Biomechanical Analysis of Anterior Stability After 15% Glenoid Bone Loss - Comparison of Latarjet, Longhead biceps transfer, and Bankart Repair

Short running title: Anterior Stability 15% Glenoid Bone Loss

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Abstract

Background: Dynamic anterior shoulder stabilization (DAS) with Bankart repair is a recently described stabilization technique thought to be more robust than an isolated Bankart repair while avoiding many coracoid transfer related complications and technical demands. DAS involves transfer of the long head biceps through a subscapularis split to the anterior glenoid to create a sling effect. We hypothesize that DAS with Bankart repair will restore anterior stability in a human-cadaveric model with subcritical (15%) glenoid bone loss.

Methods: Eight cadaveric shoulders were tested using an established shoulder simulator to record glenohumeral translations with an accuracy of ±0.2mm. Shoulders were tested in five states – intact soft tissues, Bankart defect with 15% bone loss, isolated Bankart Repair, DAS with Bankart repair, isolated DAS, and Latarjet. A 45 N anterior force was applied through the pectoralis major tendon and translation of the humeral head was recorded and compared with repeated measures ANOVA.

Results: The anterior translation in the intact (native) glenoid was 4.7mm at neutral position and 4.6mm at 45° external rotation. Anterior translation significantly increased after introducing a Bankart defect with 15% glenoid bone loss to 9.1mm (neutral, p = .002) and 9.5mm (45° external rotation, p < .001). All repair conditions showed significant decrease of anterior translation relative to Bankart defect. DAS with Bankart repair decreased anterior translation compared to the Bankart defect: 2.7mm (neutral, p < .001) and 2.1mm (45° external rotation, p < .001). DAS with Bankart repair significantly decreased anterior translation compared to the isolated Bankart repair (p = .023), and the isolated DAS (p = .041) in neutral position.
The Latarjet procedure resulted in the greatest reduction in anterior translation compared to the Bankart defect: 1.2mm (neutral, p < .001) and 1.9mm (45° external rotation, p < .001).

**Conclusion:** DAS with Bankart repair is a viable alternative to restore anterior glenohumeral stability with a 15% glenoid defect at a greater degree than either DAS or Bankart repair alone. The Latarjet procedure was the most effective in reducing anterior translation but restrained the anterior translation significantly more than the native glenoid.

**Level of Evidence:** Level III Case-control study

**Keywords:** Anterior shoulder instability, dynamic anterior shoulder stabilization, trans-subscapularis biceps sling, 15% glenoid bone loss, Latarjet, Bankart.
Introduction

Anterior shoulder instability remains a challenging clinical problem and is associated with significant disability in the short and long-term. Roughly 2% of people will experience a glenohumeral dislocation in their lifetime. Unfortunately, recurrent dislocations are common after non-operative treatment, particularly in patients that experience their first dislocation at a young age. Surgical treatment of recurrent instability generally depends on the etiology and associated pathologies, but includes Bankart repair, remplissage, Latarjet, and bone-block procedures. Choice of surgical intervention is influenced by the magnitude of glenoid bone loss, morphology and size of Hill-Sachs lesion, status of capsulolabral tissues, as well as patient goals and function.

The Bankart repair is the mainstay surgical intervention for patients with small glenoid bone defects (less than 15%). However, biomechanical studies have demonstrated that an isolated Bankart repair is not capable of adequately reducing glenohumeral translation in shoulders with significant glenoid bone loss (>15-20%). The prevalence of bone loss along the anteroinferior glenoid rim among patients with recurrent anterior shoulder instability has been reported to range from 8-73%. In addition, isolated Bankart repair in shoulders with greater than 15% bone loss restricts rotational range of motion and results in a humeral head that is shifted posteroinferiorly when the arm is abducted and externally rotated. A recent systematic review found that 1 in 3 athletes do not return to their preinjury level of sports following isolated Bankart repair.

