



Distal clavicle autograft—I would like to use my own osteochondral graft please

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Abstract: Recent work has demonstrated the importance of addressing bone loss in the surgical management of anterior shoulder instability. Multiple options exist for reconstituting the glenoid articular surface to include: anatomic versus non-anatomic techniques and utilizing autograft versus allograft material. Anatomic restoration via an arthroscopic approach with distal clavicle osteochondral autograft (DCA) is the senior author's preferred technique when bone grafting is indicated for instability cases. This technique offers a low cost, readily available, and reproducible means of obtaining autograft material. Moreover, the distal clavicle graft provides an anatomic restoration of the glenoid radius with an articular cartilage cap comparable in thickness to that of the native glenoid. Along with a summary of the pertinent literature, this review article outlines the rationale, indications, and technical notes for this procedure.

Keywords: Autograft; clavicle; shoulder; instability

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Introduction

Bone loss has emerged as a critical issue in the treatment of glenohumeral instability. Its presence has been reported in up to 72% of instability cases and is known to influence the outcome of surgical intervention. Many studies have correlated poor clinical outcomes, failure, morbidity and increased cost with arthroscopic soft tissue stabilization in the setting of significant bone loss.

Although glenoid bone loss in this setting is a poor predictor, the amount of bone deficiency that places an arthroscopic soft tissue repair at risk continues to evolve. Traditionally, bone loss greater than 20% has been shown to adversely affect biomechanical stability and clinical

results. Utilizing Lo and Burkhart's "inverted pear" concept of glenoid bone loss morphology, a defect as small as 6 to 8 mm can result in recurrent instability following soft tissue stabilization. Even in the absence of recurrence, sub-critical bone loss of 13.5% can be detrimental to clinical outcomes. More recently, greater interest has been paid towards the interaction of glenoid bone loss and the Hill Sachs lesion of the humerus. Larger Hill Sachs lesions may "engage" glenoid defects of all sizes in functional positions and have been shown to negatively affect arthroscopic results. The biomechanical and clinical effect of these two bone loss conditions have been combined into an "on-track, off-track" concept (1-4).

The recognition and treatment of bone loss are critical

Table 1 Advantages of distal clavicle autograft for treatment of glenoid bone loss in shoulder instability

Considerations	Advantages
Versatility	Can be used for anterior or posterior bone loss
Cartilage source	Patient's own cartilage with similar in thickness to native glenoid cartilage
Restoration	Increases contact area by restoring up to 44% of the glenoid radius
Technique	Can be placed arthroscopically
Availability	Harvest site adjacent to operative field with low morbidity
Cost	Free
Rejection	None

factors to ensure the successful management of anterior shoulder instability. Multiple bone grafting options exist to address this deficiency. Each approach has advantages and disadvantages unique to its application, which is covered in this review. The rationale, indications and technical notes for the senior author's preferred technique of distal clavicle osteochondral autograft (DCA) are also discussed.

Surgical treatment options

There are numbers of options described to treat bone loss in shoulder instability. These include coracoid transfers such as the Latarjet and Bristow procedures, iliac crest graft bone grafting, and osteochondral allografts. Factors such as graft size, the presence or absence of articular cartilage, availability, immunocompatibility, and cost are all considerations in graft selection (*Table 1*). In addition to restoring the bone and cartilage loss seen in erosive glenoid bone loss, the ideal graft should also be readily available, free, and sourced without donor site morbidity.

Coracoid bone autograft

In 1954, Latarjet first described his technique of coracoid bone transfer to the anterior glenoid for treatment of recurrent anterior dislocation of the shoulder. In 1958, Helfet proposed an alternative coracoid tip transfer and named it the Bristow technique. More than a half century later, the open coracoid transfer is still considered the gold standard technique for glenoid bone loss treatment. In addition to restoring glenoid articular bone, this technique

offers further stabilization via capsuloligamentous reconstruction and inferior subscapularis myodesis from tightening of the conjoined tendon in the provocative position, which has become known as the "triple blocking effect". Biomechanical studies demonstrate that this procedure is quite effective in restoring shoulder stability, and clinical outcomes studies have demonstrated low recurrence rates with excellent patient reported outcomes (5-8).

