Management of Humeral and Glenoid Bone Loss Associated with Glenohumeral Instability
Results with Anatomical Bone Grafting

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Abstract
Anterior glenohumeral instability complicated by bone loss is a challenging problem and, when severe, may require surgical treatment with bone grafting. We review our institution’s experience with humeral head and glenoid bone grafting for large Hill-Sachs lesions and glenoid defects.

Materials and Methods: Patients who underwent intra-articular bone reconstruction for Hill-Sachs and large glenoid defects for anterior instability at our institution during 2002-2008 were retrospectively reviewed. Those who had undergone concomitant humeral head replacement were excluded. Six patients were identified as having undergone allograft or autograft iliac crest bone graft reconstruction of the glenoid, with four available for full follow-up (average 39 months; range, 7 to 63). Five patients were identified as having undergone humeral head allograft reconstruction and four were available for full follow-up (average 28 months; range, 11 to 40). The remaining three patients were available for telephone follow-up. American Shoulder and Elbow Society (ASES) and University of California, Los Angeles (UCLA) scores were recorded and radiographs obtained.

Results: Average postoperative ASES and UCLA scores for glenoid bone graft patients were 91 and 33, respectively. Glenoid bone graft shoulders, when compared to the opposite normal side, lost an average of 3° of forward flexion, 10° of external rotation, and two levels of internal rotation. Humeral head bone-grafted shoulders, lost an average of 23° of forward flexion, 8° of external rotation, and two levels of internal rotation. No episodes of recurrent subluxation or dislocations were reported. Radiographs showed no evidence of graft resorption or hardware prominence.

Conclusions: Bone grafting procedures around the shoulder for the treatment of instability provided relief from recurrent instability and good functional results.

Glenohumeral instability is a relatively common problem and may be complicated by either humeral or glenoid bone loss, or both. Recent studies using advanced imaging techniques, such as three-dimensional (3D) computed tomography (CT) reconstruction and magnetic resonance imaging (MRI), suggest that glenoid bone loss occurs in up to 90% of cases of traumatic anterior glenohumeral instability; in terms of presentation, in up to 76% of first-time traumatic anterior glenohumeral instability and in up to 100% with recurrent instability. Rarely, however, is the bone loss on either the glenoid side or humeral head side significant enough to warrant bone grafting procedures. Warner and colleagues reported on their experience in a tertiary referral shoulder practice and noted that only 4% of patients undergoing reconstructive procedures for traumatic anterior instability had defects large enough to necessitate bone graft reconstruction of the glenoid rim. Humeral-sided grafting is even more rare. A few papers outline treatment strategies for large reverse Hill-Sachs lesions acquired from locked posterior dislocations. However, there are only small case reports and series of bone grafting procedures for large classic...
Hill-Sachs lesions. Most patients in either group who require grafting have a history of multiple dislocations or failed repairs, or both.

Burkhart and De Beer were the first to coin the terms “inverted pear glenoid” and “engaging Hill-Sachs lesion.” Their work drew attention to the essential role of bone loss in instability and fueled needed and further clinical research into this topic. Recent biomechanical and observational work has better defined the “critical” size defects on both the glenoid and humeral head. Advanced imaging is now extremely helpful in preoperative planning and, in most cases, can accurately predict the need for grafting procedures when bone loss is severe. In general, glenoid defects in the 33% range and Hill-Sachs defects that either engage in a physiological range of motion or are in the 30% to 40% range should be considered for grafting.

Historically, bone grafting for instability reconstruction has been performed most commonly via the Bristow-Latarjet procedure; there is excellent long-term data supporting this procedure. However, there are some notable shortcomings to both the procedure and the reported data. The procedure is technically challenging and produces a non-anatomical repair and a complicated revision surgery if failure occurs. Furthermore, the data is from a non-homogenous population, in that surgeons who report on this procedure often indicate it for cases of mild or moderate bone loss, not just severe.

