Distal Tibia Allograft Glenoid Reconstruction in Recurrent Anterior Shoulder Instability: Clinical and Radiographic Outcomes

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Purpose: To assess the clinical and radiographic outcomes of patients with recurrent anterior shoulder instability treated with fresh distal tibia allograft (DTA) glenoid reconstruction. **Methods:** Consecutive patients with a minimum 15% anterior glenoid bone loss associated with recurrent anterior instability who underwent stabilization with DTA glenoid reconstruction were retrospectively reviewed. Patients were evaluated with the American Shoulder and Elbow Society score, Western Ontario shoulder instability index, and single numerical assessment evaluation score at a minimum 2 years after surgery. All patients also underwent postoperative imaging evaluation with computed tomography where graft incorporation and allograft angle were measured. Statistical analysis was performed with paired *t*-tests, with $P < .05$ considered significant. **Results:** A total of 27 patients (100% male) with an average age of 31 ± 5 years and an average follow-up of 45 months (range, 30-66) were included. There were significant improvements in preoperative to postoperative American Shoulder and Elbow Society score (63-91, $P < .01$), Western Ontario shoulder instability index (46% to 11% of normal, $P < .01$), and single numerical assessment evaluation score (50-90.5, $P < .01$) outcomes. Analysis of computed tomography data at an average 1.4 years postoperatively (available for 25 patients) showed an allograft healing rate of 89% (range, 80% to 100%), average allograft angle of 14.9° (range, 6.6° to 29.3°), and average allograft lysis of 3% (range, 0% to 25%). Grafts with lesser allograft angles (<15°) were better opposed to the anterior glenoid, showing superior healing and graft incorporation. There were no cases of recurrent instability. **Conclusions:** At an average follow-up of 45 months, fresh DTA reconstruction for recurrent anterior shoulder instability results in a clinically stable joint with excellent clinical outcomes and minimal graft resorption. Optimal allograft placement resulted in superior bony incorporation with the native glenoid. **Level of Evidence:** Level IV, therapeutic case series.

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Recurrent anterior shoulder instability remains a growing concern, with rates as high as 90% to 100% in the setting of glenoid bone loss.[1,2] A variety of bone grafts have been described for reconstruction of glenoid bone deficiency in the setting of recurrent anterior shoulder instability. Although anterior glenoid reconstruction with both iliac crest bone graft and coracoid process via the Latarjet procedure provides good to excellent outcomes with regard to shoulder stability, the development of early, symptomatic glenohumeral arthritis remains a growing concern, likely related to the nonanatomic reconstruction of the anterior osseous profile of the glenoid and to graft reabsorption. Certainly, the Latarjet procedure is successful in establishing a mechanical block toward recurrent instability; however, this procedure results in a nonanatomic reconstruction of the glenoid arc, devoid of any true articular surface. Further, several authors have described high rates of graft osteolysis and resorption after Latarjet as shown on computed tomography (CT)

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scan, which is a risk factor for recurrent instability, and ultimately may be a risk factor for early arthritis.[3,4]

Thus, alternative options for reconstruction of the anterior glenoid are necessary, and techniques involving allograft reconstruction with a fresh femoral head allograft, fresh glenoid allograft, and fresh distal tibia allograft (DTA) have been described. With respect to DTA, early laboratory work has shown a nearly identical radius of curvature between the distal tibia and the glenoid, even among nonlaterality-matched cadaveric specimens.[2,5,6] Similar to the glenoid surface, the distal tibia articular surface maintains excellent conformity to the humeral head throughout a full arc of motion. Further, fresh DTA contains dense, weight-bearing corticocancellous bone, making it ideal for screw fixation, and in addition, contains a robust cartilaginous surface that allows for an anatomic, osteoarticular glenoid surface reconstruction.

Although the anatomical and biomechanical properties of various bone grafting procedures for glenoid bone loss have been reported,[7-9] very little is known regarding clinical and radiographic outcomes of DTA reconstruction. The purpose of this study, therefore, was to assess the clinical and radiographic outcomes of patients with recurrent anterior shoulder instability treated with fresh DTA glenoid reconstruction. We hypothesized that patients would have an overall low recurrent instability rate, and would have good to excellent clinical outcomes at a minimum 2 years after DTA reconstruction for glenoid bone loss.

