Allograft Reconstruction for Glenoid Bone Loss in Glenohumeral Instability: A Systematic Review


Purpose: The aim of this study was to assess clinical outcomes and radiological outcomes after osteochondral allograft reconstruction for glenoid bone loss. Methods: Glenoid bone loss can occur in the setting of recurrent glenohumeral instability and poses a challenge for surgeons. Reconstruction of these defects with allografts has been proposed as an alternative to both arthroscopic stabilization and nonanatomic bony augmentation procedures with autografts. We conducted a systematic review of the literature for studies of any level of evidence that reported clinical or radiological outcomes (or both) after allograft reconstruction for glenoid deficiency in the setting of recurrent shoulder instability. Data collected included study and patient characteristics, surgical technique, outcome scores, range of motion, strength, subjective outcomes, radiological outcomes, and complications. Data from studies with a sample size of at least 5 were pooled in the main analysis. Studies were assessed for the presence of methodological bias. Results: Eight studies met the inclusion criteria and were included in the review. Three studies were deemed eligible for pooled analysis. The study group consisted of 70 shoulders with a mean age of 27.7 years (74.6% of participants were men) and a mean follow-up period of 44.5 ± 17.7 (range, 32 to 90) months. The mean final Rowe score was 90.6, representing a mean improvement of 57.5. Only 9.8% of patients complained of persistent or unimproved pain, and 93.4% were satisfied. Bony integration of the allograft was documented in 100% of shoulders. Recurrence of glenohumeral dislocation and overall instability were seen in 2.9% and 7.1% of cases, respectively. Conclusions: The current body of Level IV data suggests that allograft reconstruction for glenoid bone loss provides excellent clinical outcomes, low rates of recurrent instability, and high osseous incorporation rates with no evidence of graft resorption. Level of Evidence: Level IV, systematic review of Level IV studies.

Glenoid bone loss can play a significant role in recurrent glenohumeral instability and is often identified as the source of failure after shoulder stabilization.1,2 The prevalence of anteroinferior glenoid rim deficiency in recurrent instability ranges from 5% to more than 70% of cases.3-5 The likelihood of glenoid bone loss is increased in patients with chronic recurrent instability, a high-energy mechanism of injury (i.e., in collision athletes), and a history of recurrent dislocations occurring with less force.6 Loss of the anteroinferior glenoid rim leads to loss of the glenoid articular arc, compromising the concavity compression mechanism and thus increasing the risk of recurrence of instability. It also reduces the articulating surface area of the glenoid, which may potentially increase contact pressures and the risk of future degenerative joint disease. Arthroscopic Bankart repair has been associated with a recurrence rate of 4% in the absence of significant glenoid bone loss versus 67% in patients with greater than 25% loss of inferior glenoid diameter or an engaging Hill-Sachs lesion.1 Untreated glenoid deficiency can also limit the recovery of range of motion after Bankart repair7,8 and is a recognized cause of failed shoulder stabilization surgery.6 Glenoid reconstruction is typically indicated in situations of 25% or greater bone loss9-11 or when revision stabilization becomes necessary.12 The surgical management of glenoid deficiency is challenging. Both open1,13 and arthroscopic14-20 techniques have been used, and common strategies include the use of...
coracoid transfer and iliac crest autografts or allografts. Although these procedures have been successful in restoring glenohumeral stability, nonanatomic coracoid transfer procedures to address glenoid bone loss have been associated with progression to instability arthropathy.

Osteochondral allografts have been widely used in the management of articular pathologic conditions, especially osteochondral lesions of the knee. This technique was first described successfully in the shoulder by Gerber and Lambert for the treatment of chronic locked posterior shoulder dislocation. There are several advantages to the use of allografts over autografts in reconstructive procedures for glenoid bone loss, including a more anatomic restoration of the articular contour and the addition of a cartilaginous interface for articulation with the humeral head. The theoretical benefits of this cartilaginous interface include a decrease in the risk of future instability arthropathy and the prevention of recurrence by restoration of the natural glenoid concavity. However, the reliability of allograft incorporation into the glenoid without resorption has yet to be evaluated.

The objective of this review was to assess clinical and radiological outcomes after osteochondral allograft reconstruction for glenoid bone loss. To our knowledge, this is the first systematic review examining the use of allografts to the glenoid in the setting of chronic glenohumeral instability. We hypothesized that allograft reconstruction would provide excellent clinical outcomes, low recurrence rates, and of foremost interest, high rates of radiographic union.