Direct bone grafting of the anterior glenoid margin with autograft or allograft iliac crest has recently been advocated by some as a more anatomical approach. It shares some of the same limitations as the Bristow-Latarjet procedure, such as potential hardware complications and technical difficulty. Clinical results have been reported sparingly, as indications for the procedure remain limited; however, early results seem promising.

In addition, direct bone grafting for large Hill-Sachs lesions with allograft humeral head or femoral head has recently been advocated for “engaging Hill-Sachs lesions” as well. There are few published clinical reports of this strategy. Multiple surgical approaches have been employed: arthroscopic, anterior deltopectoral only, combined arthroscopic, and posterior.

We report on a small series of cases from 2002-2008 at our institution of anterior glenohumeral instability, with severe bone loss, treated using either open femoral head and humeral head allograft reconstruction of the humeral head for large Hill-Sachs lesions, or open allograft and autograft iliac crest reconstruction of the glenoid rim.

Materials and Methods

Patient Selection

The institution’s medical records from 2002-2008 were searched and all instability patients (humeral head defect and glenoid defect patients) were identified. Six patients were identified who were operated on by two surgeons and underwent iliac crest bone grafting of the glenoid and humeral head for severe bone loss due to instability. All patients had multiple dislocations (Table 1). All patients also demonstrated severe apprehension and a positive relocation test on physical examination. Bone loss was documented preoperatively in all cases by means of 3D CT reconstruction or MRI, or both, using the method of Gerber and Nyfeller, as documented previously by War-

![Figure 1](image1.png) CT of glenoid (transverse cut), demonstrating greater than 33% loss of anterior bony rim.

![Figure 2](image2.png) Large Hill-Sachs defect.
ner and coworkers5 (Fig. 1). Bone loss was confirmed in the operating room in some of the cases by means of arthroscopy, using the method of Burkhart to measure the glenoid width.7

For humeral head defects, patients were identified by MRI or CT as having “large Hill-Sachs” lesions (33% to 40% of articular arc) (Fig. 2) and “engaging Hill-Sachs” lesions at the time of the preoperative examination, under anesthesia. Two different surgical techniques were employed. Two surgeons used an open bone grafting technique with allograft femoral head, and one surgeon used an arthroscopic technique with osteochondral plugs.

**Surgical Procedure: Glenoid Bone Grafting**

All patients underwent open reconstruction of the glenoid bone defect with either autogenous iliac crest bone graft or fresh frozen allograft iliac crest graft, and procedures were reviewed. In two of the cases, open reconstruction was preceded by an arthroscopic evaluation and measurement of the glenoid defect. Patients underwent regional anesthesia in all cases, followed by sedation with laryngeal mask airway (LMA) support. Patients were placed in the beach chair position in a “Captain’s Chair” table attachment, positioned with the head inclined 30° (referenced from the floor), and all bony prominences padded appropriately. The contralateral iliac crest was then prepped. A similar method described by Warner and associates4 was used for iliac crest harvest and preparation.

For the open shoulder reconstruction, a standard deltopectoral approach was used. An incision was made from the palpable landmark of the coracoid process to the skin overlying the deltid insertion. The cephalic vein was preserved and retracted laterally, and the subdeltoid and subconjoint tendon spaces were mobilized. A Kobel retractor was placed in the subdeltoid and subconjoint tendon space, exposing the subscapularis and rotator interval. The circumflex vessels were cauterized. A tenotomy of the subscapularis was made approximately 1 cm medial to its origin, superiorly, from the rotator interval to the inferior one-third of the subscapularis. A Cobb elevator was inserted between the muscular subscapularis and the glenohumeral capsule, thus, protecting the axillary nerve. The subscapularis tendon was gently dissected from the capsule and controlled with nonabsorbable No. 2 Merseline™ sutures. A T-shaped capsulotomy was performed, with the lateral margin, approximately, 0.5 cm medial to the subscapularis tenotomy. The capsulotomy was taken to the 6 o’clock position on the humeral neck.