Methods

Participants

This study underwent approval by the university's institutional review board. A retrospective review of prospectively collected data on consecutive patients who underwent anterior shoulder stabilization with a fresh DTA allograft for recurrent anterior shoulder instability between 2008 and 2012 by the senior authors (A.A.R.) was reviewed. The inclusion criteria included all patients with a minimum 15% anterior glenoid bone loss deficiency who underwent anterior glenohumeral stabilization using fresh DTA reconstruction. Patients were offered DTA reconstruction if they had glenoid bone loss of greater than 15%, and symptoms of recurrent instability. In addition, the status of the humeral head was assessed via preoperative imaging and intraoperative assessment; no patients were found to have clinically significant, or engaging, Hill-Sachs lesions and thus no surgical procedures for the humeral head were required. In addition, other than diagnostic shoulder arthroscopy, no other concomitant procedures were performed at the time of DTA reconstruction. The exclusion criteria included patients with evidence of systemic hyperlaxity, ipsilateral arm neurologic injury, and posterior and/or multidirectional instability; no patients met these exclusion criteria and thus all patients who underwent DTA during the study period were included.

Preoperative data including demographic data, physical examination findings, radiographs, and preoperative CT scans with 3-dimensional (3D) reconstructions of the glenoid using digital subtraction of the humeral head were obtained for all patients. All preoperative and postoperative images were assessed by the senior author (M.T.P.). Glenoid bone loss was measured via the perfect circle method, using the percentage of missing glenoid relative to the surface area of the glenoid on the en face axial 3D reconstruction view. Using the en face 3D CT reconstruction, the inferior portion of the glenoid was assumed to be estimated by a circle of best fit.[10-14] Using open-source DICOM software Osirix MD (version 2.5.1 65-bit), the area of estimated glenoid bone loss was divided by the circle area to determine the percentage of bone loss by area. The anteroposterior dimension was also calculated using the equator of the glenoid, which is a line that passed through the center of the circle of best fit and was perpendicular to the long axis of the glenoid. This was divided by the diameter of the circle of best fit to determine the percentage of bone loss based on anteroposterior measurement. This was correlated with the percentage of glenoid bone loss based on the circle area. In addition, preoperative clinical assessments including the American Shoulder and Elbow Society (ASES) score, Western Ontario shoulder instability index (WOSI), and single numerical assessment evaluation (SANE) score were collected. Intraoperative data, including defect size, concomitant pathologies, and articular cartilage assessment by the senior author, were collected.

Intervention—Surgical Technique

The authors' preferred surgical technique for DTA reconstruction of the anterior glenoid rim has been previously described.[5,6,15] In brief, the procedure is conducted in the beach-chair position with the head elevated to 40° with the operative arm placed in a commercially available arm holder. A modified delto-pectoral exposure is performed and a subscapularis splitting[16] approach is used to expose the glenohumeral joint. After capsulotomy and exposure of the joint, any viable labral tissue is elevated from the anterior glenoid rim and the anterior glenoid is prepared with a high-speed burr down to a bleeding surface to accommodate the allograft (Fig 1). On the back table, the lateral one-third of the fresh, osteochondral DTA is prepared using a 0.5-inch sagittal saw; care is taken to protect the graft from necrosis with continuous irrigation.[5,6] The size of the graft and fresh cartilage is generally 20 to 25 mm from its superior to its inferior border, and anywhere from 6 to 10 mm in its anterior-to-posterior