There are a number of drawbacks with this technique, however. First, coracoid transfer is a non-anatomic approach, which can make future revision surgery more difficult with an overall complication rate of up to 30%. Second, there is a limit to the amount of glenoid surface that can be restored. Paladini *et al.* demonstrated that this technique may be insufficient to restore defects exceeding 31% (9). Bueno *et al.* showed that, in comparison to the traditional Latarjet technique, the modified congruent arc technique may be used to reconstruct bone loss up to 54% of the glenoid surface (10). This modification, however, results in a greater graft displacement and a lower clinical failure load. Third, other authors have shown that up to 60% of the graft may undergo osteolysis (2,11). Fourth, the transferred graft lacks articular cartilage. This drawback has been cited as a potential reason for osteoarthritis development after Latarjet surgery, which can occur in up to 62% of cases (12). Finally, perhaps the most often cited concern regarding this technique is its associated complications. Unplanned reoperations have been reported at a higher rate than that of the traditional Bankart, and the overall complication rate has been reported as high as 25% (13,14). Delaney *et al.* published that neuromonitoring during Latarjet surgery resulted in a nerve alert in 77% of patients, and resulted in 21% of patients with a clinically detectable nerve deficit postoperatively (15).

Iliac crest bone autograft (ICBG)

The first reports of using a bone block to restore glenoid deficiency were made by Eden [1918] and Hybbinette [1932] (16,17). In 2006, Warner *et al.* reported autogenous tricortical iliac crest bone graft to be effective in treatment of recurrent instability in setting of glenoid bone loss (18).

The authors determined that this graft could restore defects up to 35 mm in length, which covers significantly more surface area than that of coracoid graft. They also reported excellent short-term results with a relatively low

complication rate (4% of patients). The technique has the advantage of being readily available, essentially free, and is an autograft source of bone (18).

There are several potential drawbacks to this technique, however. First, the iliac crest is non-articular and thus cannot restore the osteoarticular loss seen in the glenoid. This may lead to secondary osteoarthritis which has been reported after this procedure (19,20). An additional drawback is the potential for donor side morbidity, from which persistent pain, greater than 1 year post-operatively, can occur in up to 100% of cases. Other complications such as local infection (14%) and anterior superior spine fracture (3%) incidences have been reported (18,21,22). Finally, like all free grafting techniques, the ICBG graft does not, in itself, address the soft tissue pathology that is frequently present in instability cases where it is utilized (23).

Distal tibia allograft

Distal tibial allograft has recently been introduced as an osteochondral source for glenoid bone loss treatment. Studies have shown that it can provide at least equivalent biomechanical properties to the iliac crest bone graft, and the technique has been shown to produce a better articular pressure profile than that of the Latarjet. Furthermore, some authors have demonstrated that glenoid arc articular conformity can be reproduced with this graft source (24,25). Promising clinical outcomes have been presented, but limited data has been published in the peer reviewed literature to this point (26).

This technique, however, has some limitations. While initial work has demonstrated that the distal tibia is well matched to glenoid articular anatomy, more recent studies have reported conflicting results. Decker *et al.* published that the chance of a random pairing of a distal tibial allograft matching the radius of curvature of a recipient glenoid is low (27). The degree of match precision necessary to achieve optimal results remains to be studied. The possibility of graft resorption secondary to immunologic response associated with this technique has not been investigated, but this concern has plagued allograft usage in other transplant settings (28-31).

The largest limitation to this method is its logistic application. The cost of a fresh osteochondral allograft can exceed tens of thousands of dollars, and there is often significant wait time which can exceed 6 months. Fresh allograft preparation requires a minimum of 14 days quarantine for infectious disease screening, and chondrocyte

viability has been shown to significantly drop after 28 days post mortem. This limitation requires surgeons to perform transplantation in roughly a 2-week window, which can be a scheduling challenge for both patient and surgeon in many facilities (6).

