y*-axis, resulting in anteroinferior humeral head translation.[54] Displacement and reaction forces in the *x*-, *y*-, and *z*-directions were measured, and the mean of 2 trials was used for data analysis.

After testing the intact glenoid, a Bankart lesion was created by elevating the labrum between the 2 and 8 o'clock positions for right shoulders and the mirrored equivalent for left shoulders, as previously described.[22] The repaired condition was tested after reattaching the labrum to the glenoid rim by means of three 2.8-mm FASTak titanium suture anchors (Arthrex, Naples, FL, USA) at the 3, 4, and 5 o'clock positions on the anterior glenoid rim using a simple suturing technique.[55] The bone-grafted condition was tested after removing the previously elevated part of the labrum and the suture anchors. A tricortical oblique bone graft was taken from the anterior iliac crest approximately 5 cm from the anterior superior iliac spine with an oscillating saw. The graft was secured to the prepared anterior glenoid rim with two 3.5-mm AO cortical screws[41,50,54] (Fig. 1). The graft size (2 cm × 1.5 cm × 1 cm) was selected to match the average harvested coracoid size in Bristow-Latarjet procedures to avoid overestimating the effect of the free iliac bone graft.[56] Grafts were shaped as needed with a high-speed burr to fit the glenoid neck, but the articular (inner) side of the iliac grafts was not reshaped. The bone graft was positioned such that the concave (inner) side was flush with the glenoid cartilage, creating a smooth continuation of the articular surface (Fig. 2). Three graft positions in the sagittal plane were tested in random order: grafts were positioned such that 50%, 75%, or 100% of the graft surface area was below the glenoid equator (Fig. 3).

The primary outcome measure was peak translational force (PF), defined as the greatest force in N recorded in the direction opposing translation. Absolute force values were reported instead of stability ratios[14] because a uniform compressive force of 50 N was applied in all conditions for this study. In addition to the instantaneous PF value, the energy to dislocate (ETD) in N/mm or mJ was calculated by numerically integrating the instantaneous translational force vs anterior displacement of the humeral head curve from the start of the motion until the point of dislocation, as described previously.[26] The point of dislocation was determined as the position where the most medial part of the humeral head reaches the most lateral part of the glenoid surface.[30,49]