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Evaluating Healing of Allograft Tissues in the Shoulder—Cartilage and Bone

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Glenohumeral bone loss and articular defects are often treated by using osseous or osteoarticular allografts. These aid in glenohumeral joint stability and in reconstruction of the native articular surface. Grafts include those such as iliac crest, coracoid, distal tibia, femoral head, or humeral head, depending on the specific surgical pathology. Articular grafts can be further subdivided into viable or nonviable sources. The outcome of grafts that are implemented for stability could be subject to osteolysis, which may portend a poor clinical outcome and recurrent instability. Similarly, grafts required for reconstruction of the articular surface may undergo avascular necrosis, nonunion, and collapse, rendering them useless. The status of these grafts is best assessed with postoperative imaging modalities, which range from plain film radiography to 3-dimensional computed tomography reconstructions. The purpose of this article is to review the current literature regarding the rate of graft resorption, integration, collapse, and union for each of the grafts mentioned using postoperative imaging.
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Introduction

The indication for using glenohumeral allografts typically arises from any of 2 main indications: glenohumeral instability and articular cartilage damage. However, these categories do not always exist in isolation, as in the case of large glenoid defects and Hill-Sachs lesions. The grafts used may contain either an osseous component or an osseous component, with either viable or nonviable articular cartilage. When considering instability, grafts used to treat glenoid bone loss include iliac crest,[1] distal tibia,[2] and for completeness, the coracoid.[3] Regarding the humerus, defects can be treated with either femoral head[4] or humeral head[5] osteochondral allograft. When the goal of these grafts is to maintain the stability of the shoulder, fibrous unions or significant resorption can lead to clinical failure.[6-8] Grafts used to treat Hill-Sachs lesions have largely been frozen and are therefore nonviable regarding the chondrocytes. In contrast to this, allografts used for articular cartilage damage involve the use of a bulk humeral head or mushroom[9] graft or a focal osteochondral allograft.[10] Because the ultimate goal is long-term subchondral bone incorporation to improve patient symptoms and ideally prevent advancement of disease, these grafts are processed as "fresh," stored at 4°C and not frozen. The goal of this article is to review the current available literature on the eventual remodeling and incorporation of these grafts as evaluated by postoperative imaging.

Glenohumeral Instability: Glenoid Bone Loss

Latarjet

Though not an allograft, radiographic evaluation of the Latarjet procedure is pertinent, as this method is currently the gold standard in treating glenoid bone loss, typically in a setting of recurrent glenohumeral instability.[3] Although multiple variations of the Latarjet procedure have been described, the general technique involves detaching the pectoralis minor from the coracoid and transecting it at its base. A portion of the coracoacromial ligament can be maintained on the coracoid

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Figure 1 A 3D CT reconstruction of a Latarjet procedure (coracoid transfer). This graft demonstrated no evidence of resorption or nonunion.

for eventual capsular repair. This graft is then transferred through a subscapularis splitting approach and is placed intra-articularly along the anterior-inferior glenoid neck surface. Multiple methods of fixation are available, but all of them focus on compression though lag screw fixation by technique or by design. Orientation includes positioning either the medial or inferior (where the pectoralis minor was detached from) portion of the graft toward the humerus. The later is referred to as the congruent-arc technique.[11] This methodology results in less contact for osseous integration as the graft is thinner in the medial-lateral dimension but wider in the anteroposterior dimension. Benefits of the Latarjet procedure are extending the glenoid boney constraint and providing a sling effect, as conferred by the conjoined tendon attachment through the subscapularis that is activated as the arm is abducted and externally rotated.[12]

Although the Latarjet procedure has been successful for treating anteroinferior shoulder instability, osteolysis of the graft has been reported. Di Giacomo et al[13] reported results of 26 patients undergoing Latarjet with 3-dimensional (3D) computed tomography (CT) scan reconstructions both at 3 days and at an average of 17.5 months after surgery (Fig. 1). The 3D reconstructions of each coracoid graft were divided into 8 parts (2 major, superficial and deep; each divided into proximal, distal, medial, and lateral) for further analysis. The largest percentage of average osteolysis was seen in the superficial and medial aspect of the proximal coracoid (93.4% ± 12.1%) and in the superficial and lateral aspect of the proximal coracoid (88.5% ± 17.8%). The lowest percentage of average osteolysis was seen in the deep and lateral aspect of the distal coracoid (37.5% ± 19.8%) and the deep and medial portion of the distal coracoid (36.2% ± 26.8%). The overall amount of a graft that underwent osteolysis on average was 59.5%. This finding is likely secondary to Wolff's Law, as bone adapts in response to the load under which it is placed. This concept was further reinforced by Di Giacomo et al[14] by demonstrating that after 1 year of follow-up, resorption in patients with $>15\%$ of glenoid bone loss was 39.6%, whereas it was 65.1% of the graft in patients without bone loss treated with Latarjet. Theoretically, it is conceivable that using the congruent-arc technique, where a relatively large graft surface area is placed along the articular surface, may result in an increased incidence of osteolysis.

Iliac Crest Bone Graft

In patients with extensive glenoid bone loss, an iliac crest bone graft can provide sufficient graft to repair a large defect. The inner table of the iliac crest is used owing to its concave architecture and ability to match the articular surface of the glenoid.[1] Warner et al used an iliac crest bone graft for repair of large glenoid defects in 11 patients, and at a mean follow-up of 33 months, none had experienced recurrent shoulder instability. Graft union was evaluated at 4-6 months after surgery using CT and the rate of union was 100% with no evidence of resorption (Fig. 2).

Although the structural status was not reported, Auffarth et al[15] described a variation of an iliac crest graft known as the J-bone technique in which an iliac crest bicortical graft is crafted into a J-shape and held in place on the glenoid rim without screw fixation. Moroder et al[16] used the previously described J-bone technique to review the 3D CT status of the grafts in 20 patients without bone loss immediately postoperatively and at 1 year from surgery. The 3D reconstructions were used to measure glenoid diameter and surface area, and the measurements were reported as relative values based on the theoretical shape of a normal, intact glenoid. All grafts

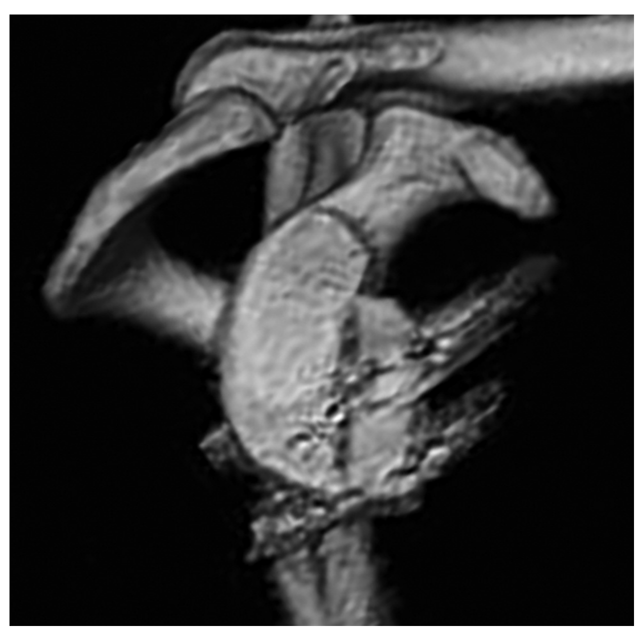

Figure 2 A 3D CT reconstruction of an iliac crest bone graft reconstruction for anterior glenoid bone loss. There is no evidence of nonunion or resorption in this case.