The glenohumeral joint was exposed, and the humeral head was retracted posterolaterally with a Fukuda retractor. The anterior glenoid margin was identified, and the capsule was bluntly dissected with an elevator from the scapular neck. A curved anterior single-spine retractor was placed along the anterior scapular neck. The glenoid width was measured and, in all cases, the defect measured. The glenoid defect then was roughened with a high speed burr.

The iliac crest graft was prepared using an oscillating saw and high speed burr. The graft was contoured to match the glenoid curvature. The graft was preliminarily fixed in place with three K-wires, placed parallel and medial to the glenoid surface. Care was taken to place the graft in an anatomical position. Three 4.0 mm partially threaded cannulated screws (Synthes®, Paoli, Pennsylvania) were placed over the K-wires. Prior to fully seating the screws, a No. 2 FiberWire® (Arthrex®, Naples, Florida) suture was tied under each screw head, to be used later to repair the capsule. The graft was fully seated and the articular surface was assessed for a smooth transition. A burr was used to contour the graft further, if needed. The Fukuda retractor was removed, and the glenohumeral articulation was assessed. The No. 2 FiberWire® sutures were placed in a horizontal mattress fashion through the capsule, and the capsule was secured to the edge of the iliac crest bone graft. The capsulotomy was repaired with interrupted non-absorbable No. 2 Merseline™ sutures. During the repair, the arm was held in 30° of flexion and 30° of external rotation. The subscapularis tenotomy and rotator interval were repaired in a similar fashion. The remainder of the closure was performed in a layered manner, and a sterile dressing was placed.

**Humeral Head Bone Graft Technique: Open Technique**

For the open shoulder reconstruction, a standard deltopectoral approach was used (see previous section for details). Following completion of the deltopectoral approach and joint exposure, the humeral head was externally rotated, a retractor was placed in the joint to protect the glenoid surface, and the Hill-Sachs lesion was exposed. The lesion was roughened with a high speed burr back to a bleeding bone bed. The graft was obtained from the back table, shaped accordingly and placed with two headless, buried Acutrak® (Acumed, Hillsboro, Oregon) screws. The graft is placed about 2 mm proud to allow for expected subsidence. Stability was checked during a full range of motion evaluation, and a standard capsular shift with labral repair was performed, if warranted. A layered closure was performed.

**Humeral Head Bone Graft Technique: Arthroscopic Technique**

Two patients underwent arthroscopic osteochondral allograft transplant (OATS). The technique was performed in a fashion similar to that used by Chapovsky.19 In each case, the Bankart bony bed was debrided with a rasp and the Arthrex® OATS instrument set was employed. Three osteochondral plugs EBI® were fit into the defect and fit flush to the surface. The labral reattachment was performed via arthroscopic...
techniques with 3 suture anchors in the anterior inferior quadrant of the anterior lateral glenoid rim.

Postoperative Care
Patients were maintained in an abduction sling for 2 weeks postoperatively and were encouraged to wear the sling at night and while out of the house until week 4. They began a monitored therapy program at 2 weeks, starting with gentle passive range of motion and working-up to active assisted and full active range of motion. At 3 months, strengthening was begun.

Assessment
Patients were seen in the office postoperatively at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year. Functional data using the ASES and UCLA validated instruments were collected during the office visit or via telephone interviews. All patients were asked to return to the office for a physical examination. Both the normal and affected shoulders of patients were examined for range of motion, strength, apprehension, relocation testing, and translation. Range of motion testing was done with a goniometer, and strength testing was performed manually. At a follow-up visit, radiographs of the affected extremity were obtained for anterior-posterior (AP) internal rotation, AP external rotation, axillary, and scapular Y-planes.