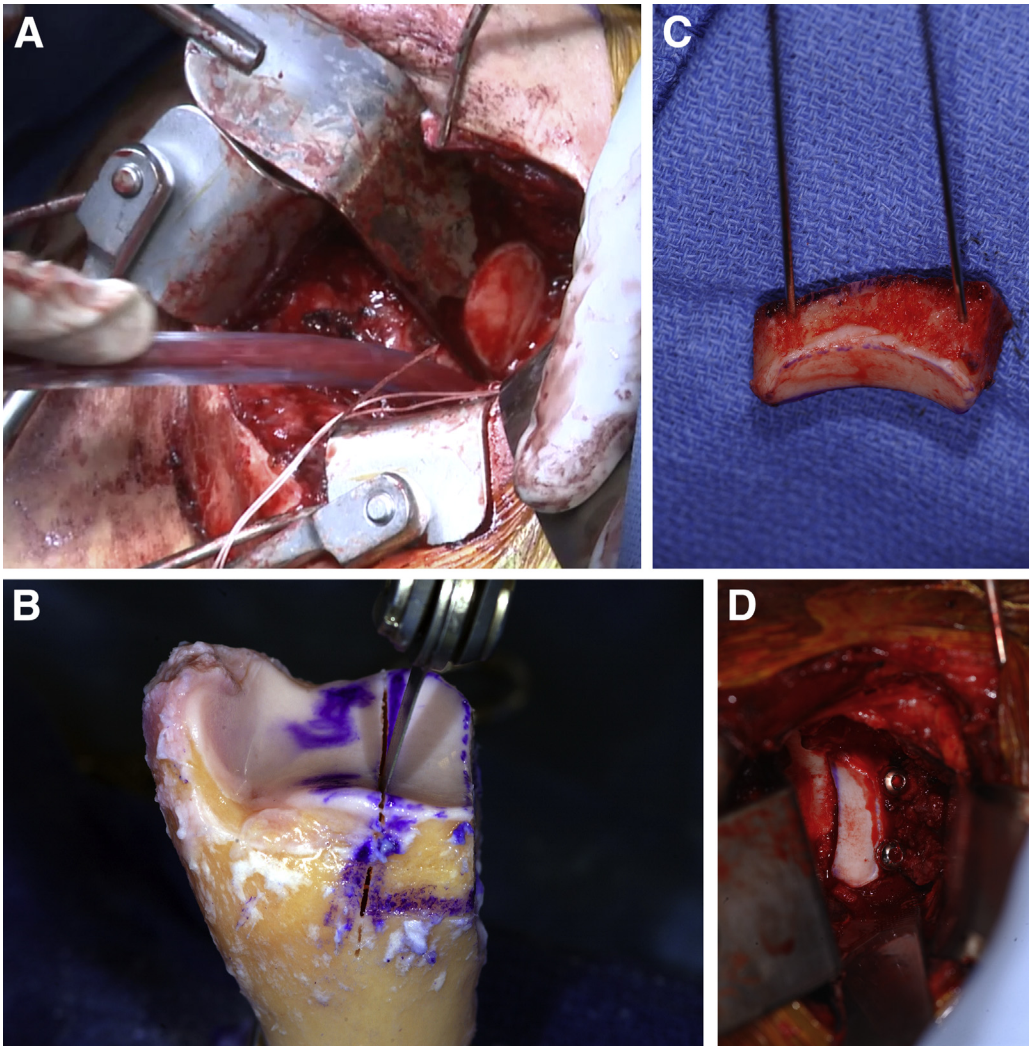

Fig 1. Photographs showing (A) the preparation of the right anterior glenoid rim before reconstruction with the distal tibia allograft; (B) intraoperative photograph showing the preparation of the lateral one-third of the distal tibia allograft; (C) allograft preparation with 2 smooth 1.6-mm Kirschner wires before insertion; and (D) reconstruction of the anterior-inferior glenoid bone defect with the distal tibia allograft, fixated with two 3.5-mm fully threaded, noncannulated cortical screws (right shoulder).

dimension based on prior templating from the 3D CT scan. The graft typically extends approximately 1 cm deep (medially in the glenoid neck), and is shaped to match the anterior glenoid defect. After pulsatile lavage[17,18] of the graft, 2 smooth 1.6-mm Kirschner wires are placed in the allograft at a 20° angle to the articular surface. The DTA is then transferred to the operative field and placed into the defect bed and assessed for fit; the Kirschner wires are drilled across the glenoid to temporarily hold the graft in place. The graft is then fixed in place with two 3.5-mm fully threaded, noncannulated, bicortical interference screws with washers, using a lag technique, to obtain graft compression against the anterior glenoid. The screws are typically 32 to 38 mm long. If the capsule and/or labrum are available for repair, they are repaired with sutures attached to the screw heads (with or without washers) before final tightening of the screws. The soft tissues are repaired meticulously, including the capsule, subscapularis split, and superficial soft tissues.

Rehabilitation

A standard abduction sling is used to support arm for the initial 4 to 6 weeks. For the first 2 to 4 weeks, pendulums and passive range of motion in the scapular plane are initiated. At 4 weeks, the patient begins active-assisted exercises. At 6 to 8 weeks, the patient begins strengthening. Full return to activity is expected at approximately 4 to 6 months postoperatively.