The Latarjet procedure, first described by Michel Latarjet in 1954, involves the transfer of the coracoid process and the attached conjoint tendon to the anterior glenoid. This procedure is generally reserved for patients with significant glenoid bone loss (more than 20%).
success of this procedure relies on the “bone-block effect” and the “sling effect”. The “bone-block effect” imparts stability to the joint by restoring the anterior glenoid bone loss caused by recurrent dislocations.\textsuperscript{28} The “sling effect” provides stability through the interaction of the conjoint tendon and the lower-half of the subscapularis tendon, particularly at the mid-range and end range positions of the glenohumeral joint.\textsuperscript{1, 28} The Latarjet procedure has shown low recurrent instability rates of 0-8\%.\textsuperscript{2} However, the procedure is technically challenging and has a significant learning curve with both open and arthroscopic techniques.\textsuperscript{6} Furthermore, complications following the procedure are relatively common and can be significant. Schmid et al reported wound complications in 8\% of patients, and malunion of the coracoid in 2\%.\textsuperscript{18} Shah et al reported complications in 25\% of 48 patients, with infection in 6\% of cases and neurologic injury in 10\%.\textsuperscript{19} Considering the complication profile, patients undergoing Latarjet should be carefully selected.

Given the limitations the Bankart repair and the significant risks associated with the Latarjet procedure, the development of a technique that provides greater stability than Bankart repair alone but a better risk profile than Latarjet is critical, especially for patients with glenoid defects too large for a Bankart repair (\textgreater{}15\%) yet too small to justify a Latarjet (<20\%). Dynamic anterior shoulder stabilization with creation of a trans-subscapularis biceps sling and Bankart repair will ideally meet those objectives. First described by Collin and Läderman in 2018, DAS involves moving the long head biceps tendon (LHBT) from its origin on the superior glenoid biceps anchor to the anterior glenoid rim after shuttling the tendon through a subscapularis split.\textsuperscript{4} By replicating the “sling effect” seen with the conjoint tendon during a Latarjet procedure, the long head biceps tendon provides a restraint to anterior translation of the humeral head, while avoiding many of the aforementioned risks seen in the Latarjet procedure.
The purpose of the present study was to evaluate the biomechanical effects of the DAS technique in shoulders with 15% glenoid bone loss in cadaveric specimens and to examine DAS with Bankart repair vs DAS alone. We hypothesize that DAS with Bankart repair would provide greater stability with regards to anterior glenohumeral translation compared to Bankart repair or DAS alone and that there would be no difference in anterior glenohumeral translation between DAS with Bankart repair and Latarjet.
Methods

Specimens and testing set-up

All specimens were obtained from Anatomy Gifts Registry. Institutional review board approval was obtained. A total of eight cadaveric shoulders were included in the study (age range: 47-65, 2 female v. 6 male, 2 Left v. 6 right). Prior to each dissection, specimens were thawed from frozen overnight at room temperature. All skin and subcutaneous tissue was removed to allow visualization of the rotator cuff muscles. The anterior and middle heads of the deltoid were removed, exposing the subscapularis as well as the other rotator cuff muscles and humeral head.

The specimens were placed in a previously validated custom shoulder testing device which allowed for six degrees of freedom at the glenohumeral joint. The scapula was fixed to the shoulder simulator with a 30° superior tilt and the humerus was positioned at 60° of glenohumeral elevation (simulating 90° of humero-thoracic elevation). The subscapularis was loaded with 3 pounds, the supraspinatus with 2 pounds, the infraspinatus with 2 pounds, the teres minor with 1 pound, and the biceps with 2 pounds. During testing, an anterior directed force of 10 pounds was applied via the pectoralis tendon. Testing was performed with the arm at neutral or 45 degrees of external rotation and glenohumeral translations were recorded with a 4-camera motion capture system (Cortex, Motion Analysis Corp, Santa Rosa, CA). The motion system captured the motion of retroreflective markers that were placed on the humeri and scapulae with accuracy of 0.2mm. All specimens were CT scanned to insure there was no presence of osteoarthritis and to be able to measure the size of the glenoid. A coordinate system was defined using glenoid landmarks to calculate humeral head anterior translation with respect to the glenoid center.
Repeated measure ANOVA with a Bonferroni post-hoc pairwise analysis was performed for all pairwise comparisons with p-value < 0.05 considered significant using statistical software (SigmaPlot, Systat, San Jose, CA)).