**Methods**

**Eligibility Criteria**

This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. Therapeutic studies were included if they addressed glenoid deficiency in the setting of glenohumeral instability with allograft reconstruction. Studies were excluded if they (1) used an autograft, (2) did not identify the anatomic source of the allograft, (3) treated only humeral head deficiency, or (4) used glenoid reconstruction in the setting of tumor resection or revision shoulder arthroplasty. No restrictions were imposed on publication date, study design, level of evidence, or follow-up period, although studies that did not report the follow-up period were also excluded. Laboratory studies and review or technique-only articles were excluded.

**Literature Search**

Two independent reviewers performed the literature search to identify eligible studies. MEDLINE, EMBASE, and Scopus were queried to identify relevant English-language studies. The search term was as follows: “glenoid AND graft.” The resulting study titles and abstracts were reviewed according to the eligibility criteria. Full articles were procured and reviewed for potentially eligible studies, and their citations were manually screened in an effort to identify additional studies that might have been missed. A PRISMA trial flow shows the study selection algorithm (Fig 1).

**Data Extraction**

Data were extracted for study and patient characteristics, surgical technique, outcome scores, range of motion, strength, subjective outcomes, radiological outcomes, and complications. Outcome scores included the Rowe; Constant; American Shoulder and Elbow Surgeons; University of California, Los Angeles; and Disabilities of the Arm, Shoulder, and Hand scores. Range-of-motion parameters included forward flexion, abduction, external rotation (ER) in the adducted position, and internal rotation (IR). Recurrence of instability was defined as recurrent dislocation, subluxation, apprehension, or a combination of these conditions. Finally, studies were assessed for the presence of methodological bias, including selection, detection, performance, and attrition biases.

**Data Synthesis**

Data from studies with a sample size of at least 5 were pooled in the main analysis. Data aggregation was performed when an outcome was uniformly reported by more than one study. Continuous data were analyzed through calculation of weighted means and standard deviations. Dichotomous data were analyzed through summation of the number of events and total observations to compute an aggregated rate. All other data were summarized in descriptive fashion.

**Results**

**Literature Search**

The literature search identified 233 studies whose titles and abstracts were preliminarily screened. Full-text articles for 59 studies were procured and reviewed. After application of the eligibility criteria, 8 studies included in the systematic review (Table 1). The 3 studies with a sample size greater than 5 were included in the pooled analyses.

**Patient Characteristics**

Of the 8 studies, the 3 studies included in the pooled analyses contained a total of 70 shoulders with follow-up data (Table 2). The weighted mean follow-up period and age were 44.5 ± 17.7 (range, 32 to 90) months and 27.7 years, respectively. The proportion of male patients and dominant or right arms was 74.6% and 68.0%, respectively. Previous surgery had
been performed in 10.3% of shoulders and included capsular shift, Bankart repair, and Bristow or Putti-Platt procedures.

**Surgical Technique**

The 3 studies included in the pooled analysis used either iliac crest bicortical allografts or femoral head allografts. The remaining 5 studies used distal tibial allografts, glenoid allografts, or humeral head bicortical allografts (Table 3). The tissue preservation status of the graft was fresh in 2 studies and cryopreserved in one study. The beach chair surgical position was used in 3 of 5 studies, whereas the surgical approach was arthroscopic in 2 studies and deltopectoral in 4 studies. Although Zhao et al. used suture anchor fixation, the remainder of studies used cortical or cancellous screw fixation of the graft at the osteotomy site.

**Outcome Scores**

Two of the 3 studies provided both preoperative and postoperative outcome scores (Table 4). The

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**Table 1. Overview of Included Studies**