Outcome Measures

Postoperative data, including complications, recurrence instability events, physical examination findings, clinical outcomes scores (ASES, SANE, WOSI) at a minimum of 2 years, and postoperative CT findings at an average of 1.4 years (range, 0.13-5.74), were

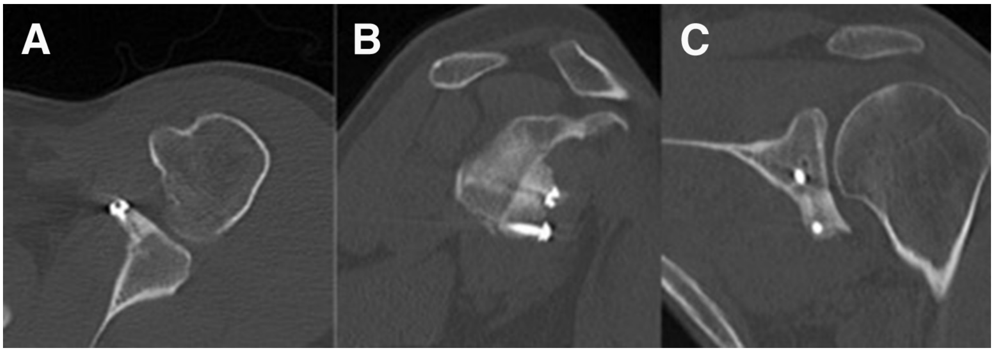

Fig 2. Postoperative computed tomography scan of the left shoulder taken approximately 2.5 years after distal tibia allograft reconstruction of the left glenoid showing excellent graft incorporation without evidence of lysis: (A) axial, (B) sagittal, and (C) coronal views.

collected and analyzed. The CT scans were graded on the axial plane by the senior author based on 3 criteria, including (1) overall healing of the DTA graft to the native glenoid, in which graft apposition to the glenoid was assessed on sequential axial images, with each image given a score ranging from 0 (0% healed) to 100 (100% apposed), with the summation of all scores averaged over the total number of images analyzed; (2) allograft angle (Fig 2), defined as the angle of the DTA graft relative to the native glenoid axis on the axial view; and (3) amount of DTA lysis, assessed by using sequential axial images and the geometric assumption of the graft being a rectangular cube, with any axial image that had a deficiency in cortical or cancellous bone (i.e., resorption) documented into an automated computer algorithm. Over the entire axial series, all degrees of resorption were then summed, and that summation was subtracted from the total area of the graft (rectangular cube), providing the percent of allograft lysis.

Data Analysis

Descriptive analysis consisted of frequencies and percentages for discrete data and means and standard deviations for continuous data. Paired *t*-tests were performed to compare preoperative and postoperative measures including ASES, WOSI, and SANE scores (SPSS Statistics Version 21.0, IBM, Armonk, NY). Significance was assumed for *P* values less than .05.

Results

Twenty-seven of 27 patients underwent clinical follow-up (100%) at an average duration of 45 months (range, 30-66 months) after surgery. All patients were diagnosed with chronic shoulder instability with a mean length of instability symptoms of 36 months. All patients were male (100%) and 18 patients (67%) were active duty military. All patients were nonsmokers, with an American Society of Anesthesiologists score of 1. Three patients (7.4%) were lost to imaging follow-up because of active duty service, leaving 25 patients (92.6%) with follow-up CT scans at an average of 1.4 $\pm$ 1.6 years (range, 0.13-5.74 years). The average preoperative glenoid bone loss was 23.7 $\pm$ 6.7% (range, 15.9% to 36.2%).

In 5 cases, DTA was performed after a prior failed stabilization procedure. A total of 4 patients (15%) had undergone prior shoulder stabilization via the Latarjet procedure, and 1 patient (4%) had undergone prior anterior arthroscopic stabilization.