Results
Demographics
Six patients were identified who underwent bone graft reconstruction of the glenoid; four were available for full follow-up. The average age of these patients at the time of surgery was 26 years; all patients were male. Two of the patients had previously failed surgery, both of which were arthroscopic Bankart repairs. The dominant arm was affected in 3/6 cases. The average follow-up was 30.6 months. Five patients were identified who underwent allograft reconstruction of large Hill-Sachs lesions (1 female and 4 males). The patients were operated on by three surgeons. Four patients were available for full follow-up at an average of 27.4 months. One patient had a failed previous Putti-Platt procedure. The dominant arm was affected in 3/5 cases. Average age of the patients was 33 years (Table 1).

Physical Examination and Operative Findings
Operative findings correlated well with preoperative clinical history, physical examination, and imaging studies. In all cases, a severe anterior glenoid defect was noted, comprising greater than one-third of the width of the glenoid. All patients were found to have 3+ humeral head laxity, with frank dislocation under anesthesia through a physiological range of motion. In all cases, an engaging Hill-Sachs lesion was noted on preoperative exam under anesthesia; preoperative and intraoperative direct observation demonstrated that the Hill-Sachs lesions were large (approximately 40% of the articular surface).

Clinical Follow-Up
All 11 patients were available for limited phone follow-up, and there were no reported recurrences of subluxation or dislocation. Results for full follow-ups are listed below.

Glenoid Defect Group
Average postoperative ASES score was 91.3 (range, 90.6 to 96.1) and average postoperative UCLA score was 33 (range, 31 to 35), with a follow-up, on average, of 39.2 months (range, 7 to 63). Average loss of forward flexion, when compared to the normal side, was 3° (range, 0 to 10), average loss of external rotation was 10° (range, 0 to 20). All patients demonstrated full strength. No patients demonstrated any recurrent instability. Subscapularis testing was intact for all patients. No complications or reoperations were noted. All grafts remained in place, with no evidence of prominent hardware. Radiographs did not demonstrate any appreciable resorption. Measures were made using digital radiography with standard calibrating software.

<table>
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<th>Humeral Head Patients</th>
<th>Age (Years)</th>
<th>Gender</th>
<th>Injury</th>
<th>Number of Dislocations</th>
<th>Prior Surgery</th>
<th>ASES Score</th>
<th>UCLA Score</th>
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<td>Fall</td>
<td>6</td>
<td>Putti-Platt</td>
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<td>M</td>
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<td>Seizure</td>
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<th>Glenoid Patients</th>
<th>Age (Years)</th>
<th>Gender</th>
<th>Injury</th>
<th>Number of Dislocations</th>
<th>Prior Surgery</th>
<th>ASES Score</th>
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<td>93.5</td>
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</table>
Hill-Sachs Group
Average postoperative ASES score was 85.3 (range, 61 to 94.5) and average postoperative UCLA was 28.4 (range, 23 to 31). Follow-up, on average, was 27.4 months (range, 11.2 to 40.1). Average loss of forward flexion, when compared to the normal side, was 23° (range, 0° to 70°), average loss of external rotation was 8° (range, 5° to 10°), and average loss of internal rotation was two levels (0 to 3). All patients demonstrated full strength. No patients demonstrated any recurrent instability. Subscapularis testing was intact for all patients. One patient developed reflex sympathetic dystrophy (RSD), and one patient developed prominent hardware that required removal. This was the only case of reoperation.

Discussion
Great strides have been made in biomechanically and clinically defining the size of glenoid and humeral head defects likely to progress to recurrent instability. Controversy still exists, however, regarding the best treatment plan for a given defect.

In an early biomechanical study, Lippitt and Matsen\(^9\) elegantly demonstrated that the labrum significantly deepens the glenoid and aids in preventing dislocation. They showed a decreased translational force to dislocation when the labrum was removed from the edge of the glenoid. Itoi and colleagues\(^{12}\) created standardized bone cuts to simulate graduated bone loss in a similar cadaver model. They found that when the missing bone was equal to 21% of the length of the glenoid, significantly less translational force was needed to dislocate the shoulder. Restoration of bone and the Bankart lesion restored stability. Of note, Itoi and coworkers created a model in which the bone loss was created at an oblique 45° angle to the superior-inferior axis and coworkers created a model in which the bone loss was equal to 21% of the glenoid. Saito and associates\(^{20}\) later work with CT created at an oblique 45° angle to the superior-inferior axis and coworkers created a model in which the bone loss was equal to 21% of the glenoid. Sugaya showed via CT with 3D reconstruction that large defects were rare.\(^1\)