<table>
<thead>
<tr>
<th>First Author (Year)</th>
<th>Study Design</th>
<th>Level of Evidence</th>
<th>Shoulders (n)</th>
<th>Follow-up Period (mo)</th>
<th>Follow-up Rate (%)</th>
<th>Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhao (2014)</td>
<td>Retrospective case</td>
<td>IV</td>
<td>52</td>
<td>38.8 (24-64)</td>
<td>80.0</td>
<td>Selection, detection</td>
</tr>
<tr>
<td>Weng (2009)</td>
<td>Prospective case</td>
<td>IV</td>
<td>9</td>
<td>90 (54-168)</td>
<td>100</td>
<td>Detection</td>
</tr>
<tr>
<td>Hutchinson (1995)</td>
<td>Retrospective case</td>
<td>IV</td>
<td>9</td>
<td>32 (8-61)</td>
<td>88.2</td>
<td>Selection, detection</td>
</tr>
<tr>
<td>Millett (2013)</td>
<td>Case report</td>
<td>IV</td>
<td>2</td>
<td>&gt; 24</td>
<td>NA</td>
<td>Selection, detection</td>
</tr>
<tr>
<td>Gupta (2013)</td>
<td>Case report</td>
<td>IV</td>
<td>1</td>
<td>12</td>
<td>NA</td>
<td>Selection, detection</td>
</tr>
<tr>
<td>Petrera (2013)</td>
<td>Case report</td>
<td>IV</td>
<td>1</td>
<td>24</td>
<td>NA</td>
<td>Selection, detection</td>
</tr>
<tr>
<td>Tjoumakaris (2008)</td>
<td>Case report</td>
<td>IV</td>
<td>1</td>
<td>–</td>
<td>NA</td>
<td>Selection, detection</td>
</tr>
</tbody>
</table>

*The study design of Zhao et al. was a retrospective study of prospectively collected data.
A weighted mean final Rowe score was 90.6 ± 2.8, representing a weighted improvement of 57.5 ± 1.5 from the preoperative value, based on 2 studies.29,38 Hutchinson et al.25 reported a mean final Constant score of 91.3 in their 9 patients.

**Range of Motion and Strength**

ER was nonuniformly assessed in the 3 studies, and IR was assessed in one study. Zhao et al.38 documented deficits in ER at postoperative follow-up in 2 of 52 patients in the adducted position and 5 of 52 patients in the abducted position, with deficits greater than 10° in 2 patients. Weng et al.29 noted a mean loss in ER of 7° in their cohort of 9 patients. Although Hutchinson et al.25 did not provide a preoperative measurement, they reported a mean postoperative ER of 38° during adduction and 63° during abduction. Zhao et al.38 noted a deficit in IR in 2 of 52 patients. Hutchinson et al.25 were the sole authors to assess postoperative strength. Using the 25-point Constant strength score, they reported postoperative scores of 23.1 for abduction, 18.4 for ER, and 20.1 for IR.

**Subjective Outcomes**

Pain improvement or resolution was achieved in 90.2% of patients in 2 studies.29,38 Only one study quantitatively assessed pain status using the Constant pain score.25 Ninety-four percent of patients were satisfied after the allograft reconstruction in 2 studies.25,38

**Radiological Outcomes**

Bony integration of the allograft was assessed in 2 studies29,38 and was achieved in 100% of patients, with all bony unions occurring within 6 months. Computed tomography and magnetic resonance imaging were used in one study,38 whereas the other used standard radiography.29 Zhao et al.38 further reported that the mean glenoid defect width changed from 32.7%...
<table>
<thead>
<tr>
<th>First Author (Year)</th>
<th>Reconstructive Technique</th>
<th>Outcome Scores</th>
<th>Range of Motion (°)</th>
<th>Strength</th>
<th>Pain</th>
<th>Satisfaction</th>
<th>Return to Activity</th>
<th>Radiological Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhao (2014)</td>
<td>Iliac crest bicortical allograft</td>
<td>Oxford (pre): 29.7&lt;br&gt;Oxford (post): 42.4&lt;br&gt;Rowe (pre): 34.7&lt;br&gt;Rowe (post): 91.8</td>
<td>Deficits: &gt; 10° external rotation (2 of 52)&lt;br&gt;ER (adduction) (2 of 52)&lt;br&gt;IR (2 of 52)</td>
<td>–</td>
<td>Persistent slight pain: 6 of 52</td>
<td>48 of 52</td>
<td>–</td>
<td>Integration: 52 of 52 (CT)&lt;br&gt;Progression of arthrosis: 0 of 52&lt;br&gt;Glenoid edema: 3 of 52&lt;br&gt;9 of 9 integrated (XR)</td>
</tr>
<tr>
<td>Weng (2009)</td>
<td>Femoral head allograft</td>
<td>Rowe (pre) = 24&lt;br&gt;Rowe (post) = 84°</td>
<td>Loss of ER = 7</td>
<td>–</td>
<td>9 of 9 improved</td>
<td>–</td>
<td>0 of 9 limited in ADL</td>
<td>9 of 9 integrated (XR)</td>
</tr>
<tr>
<td>Hutchinson (1995)</td>
<td>Femoral head allograft</td>
<td>Constant (post) = 91.3</td>
<td>ER = 38 (adduction)&lt;br&gt;ER = 63 (abduction)</td>
<td>Abduction° = 23.1&lt;br&gt;Constant (pain): 14 of 15</td>
<td>9 of 9</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Provencer (2009)</td>
<td>Distal tibial allograft</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>3 of 3 integrated (CT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millett (2013)</td>
<td>Distal tibial allograft</td>
<td>DASH (post) = 9&lt;br&gt;ASES (post) = 86</td>
<td>–</td>
<td>–</td>
<td>2 of 2 improved VAS (post) = 2</td>
<td>–</td>
<td>2 of 2 (sport)</td>
<td>2 of 2 integrated (CT)</td>
</tr>
<tr>
<td>Gupta (2013)</td>
<td>Distal tibial allograft</td>
<td>–</td>
<td>Regained full range of motion</td>
<td>–</td>
<td>–</td>
<td>1 of 1 (work)</td>
<td>1 of 1 integrated (CT)</td>
<td></td>
</tr>
<tr>
<td>Petera (2013)</td>
<td>Glenoid allograft</td>
<td>–</td>
<td>Complete forward flexion&lt;br&gt;Abduction, ER, and IR limited to thoracolumbar level</td>
<td>Forward flexion = 5 of 5&lt;br&gt;Abduction = 5 of 5&lt;br&gt;IR = 5 of 5</td>
<td>1 of 1</td>
<td>0 of 1 limited in ADL</td>
<td>1 of 1 integrated (XR)&lt;br&gt;Concentric glenohumeral alignment: 1 of 1</td>
<td></td>
</tr>
<tr>
<td>Tjoumakaris (2008)</td>
<td>Humeral head bicortical allograft</td>
<td>–</td>
<td>–</td>
<td>Normal</td>
<td>Improved</td>
<td>–</td>
<td>–</td>
<td>1 of 1 integrated (XR + CT)</td>
</tr>
</tbody>
</table>