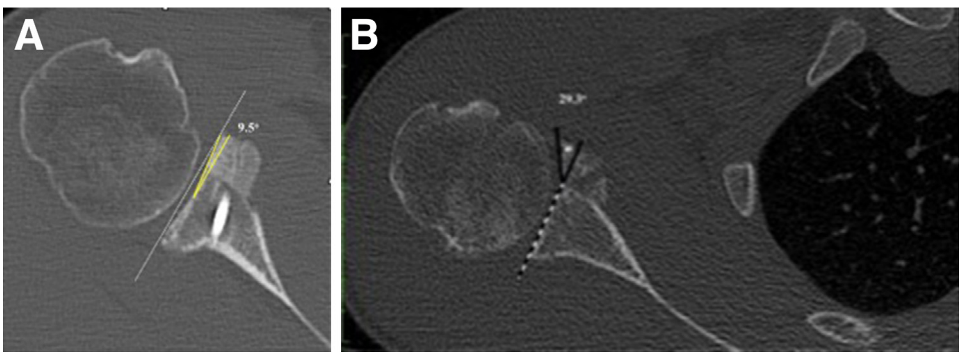

Fig 3. (A) Axial cut of a computed tomography (CT) scan taken at 8 months after right shoulder stabilization with the distal tibia allograft showing that an allograft angle value closely resembles the native glenoid anatomy. (B) Axial cut of a CT scan taken at 8 months after right shoulder stabilization with the distal tibia allograft showing an allograft angle of 29.3° to the native glenoid. This distal tibia allograft healed the worst of the series, but still showed incorporation at the surface and on multiple CT axial cuts.

For all patients, there were statistically significant improvements in preoperative to postoperative average ASES (63-91, $P = .002$), WOSI (46% to 11% of normal, $P = .003$), and SANE (50-90.5, $P = .0001$) outcomes scores. At the final follow-up, the average external rotation at the side (affected shoulder) was 51°, compared with 53° on the nonaffected shoulder ($P = .83$). The average final forward flexion was 177° (affected shoulder), compared with 178° on the nonaffected shoulder ($P = .91$). The average final abduction in external rotation was 86° (affected shoulder), compared with 90° on the nonaffected shoulder ($P = .29$). On stability examination, for all patients, no evidence of apprehension was noted on clinical examination at the final follow-up.

Analysis of CT data at an average 1.4 years postoperatively (available for 25 patients) showed an allograft healing rate of 89% (range, 80% to 100%), an average allograft angle of 14.9° (range, 6.6° to 29.3°), and an average allograft lysis of 3% (range, 0% to 25%) (Figs 2 and 3). Grafts with lesser allograft angles (<15°) were better opposed to the anterior glenoid, showing superior healing and graft incorporation ($P = .001$). There were a total of 14 grafts with allograft angles <15°, which essentially recreated anatomical glenoid curvature.

There were no cases of recurrent instability. One patient (4%) sustained a superficial *Propionibacterium acnes* infection and underwent allograft removal followed by revision DTA reconstruction. This patient had a final ASES score of 90, WOSI score of 15%, and SANE score of 90.

Discussion

The principal findings of this study show that at an average of 45 months, fresh DTA provides results in a clinically stable joint with excellent clinical outcomes and minimal graft reabsorption and graft lysis. A recent systematic review of glenoid allograft options for recurrent instability, including iliac crest allograft, femoral head allograft, humeral head allograft, glenoid allograft, and DTA, showed that allograft reconstruction for glenoid bone loss results in low rates of recurrent instability, excellent clinical outcomes, and high osseous incorporation with native glenoid.[19] Although certainly an evolving technique, clinical applications of fresh DTA for anterior shoulder instability with glenoid bone loss have recently been published.[5,6,15,20-22] Anterior glenoid augmentation with DTA has been proposed as an effective surgical technique for treatment of anterior shoulder instability associated with anterior glenoid bone loss, both in reducing the rate of dislocation and in improving pain and function.[5,6] Posterior glenoid augmentation with fresh DTA has also been described, with encouraging early outcomes. Millet et al.[21] described their 2-year results in 2 patients after open posterior shoulder stabilization with fresh DTA, and noted successful clinical and imaging (via CT) outcomes. More recently, Romeo et al.[20] described the surgical technique for an arthroscopic approach to posterior glenoid augmentation with fresh DTA; however, before the present study, no clinical outcomes had been published available.

The indications for anterior glenoid bone augmentation for treatment of both primary and recurrent anterior shoulder instability are evolving. Most authors agree that glenoid bone loss of 15% or greater warrants glenoid augmentation, particularly in the setting of recurrent instability. Given its low long-term recurrent instability rates, the gold standard of glenoid bone augmentation is the Latarjet procedure.[16,23-30] Unfortunately, despite the Latarjet procedure providing a stable joint, there is growing concern over the early development of glenohumeral arthritis in this young, high-demand patient population. Although it is unclear as to what specifically leads to the development of early arthritis in these patients, the absence of a true, hyaline-type articular surface, as well as the potential for graft resorption or lysis, may play a role.