DCA

Recently, Tokish *et al.* described a technique of employing the distal clavicle as a fresh, osteochondral autograft in the treatment of glenoid bone loss (32). The DCA is the first reported option that provides an autograft source of bone and cartilage to replace similar tissue loss on the glenoid. It has the advantage of being readily available and sourced with minimal cost. It also can be placed arthroscopically, as well as utilized in both anterior and posterior cases of bone loss. While donor site morbidity has not been reported with this specific technique, graft harvest is similar to the Mumford technique which is known to give excellent to good outcomes in up to 85% of treated patients. Dissatisfaction is typically correlated with over- or under-resection of the distal clavicle in the setting of arthritis. Researchers have previously suggested excising 5 to 10 mm of distal clavicle to optimize results, which is similar to our technique (33).

Recent work has shown that the DCA can, on average, reproduce up to 44% of the glenoid radius, which compares favorably to the 31% restoration achieved with the traditional coracoid transfer (5). Moreover, the distal clavicle graft is capped with articular cartilage which is within 1 mm of native glenoid cartilage thickness. It is a fresh, unprocessed tissue source that is immediately transplanted, so concerns about chondrocyte viability, immunorejection, or infection are minimized. The theoretical advantages of this technique are summarized in *Table 1*.

While promising anatomic results have been reported, there is a lack of clinical outcomes with this technique. Thus, concerns about recurrence rates, complications and long-term results, while initially promising in the senior author's hands, have not been published in the peer-reviewed literature. However, supporting biomechanical data is available for this technique. Petersen *et al.* examined contact pressure differences between the clavicular grafting and congruent arc coracoid transfer techniques and determined a more favorable profile for the DCA (34).

It is the preference of the senior author to use the DCA in young patients who have glenoid bone loss as the primary

reason for their instability, with defects from 15% to 30%, and relatively preserved soft tissue structures.

This technique also has several potential limitations. First, it does not augment or address anterior capsular structures that are often a part of complex instability cases. Thus, in cases of collagenopathies, such as Ehlers-Danlos syndrome, previous thermal capsulorrhaphy, or multiply operated patients, we prefer an alternative technique which may address these issues.

Author's preferred surgical technique

Preoperative preparation

Patients with glenohumeral instability should undergo a standard history and physical examination, as well as preoperative advanced imaging such as CT or MRI. Glenoid bone loss is calculated in every patient, and this calculation aids in determining the operative approach to the patient according to the “on-track, off-track” concept. Relative measurement indications for bony augmentation in the setting of instability include bone loss greater than 15% of the glenoid diameter in the “off track” shoulder and significant retroversion in the context of posterior instability. Other factors such as age, athletic status, capsular laxity, and patient preferences are weighed when deciding between different treatment options.

Arthroscopic portal positioning

After the induction of general anesthesia, examination under anesthesia is performed to confirm the preoperative diagnosis. The patient is positioned in the lateral decubitus position on a beanbag with a padded axillary roll. The senior author prefers a padded arm sleeve (STAR sleeve; Arthrex, Naples, FL) with balanced suspension for limb positioning.

A standard posterior portal is established approximately 1-cm medial and 2-cm distal to the posterolateral acromial border. The arthroscope is introduced and additional portals are established using an outside-in technique under direct visualization with the use of a switching stick. The anterosuperior portal is established first, approximately 1 cm inferior to the clavicle and lateral to the coracoid. The mid-glenoid portal is created just superior to the superior border of the subscapularis. In cases of posterior augmentation, a 7-o'clock portal is positioned approximately 4 cm distal to the posterolateral corner of the acromion, bisecting the angle created by the posterior and lateral borders of the acromion. To allow efficient switching of the camera and

instruments throughout the case, 8.25-mm cannulas are routinely used.

Diagnostic arthroscopy and biologic preparation

Following diagnostic arthroscopy while viewing from the posterior portal, the arthroscope is switched to the anterior-superior portal and a 3-mm graduated probe is placed to confirm our preoperative measurements for glenoid bone loss. Biologic preparation includes a wide release of the glenoid labrum to ensure its mobility for accurate reduction over and around the transplanted graft. Tissue is carefully mobilized with arthroscopic liberators and ablaters. The glenoid is also biologically prepared with either an arthroscopic rasp or high-speed cylindrical burr, with the goal to create a healthy bed of bleeding cancellous bone, as well as to create a flat surface perpendicular to the glenoid margin to ensure a flush fit during graft placement.