ADL, activities of daily living; ASES, American Shoulder and Elbow Surgeons; CT, computed tomography; DASH, Disabilities of the Arm, Shoulder, and Hand; ER, external rotation; IR, internal rotation; pre, preoperative; post, postoperative; ROM, range of motion; XR, radiography; VAS, visual analog scale.

*Indicates a statistically significant improvement.

The Constant score and subscores reported by Hutchinson et al.25 refer to their entire cohort, which additionally included 6 patients treated with autografts.

Hutchinson et al.25 used the Constant scoring system to rate strength.
to −16.3%, whereas the mean glenoid defect area changed from 28.3% to −16.9%. Increases in the final glenoid surface area and glenoid width were achieved in 94.2% and 96.2% of their patients, respectively. None of the patients in their cohort experienced pro-
cession of arthrosis, which was present preoperatively
in 94.2% and 96.2% of their patients, respectively.

Complications
Weng et al. were the only authors to comment on the rate of overall complications, which was 0 of 9 in their cohort. All 3 studies assessed patients for recur-
rence of glenohumeral instability, which occurred in 71.1% of patients and consisted of 2 dislocations, one subluxation, and 2 instances of apprehension. Thus, the rate of recurrent dislocation was 2.9%. Neither graft resorption nor hardware prominence occurred in any patients in 2 studies.

Bias
All 3 studies were Level IV case series. As a result, they were susceptible to selection bias, with the exception of one study that was a series of consecutive patients. Two of 3 studies had a prospective design for data collection. Because none of the studies indicated the use of an independent examiner to evaluate patients, detection bias was possible in all cases. A control group was not used in any study. Statistical power, as a function of sample size, was limited in all but one study. Performance bias was present in only one study, resulting from the performance of concomitant procedures, namely, Bankart or bony

Reports from Smaller Studies
In addition to the 3 studies included in the preceding analyses, 5 small case series and case reports have reported outcomes after the use of allograft Le Fort gle-

Discussion
Allograft reconstruction of glenoid bone loss repre-
sents a potential alternative to the conventional tech-
niques of arthroscopic stabilization and nonanatomic coracoid transfer procedures. However, the reliability of allograft incorporation into the glenoid without resorption has yet to be definitively established. This review identified 8 Level IV studies examining the ef-
cacy and complications associated with allograft reconstruction for glenoid bone loss in the setting of recurrent glenohumeral instability (Table 5). Taken collectively, these data show that allograft reconstruction of the glenoid has excellent clinical outcomes, a low rate of recurrent instability, high rates of graft union, and very low rates of graft resorption. The Rowe score, a validated clinical assessment of shoulder instability, was improved by an average of 57.5 points and showed an excellent mean final score of 90.6. Ninety-three percent of patients were satisfied with the outcome of surgery, and more than 90% experienced pain improvement or resolution. Bony integration of the graft was achieved in 100% of shoulders at long-
term follow-up of 44.5 months, with no signs of graft resorption, whereas recurrence of glenohumeral insta-