Some studies have reported high rates of coracoid osteolysis after Latarjet, especially in patients in whom glenoid bone loss is <15%.[3,4] Di Giacomo et al.[3] analyzed 26 patients who underwent Latarjet and reported that on average 60% of the entire coracoid graft underwent osteolysis, with the most osteolysis occurring on the superficial/medial and superficial/lateral aspects of the proximal coracoid. In a separate study of 34 patients, Di Giacomo et al.[4] noted varying degrees of graft osteolysis after Latarjet reconstruction depending on the degree of glenoid bone loss. Interestingly, the authors found increased lysis (65%) in the patients with <15% glenoid bone loss and decreased lysis (40%) in patients with >15% glenoid bone loss.

In the present study, using CT data, there was an 89% allograft healing rate (range, 80% to 100%) to the native glenoid, with an average allograft lysis rate of approximately 3%. DTA grafts with lesser allograft angles (<15°) were better opposed to the anterior glenoid, showing superior healing and graft incorporation. Additional studies with larger patient populations and longer-term imaging follow-up are needed to find the exact factors that cause graft lysis.

Initial research has shown a nearly identical radius of curvature between the distal tibia and the glenoid,[31] even among nonmatched cadaveric specimens, allowing for unimpeded motion due to its congruency with the humeral head.[1,5] In addition, DTA contains dense, weight-bearing corticocancellous bone, making it ideal for screw fixation and further contains a robust cartilaginous surface that allows for an anatomic, osteoarticular glenoid surface reconstruction. Although it remains unclear as to how, or if, articular cartilage from allografts survive after bony incorporation, McCarty et al.[32] have shown some preliminary preclinical results that show chondrocyte viability after bony incorporation in a canine knee model. Biomechanically, several early laboratory studies have assessed glenohumeral loading mechanics in clinically relevant glenoid bone loss models as well as in clinically relevant autograft and allograft reconstruction models. Anterior glenoid reconstruction with flush Latarjet (using the inferior aspect of the coracoid as the glenoid surface) and flush iliac crest bone graft have been shown to better restore contact mechanics[8] compared with grafts placed proud, or using the lateral aspect of the coracoid, which were shown to result in worse outcomes. Further, anterior glenoid reconstruction with DTA has resulted in improved contact mechanics when compared with Latarjet reconstruction, especially in the position of abduction with external rotation.[9] Of note, although glenoid bone augmentation with the congruent-arc Latarjet technique allows for restoration of large anterior glenoid deficiency (30% or more) to the intact state, Giles et al.[33] have recently shown that the congruent-arc technique results in significantly poorer fixation stability as compared with the classic technique. Therefore, anterior glenoid reconstruction with DTA may provide an optimal surgical solution for large glenoid bone defects. Certainly, the DTA technique is new, and additional clinical studies are needed to describe the effects that these mechanical properties may have on postoperative outcomes after glenoid reconstruction. Of utmost importance is gaining a better appreciation of the potential for graft resorption, with further clinical work including follow-up imaging studies.

Limitations

There are several limitations to the current study, including its retrospective nature and small sample size. Further, only male patients were included, possibly introducing sex bias; however, given the demographics of anterior shoulder instability overall, this study population was representative of the typical patient population. Of the 27 patients, 5 had undergone prior ipsilateral shoulder surgery, which may impact outcomes in those patients and therefore skew the overall results. Similarly, the quality of the capsule and soft tissue may be varied among the patients, particularly those with prior surgery, which may also impact outcomes. Postoperative CT scans were only available for relatively short-term follow-up and were only assessed by a single observer, and it would have been helpful to view the status of the graft by radiographs, CT scan, or by second-look arthroscopy at a minimum of 2 years after surgery. Further, the CT imaging outcome measures used in this study have not yet undergone reliability assessment. Finally, there was no comparison group, and additional studies comparing outcomes after DTA to outcomes after stabilization with other techniques, including Latarjet, are warranted.

Conclusions

At an average follow-up of 45 months, fresh DTA reconstruction for recurrent anterior shoulder instability results in a clinically stable joint with excellent clinical outcomes and minimal graft resorption. Optimal allograft placement resulted in superior bony incorporation with the native glenoid.

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