All specimens underwent the following testing conditions which are shown in Figure 1:

**Bankart and Glenoid Bone Defect Creation**

A subscapularis split was utilized to create the Bankart defect. The muscle belly was split halfway between the superior and inferior edges of the muscle in a horizontal fashion. The soft tissue Bankart defect was created from the 2’oclock to 6 o’clock position on the glenoid face. Care was taken to not disrupt the labral ring. A sagittal saw was utilized to create a 15% bone loss-defect parallel to the longitudinal axis of the glenoid at its widest point. The glenoid cut was calculated prior to the procedure from the CT images. The capsule was only repaired as part of the Bankart repair in specimens within the Bankart repair group; in all other specimens, the capsule was left unattached. In all specimens, the subscapularis split was closed with #2 Ethibond suture.

**Bankart Repair**

A Bankart repair was performed through the previous subscapularis split. Two single loaded 3.5mm labral SwiveLock suture anchors (Arthrex, Naples, FL) were placed at the 3 and 5 o’clock positions on the anteroinferior glenoid. The free ends of the suture from each anchor were passed through the labrum and medial capsular tissue in a horizontal mattress fashion.
These sutures were tensioned, reducing the labral and capsular tissue to the anteroinferior glenoid. The subscapularis split was then closed.

DAS + Bankart repair

DAS with Bankart repair was performed similarly to the technique described in Collin et al. The LHBT was tenotomized at its origin on the superior glenoid labrum, taking care not to injure the labrum. The LHBT was then released from the bicipital groove, freeing the tendon from soft tissue adhesions. After removing the tendon from the intraarticular space, a FiberLoop suture was passed through the tendon in a locked fashion (Arthrex, Naples, FL). Then tendon was then shuttled back into the joint through the previously established subscapularis split. The free ends of the FiberLoop suture were loaded into a 4.75mm SwiveLock anchor, which was then inserted into the anterior glenoid in the 4 o’clock position, taking care to avoid the suture anchors placed for the Bankart repair. The sutures were then tensioned, reducing the biceps tendon to the anterior glenoid. The subscapularis split was closed.

DAS alone

The Bankart repair sutures were released through the split in the subscapularis. The subscapularis split was closed leaving the LHBT as the only anterior translation stabilizer.

Latarjet

The LHBT was removed through the subscapularis split and a coracoid bone-block transfer was performed. The coracoid was osteotomized after the pectoralis minor tendon was removed. The conjoint tendon was left intact. #2 Fiberwire sutures were passed through the
medial capsule and anterior labrum. The coracoid bone block was then transferred to the anterior
glenoid and secured using 2 metal screws. The subscapularis split was closed as above.
Results

The average anterior translation in the intact (native glenoid) was 4.7mm (SD 2.3mm) at neutral position and 4.6mm (SD 2.6mm) at 45° external rotation (Figures 2 and 3). In contrast, the Bankart defect exhibited significantly greater average anterior translation: 9.1mm (SD 3.6mm, p = .002) at neutral position and 9.5mm (SD 3.9mm, p < .001) at 45° external rotation.

Compared to the Bankart defect, both the isolated Bankart repair and isolated DAS separately reduced the anterior translation to 4.7mm (SD 1.5mm, p = .002) and 4.3mm (SD 1.9mm, p = .001) at neutral position and 4.7mm (SD 2.3mm, p < .001) and 3.8mm (SD 1.6mm, p < .001) at 45° external rotation, respectively.

DAS with Bankart repair further decreased the anterior translation compared to the Bankart defect: 2.7mm (SD 1.3mm, p < .001) at neutral position and 2.1mm (SD 1.6mm, p < .001) at 45° external rotation. The Latarjet resulted in the greatest reduction in anterior translation compared to the Bankart defect: 1.2mm (SD 2.0mm, p < .001) at neutral position and 1.9mm (SD 1.6mm, p < .001) at 45° external rotation.

The Latarjet restricted anterior translation significantly less than that of the intact condition (p = .01), the isolated Bankart repair (p = .011), and the isolated DAS alone (p = .021), all in neutral position. DAS with Bankart repair significantly decreased anterior translation compared to the intact condition (p = .02), the isolated Bankart repair (p = .023), and the isolated DAS (p = .041), all in neutral position.
Collin described the concept of dynamic anterior stabilization (DAS) transferring the long head of the biceps within a subscapularis split to the anterior glenoid margin to create a “sling effect” without cutting the coracoid process and performing a Bankart repair. This can be performed with an arthroscopic or open technique. We find that DAS with or without bankart repair for 15% glenoid defects reduces anterior glenohumeral translation to similar ranges as a native shoulder. DAS alone had similar restraint to anterior translation as a Bankart repair alone. However, performing DAS with Bankart repair reduced anterior translation significantly more than either repair individually. The Latarjet procedure reduced anterior translation the most.