Graft harvest

A single 3-cm horizontal incision is made over the subcutaneous border of the acromioclavicular joint, along the midline of the clavicular longitudinal axis. The skin and subcutaneous tissues are divided, and thick periosteal flaps are raised to expose the joint. A 1-cm wide saw blade is used to remove the distal approximate 1 cm of clavicle, and soft tissue is cleaned from around the bone. The graft is placed on the back table, and the harvest site periosteal flaps are closed with nonabsorbable No. 2 interrupted stitches. The remainder of the soft tissue is closed in two layers, and the wound is dressed at the completion of the case.

Graft preparation

The distal clavicle is a versatile graft, with a variable amount of version and an articular surface that is generally 19-mm long and 13-mm wide (Kwapisz, Tokish *et al.* unpublished data). The graft is evaluated based on its best fit and cut perpendicular to its articular surface to a width that matches the measurement of bone loss that was determined preoperatively and confirmed arthroscopically. In most cases, 7 to 8-mm of augmentation is normally sufficient to reconstruct up to 30% bone loss, and the graft is fashioned to anatomically fit and replace the loss. At this point, the method of fixation for the graft is chosen. While both screw or anchor fixation may be used, for anterior instability cases, anchor fixation is preferred. The angle for introduction required during drilling and screw advancement around or through the subscapularis can make screw fixation difficult. Prior to graft passage, two 1-mm drill holes are positioned

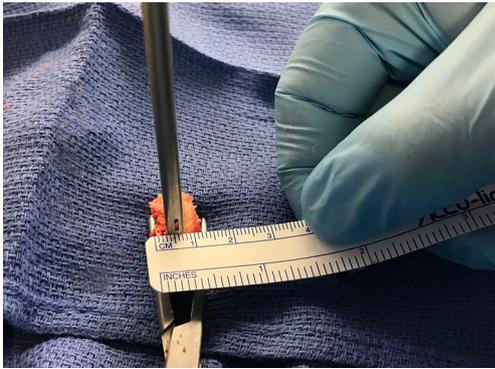


Figure 1 Following harvest, either the superior or inferior end of the distal clavicle fragment is fashioned to match the defect surface of the anterior glenoid. In preparation for suture anchor fixation, two 1-mm drill holes are positioned 3 to 4-mm away from the articular surface at the superior and inferior borders of the graft.



Figure 2 This osteochondral graft is harvested from a left distal clavicle and prepared for reimplantation into a left anterior shoulder. To ensure graft articular congruence, care is taken to position the holes relative to the distal clavicle articular cartilage in correspondence with the offset position of the suture anchors at the glenoid defect margin.

3 to 4-mm away from the articular surface at the superior and inferior borders of the graft, which will correspond to the planned offset position of the suture anchors or screws on the glenoid defect surface (*Figures 1,2*). For larger grafts, a third drill hole may be placed further from the articular surface to create an inverted triangle configuration.

Delivery and fixation of graft

Screw fixation

If the graft is to be fixed with screw fixation, it can be

passed either freely into the joint or along a K-wire guide predrilled in the glenoid. The advantage of a free pass is that the graft may fit down a standard mid-glenoid cannula and, once inserted, can be flipped 90° and advanced through the rotator interval to match its resting position at the anterior-inferior glenoid. In this position, it can be held in place with a liberator introduced from the posterior portal. Likewise, the graft can be introduced through a posterior cannula and held in place with a liberator from the mid-glenoid portal. Wider exposure through the subscapularis is required to alternatively advance the graft down a predrilled K-wire and to properly position it on the glenoid. Once in place, a K-wire is placed through the pilot holes of the clavicle graft, and advanced into the native glenoid. This is usually not difficult for posterior grafts, but with anterior screw placement, the standard mid-glenoid portal may not be sufficient to achieve the appropriate angle. In such situations, an additional 5-o'clock portal is established through the subscapularis to ensure the correct trajectory. Care is taken to protect the axillary nerve, and if any doubt exists, it is dissected arthroscopically, visualized, and protected.