Due to the 2000 study findings of Burkhart and colleagues,\(^7\) in which they described the inverted pear glenoid, Burkhart modified his practice and now performs a Bristow-Latarjet procedure for such patients. In 2007, Burkhart and coworkers\(^{21}\) followed-up on 102 patients and found good and excellent results for a majority of patients, with a recurrence rate of 4.9%. Other long-term studies have touted the Bristow-Latarjet as an effective procedure for the treatment of instability. Hovelius and his colleagues\(^{15-17}\) have produced some of the best follow-up for this procedure. However, these series included all patients with instability, not just those with significant bone loss. This makes it difficult to draw conclusions when comparing the Bristow-Latarjet procedure to the anatomical approach. Proponents of the Bristow-Latarjet cite the long track record and similar types of complications as the anatomical approach. A recent biomechanical study suggested that the Bristow-Latarjet procedure may provide greater resistance to anterior translation than the anatomical glenoid reconstruction with iliac crest graft provides, although it is not clear whether this is clinically significant.\(^{22}\) It remains unclear which approach is superior for this difficult group of patients. Warner and associates\(^4\) series of 11 patients, who underwent autograft iliac crest grafting of the anterior glenoid, showed a high success rate, excellent graft incorporation, and a low complication rate.

We reviewed six of our patients who underwent anatomical bone grafting with iliac crest for large glenoid defects. Our results compare favorably to Warner’s 2006 case series from a clinical outcomes standpoint.\(^9\) We report no complications, no recurrences, and favorable clinical outcomes. Although we did not obtain CT scans on all postoperative patients, radiographic studies did not demonstrate any evidence of hardware prominence or significant graft dissolution. In distinction to Warner and colleagues,\(^4\) we have often employed an iliac crest allograft instead of an autograft. It is unknown whether and to what extent allograft incorporates in this application. The spine literature shows us, however, that autograft iliac crest harvest leads to chronic donor site pain for a subset of these patients. Therefore, this technique is certainly worth considering. While there is no long-term data on this approach, we believe it is a viable and promising technique.

The Hill-Sachs defect group, overall, performed well with regard to instability: no cases of recurrence were noted. However, the clinical outcomes did not compare as favorably as the glenoid group. Part of this can be explained by the one patient who developed RSD and significant motion loss. Since the sample size was small, one patient could have a relatively large effect on the general group outcome. Regardless, it seems that the motion loss for these patients is somewhat greater, overall, than for patients with glenoid grafting. It is unclear why this may be so. There did not appear to be an appreciable difference in the number of previous surgeries or dislocations between groups. Of the patients who underwent bone grafting of the humeral head, those who underwent arthroscopic grafting had slightly higher outcome scores. However, our numbers are too small to draw reasonable conclusions about this finding.

This study has some limitations. It is retrospective in nature, and outcome scores were not kept preoperatively. Due to the rare nature of the procedures involved, the overall sample size for each group was relatively small; therefore, statistical analysis was not possible. Additionally there was more than one surgeon involved in performing the surgical procedures. While we believe that technique was fairly uniform across surgeons for the various approaches, this cannot be proven. A conventional goniometer was used for measurements; however, no standardization or intra-observer ratings were done.
Conclusion
Overall, bone grafting of large defects of the humeral head or glenoid can prevent recurrent instability in the short- to medium-term, with relatively low complication rates. Glenoid graft patients seem to have better clinical functioning than humeral head graft patients. Further study is needed to determine long-term efficacy of these procedures and to enable better conclusions to be drawn regarding their effectiveness and long-term outcome.

Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References