Several studies have investigated the critical amount of bone loss past which bony augmentation procedures are needed to avoid recurrent instability from soft tissue stabilization alone. Traditionally this has been considered greater than 20-25% with respect to the largest anteroposterior width of the glenoid. However, over time more recent clinical results have suggested lowering this value. Shin conducted a biomechanical study of 8 cadaveric shoulders that had motion tested with an intact glenoid, soft tissue Bankart and repair, and Bankart defect with 10-25% glenoid bone defects and Bankart repairs. They found that glenoid defects of 15% was the point at which soft tissue repair could not restore stability in terms of glenohumeral translation, rotational range of motion, and head position. However, they considered soft tissue repair in terms of Bankart repair alone, and we show that DAS with Bankart repair offers significantly more anterior shoulder stability than either DAS or Bankart repair alone.

Although bone transfer techniques such as the Latarjet procedure show lower redislocation rates in glenoid defects over 20%, they also have higher complication rates than
Consequently, intermediate sized bony defects deserve consideration of soft tissue procedures that avoid the higher complication rates of bony transfer procedures while improving stability over an isolated Bankart repair. The concept of dynamic anterior shoulder stabilization was recently described for closing the gap between indications for isolated Bankart repair and bone transfer techniques. This technique transfers the long head of the biceps tendon to the anterior glenoid rim through a subscapularis split to create a sling effect and is typically done in addition to a Bankart repair. DAS with Bankart repair allows for a less invasive approach than a Latarjet and only uses one anchor or screw for fixation of the biceps tendon and does not have risk of bone overhang or graft resorption. Collin et al recently published a 2-year followup of 23 patients who underwent DAS with Bankart repair for less than 20% glenoid bone loss, finding maintained ROM, improvement in Rowe outcomes, and three patients with recurrent instability two of whom were revised to a Latarjet. They noted that the three patients with recurrent instability were all early during their learning curve.

Mehl et al conducted a cadaveric study of 24 shoulders that were randomized to 1 of 3 defect groups (isolated Bankart, 10% glenoid defect, 20% glenoid defect), and were then tested with isolated Bankart repair or DAS with Bankart repair. DAS with Bankart repair showed significantly less anterior translation than Bankart repair in 10% and 20% glenoid defects, but led to increased inferior glenohumeral translation for the 20% glenoid defect. We performed a similar biomechanical study but at 15% glenoid loss and testing the additional condition of DAS alone, since recent literature has shown bone loss even below the 20-25% level can lead to worse outcomes with soft tissue procedures alone. We found that at 15% bone loss both DAS and Bankart repair alone restricted anterior translation to a similar range compared to an intact glenoid, but that DAS with Bankart repair restricted anterior translation significantly more. We
believe glenoid bone loss in the subcritical 15% bone loss window represents the patients most likely to benefit from DAS with Bankart repair.

Bokshan et al conducted a cadaveric study of 12 shoulders with 13% glenoid bone loss testing Bankart repair alone vs Bankart repair augmented with either long head biceps transfer or conjoint tendon transfer.³ They measured peak resistance force from creating a 1cm anterior displacement with the arm at neutral. They found that Bankart repair with DAS had the greatest peak resistance to anterior displacement compared to Bankart repair alone (54.1 N vs 46.5N, p = 0.039) and even Bankart repair augmented with a conjoint tendon transfer (54.1N vs 46.4N, p = 0.008). Their findings of the DAS and Bankart repair being a stronger construct are like our findings. Our studies differ in how anterior restraint is measured, the degree of bone loss, measuring displacement at both neutral and 45° external rotation, and examining DAS alone.