Once the graft is secured to the glenoid in the appropriate position with K-wires, a cannulated drill is advanced into the glenoid to allow lag fixation of the graft, with a cannulated, titanium 3.75-mm screw (Arthrex, Naples, FL). If the graft is too large to easily be delivered, the cannula can be removed, the portal expanded, and the graft delivered directly. If the proper trajectory cannot be achieved with wire provisional fixation, then one can consider using a suture anchor as an alternative or conversion to an open approach.

Suture anchor fixation

If suture anchor fixation is selected, the previously drilled holes in the graft are noted by their measurements from the articular surface and from each other. From these measurements, two 3.0-mm BioComposite SutureTaks (Arthrex, Naples, FL) are placed at the superior and inferior borders of the bone defect at the corresponding distances from the articular surface and each other, respectively (*Figure 3*). All limbs are delivered out of the working, mid-glenoid portal and shuttled through the corresponding holes in the graft (*Figure 4*). The graft is then manually introduced into the joint with a hemostat or small Kocher clamp through either a flexible Passport cannula (Arthrex, Naples, FL), half-slotted metal cannula employed as a sled, or freely through a cleared soft tissue portal. The graft is manipulated, positioned over the glenoid bone defect, and held securely in place with a liberator or probe from the

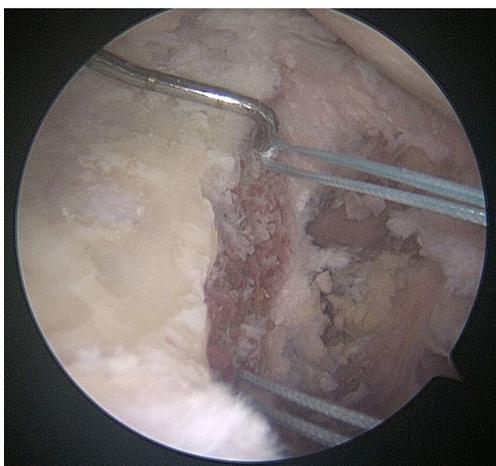


Figure 3 Viewing from an anterior-superior portal in a left shoulder, the anterior glenoid bony defect is prepared for graft placement and suture anchor fixation. The capsuloligamentous and labral structures are widely mobilized to ensure ease of reduction around the articular graft. Two 3.0-mm BioComposite SutureTaks (Arthrex, Naples, FL) are placed at the superior and inferior borders of the bone defect at the appropriate distance from the articular surface and to each other to match the articular offset of the osteochondral graft.

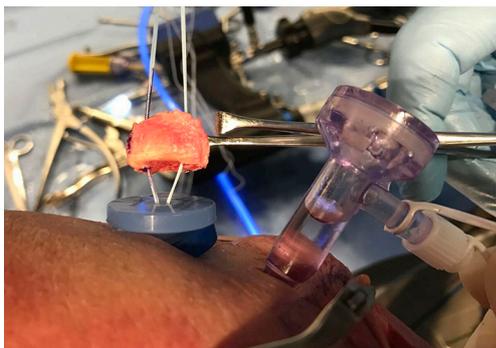


Figure 4 After both sets of suture limbs are shuttled out of the anterior mid-glenoid portal in a left shoulder, these limbs are passed through their corresponding superior and inferior holes in the distal clavicle graft. One limb from each hole is tied to the other across a central bone bridge to create a “double-pulley” configuration for graft delivery.

posterior portal (*Figure 5*). One limb from each anchor is then tied to the other outside the mid-glenoid cannula for “double-pulley” delivery and fixation. The remaining free suture limbs from each anchor are then pulled to advance