Table 5. Aggregated Demographic and Outcome Statistics for Included Studies

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Studies</th>
<th>No. of Shoulders</th>
<th>Weighted Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up rate (%)</td>
<td>3</td>
<td>70</td>
<td>83.6</td>
</tr>
<tr>
<td>Follow-up period (mo)</td>
<td>3</td>
<td>70</td>
<td>44.5</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>3</td>
<td>70</td>
<td>27.7</td>
</tr>
<tr>
<td>Male sex (%)</td>
<td>3</td>
<td>70</td>
<td>74.6</td>
</tr>
<tr>
<td>Dominant or right arm (%)</td>
<td>2</td>
<td>18</td>
<td>68.0</td>
</tr>
<tr>
<td>Previous surgery (%)</td>
<td>3</td>
<td>70</td>
<td>10.3</td>
</tr>
<tr>
<td>Outcomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Rowe score</td>
<td>2</td>
<td>61</td>
<td>90.6</td>
</tr>
<tr>
<td>Improvement in Rowe score</td>
<td>2</td>
<td>61</td>
<td>57.5</td>
</tr>
<tr>
<td>Pain improvement or resolution (%)</td>
<td>2</td>
<td>61</td>
<td>90.2</td>
</tr>
<tr>
<td>Patient satisfaction (%)</td>
<td>2</td>
<td>61</td>
<td>93.4</td>
</tr>
<tr>
<td>Bony integration (%)</td>
<td>2</td>
<td>61</td>
<td>100</td>
</tr>
<tr>
<td>Recurrence of instability (%)</td>
<td>3</td>
<td>70</td>
<td>7.1</td>
</tr>
<tr>
<td>Graft resorption (%)</td>
<td>2</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Hardware prominence (%)</td>
<td>2</td>
<td>18</td>
<td>0</td>
</tr>
</tbody>
</table>
osteochondritis dissecans and focal chondral defects and has been used extensively for this purpose in the knee.\textsuperscript{24,38,39} Because the 3 studies included in our pooled analyses used osseous rather than osteochondral grafts, any potential advantages of cartilage-bearing allografts require further investigation.

There are innate disadvantages to the use of allografts. Donor tissue may not be readily obtainable in all cases and carries a minuscule risk of disease transmission.\textsuperscript{39} including a less than one in 1,000,000 risk of human immunodeficiency transmission when proper precautions are used.\textsuperscript{40} Cryopreservation may undermine the tissue viability and overall function of the allograft, because chondrocyte viability is reduced both in vitro\textsuperscript{41} and in clinical specimens\textsuperscript{12} relative to fresh allografts. However, the use of fresh allografts is logistically challenging because they must be used within 14 to 28 days\textsuperscript{43} to avoid biological decline of the tissue.\textsuperscript{44}

Limitations

There are several limitations to this study. Because all included studies were of Level IV evidence, the likelihood of methodological bias is increased, and no comparison of allograft reconstruction against other techniques was possible. Each study contained one or more demonstrable biases, including selection, detection, attrition, or a combination of these biases. Although the smaller case series and case reports used several different clinical scoring systems, only the Rowe score was amenable to pooling in the main analysis. Pooled analysis of range of motion and strength was not possible because of nonuniform or limited outcome reporting. Aside from recurrent instability, complications were not extensively assessed in these studies. However, no significant complications were associated with this procedure in any of the reports.

Further research, ideally in the form of well-designed controlled trials or cohort studies, or both, is required to determine the comparative efficacy and safety of this technique relative to the nonanatomic bony augmentation procedures that have been favored historically. Additionally, the optimal anatomic source of the allograft represents an important question for continued investigation.

Conclusions

The current body of Level IV data suggests that allograft reconstruction for glenoid bone loss provides excellent clinical outcomes, low rates of recurrent instability, and high osseous incorporation rates with no evidence of graft resorption.

References

ALLOGRAFT RECONSTRUCTION FOR GLENOID BONE LOSS