Payne et al conducted a biomechanical study of eight cadaveric shoulders evaluating the Latarjet procedure.¹⁶ The cadaveric shoulders were tested as intact, with a 20% glenoid defect, and with a Latarjet procedure or a soft tissue only conjoint tendon transfer. The Latarjet procedure resulted in significantly decreased anterior and inferior translation at all loads. After the conjoint tendon transfer with no bone block, there was decreased anterior translation for the 20-N load, but not at 40-N load. Thus, they concluded that the conjoint tendon transfer was ineffective at resisting translation at higher loads for 20% glenoid bone loss. In contrast, our results show that DAS with Bankart repair for 15% glenoid bone loss at 45-N loads was sufficient to restore anterior stability. The difference in findings may be due to them examining 20% glenoid bone loss whereas we examined 15%, and that we performed Bankart repair with DAS whereas they did an isolated conjoint transfer without capsular repair.
Shin demonstrated a posterior shift of the humeral head after Bankart repair. Mehl et al showed that after DAS with Bankart repair the humeral head shifted posteroinferior in the abducted externally rotated position, with this the shift more evident after DAS with Bankart repair than isolated Bankart repair, and with the shift increasing with increased glenoid bone defect. Payne et al showed posterior shift of the humeral head for both the Latarjet procedure and conjoint tendon transfer. Our results also showed greater posterior shift of isolated DAS and isolated Bankart repair than a native glenoid, and even more posterior shift with DAS with Bankart repair. The Latarjet procedure resulted in the most posterior shift which was significantly translated relative to a native glenoid.

There were several limitations for this cadaveric study. The testing was focused only on anterior glenoid translation and did not consider the effects of humeral bone loss. Due to multiple testing conditions, it was very difficult to investigate the effects of remplissage. Furthermore, we do not compare DAS to bone block allografts, which may have a lower complication profile than Latarjet coracoid transfers. We also do not compare transfer of the long head biceps tendon to the conjoint tendon. This cadaveric study also has inherent limitations common to all cadaveric studies which means that results could only be determined at time zero, and postoperative healing effects, scarring, and tissue contracture cannot be included for consideration. The cadaveric shoulders were older than the age typical of a patient instability cohort and may have had different soft tissue quality. Furthermore, restoration of anterior stability in a cadaveric study does not necessarily mean that patients will have improved outcomes following DAS with Bankart repair in vivo. Last, to create a repeated measures model, the repair states of our cadaveric shoulders were performed in a very specific sequence to allow all the defects in the
same specimen, which increased the risk of tissue creep. However, the small muscle loads minimize this risk.
Conclusions

Creation of a trans-subscapularis biceps sling restores anterior stability to a similar degree as an isolated Bankart repair for glenoids with 15% bone loss. Dynamic anterior stabilization with Bankart repair offers the potential for even more anterior restraint while avoiding the complications of a Latarjet procedure. DAS with Bankart repair may be ideally suited as a soft tissue procedure avoiding the increased complication profile of Latarjet procedures while offering increased stability for patients with 15% glenoid subcritical bone loss.
Figures

Figure 1. Cadaver preparation.

(A) Defect creation - A soft tissue Bankart defect was created from 2 o’clock to the 6 o’clock position and a 15% bone-loss defect was created parallel to the longitudinal axis of the glenoid at its widest point.

(B) Bankart repair – Two single loaded 3.5mm Swivelock suture anchors were placed at the 3 o’clock and 5 o’clock positions of the anteroinferior glenoid. The free ends of the suture from each anchor were passed through the labrum and capsule in horizontal mattresses, tensioned, and tied.

(C) DAS with Bankart repair – The LHBT was tenotomized at its origin and then released from the bicipital groove. A FiberLoop suture was passed through the tendon and the free ends loaded into a 4.75 SwiveLock anchor placed on the anterior glenoid at the 4 o’clock position. The Bankart repair was not disrupted.

(D) Latarjet – The coracoid was osteotomized after the pectoralis minor tendon was removed and the conjoint tendon left intact. The bone block was transferred to the anterior glenoid and secured using two metal screws with washers. #2 Fiberwire sutures passed through the capsule and labrum were incorporated into the washers and the screws were tightened.

Figure 2. Anterior glenohumeral translation following 45N of anterior force in neutral position. Standard deviation bars are shown. (*) Significant compared to Defect, (+) significant compared to Intact, (^) significant compared to Bankart, and (-) significant compared to DAS alone.
Figure 3. Anterior glenohumeral translation following 45N of anterior force at 45° external rotation. Standard deviation bars are shown. (*) Significant compared to Defect.
References


Figure 1

Figure A

Figure B

Figure C

Figure D
Figure 2
Figure 3