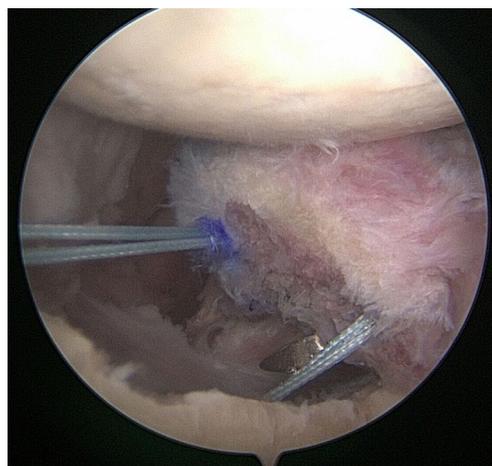


Figure 5 With the arthroscope in the posterior portal of a left shoulder, the graft is delivered into the joint by pulling the free limb from each anchor out of the shoulder in “double-pulley” fashion. A clamp, liberator, or probe is also used to manipulate the graft into final position through the mid-glenoid portal.

the pre-tied knot down the cannula and over the pre-positioned bone graft. Once the slack is pulled out of the anchor system, an arthroscopic square-knot is tied over the intervening bone bridge with three stacked half-hitches. Care is taken to ensure the graft remains in anatomic position while knots are tied (*Figure 6*).

Incorporation of native labrum to graft

The tied suture limbs are passed through the native labrum in horizontal mattress fashion to bring it up to the neo-articular surface with the aid of retrograde suture lassos, and tied down with secondary stacked knots. If screw fixation has been used, supplemental suture anchors can be placed either through a graft of larger size or at the superior and inferior borders of the graft if there is concern for inadequate bony surface area. At conclusion, all arthroscopic instrumentation is removed, and the skin is closed and dressed sterilely.

Postoperative rehabilitation

The patient is placed in a neutral rotation sling for 6 weeks. Pendulums are allowed immediately, and passive motion is started at 3 weeks, with a goal to obtain full range of motion by 8 weeks. At 8 weeks’ follow-up, imaging is obtained, and if graft healing is noted, active motion is begun. Strengthening is added at 4 months postoperatively, and return to full activity is assessed at 6 months. Final radiographs are

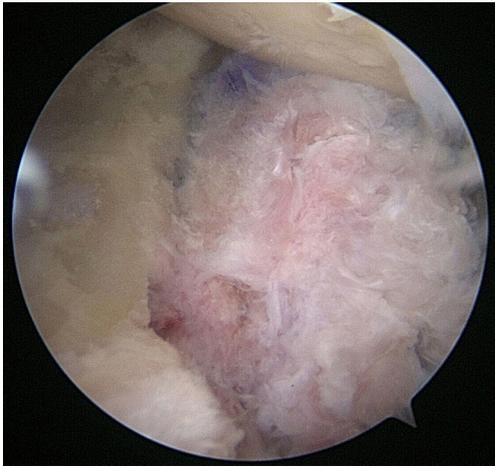


Figure 6 After positioning the graft flush to the articular surface, the free limbs from each suture anchor are tied to one another through the mid-glenoid portal for final graft fixation. When viewing from the anterior-superior portal in a left shoulder, good graft congruence to the native glenoid is appreciated. The tied suture limbs are then passed through the native capsule-labral tissue in horizontal mattress fashion to bring it up to the neo-articular surface and tied down with secondary stacked knots. Alternatively, the tissue may be repaired to the native glenoid to create an extra-articular graft.

obtained at this point to ensure complete graft incorporation.

Conclusions

Glenoid bone loss in the setting of anterior shoulder instability can be addressed using a variety of techniques, each with unique advantages and limitations. In this review, we detail our preferred use of the DCA. This autograft provides a readily available and almost no-cost method for anatomical reconstruction of glenoid bone loss. The graft restores both the radius of the native glenoid and offers articular cartilage comparable in thickness to that of the native glenoid. It also compares favorably to the coracoid in terms of arc of restoration, providing a cortico-cancellous buttress for glenoid restoration. While this graft provides promising theoretical, anatomic, and biomechanical promises, longer term outcome studies are needed to validate its use in the clinical setting.

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