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Introduction

Recurrent instability of the glenohumeral joint is usually associated with a Bankart tear—a soft-tissue injury of the glenoid labrum attachment. However, patients with recurrent shoulder instability often present with osseous injury to the glenoid and humeral head as well. Understanding and appropriately addressing irregularities in the osseous architecture of the glenohumeral joint are critical to the overall success of surgical repair for the treatment of glenohumeral instability. The integrity of the osseous architecture of the glenoid has recently been highlighted as one of the most important factors related to the success of surgical repair. After the initial traumatic shoulder dislocation, an associated glenoid rim fracture or attritional bone injury may compromise the static restraints of the glenohumeral joint, making further instability more likely. With recurrent instability, there can be further attritional glenoid bone loss.

Glenoid bone deficiency with recurrent shoulder instability is an increasingly recognized cause of failed shoulder stabilization surgery. It is critical to evaluate all patients with recurrent shoulder instability for the presence of osseous injuries to the glenoid. Specific findings in the history and the physical examination provide important clues to the presence of glenoid bone loss, and a careful preoperative evaluation to diagnose and quantify anterior glenoid deficiency is crucial for the success of surgical treatment.

Appropriate preoperative imaging is essential for detection and quantification of osseous abnormalities in patients with recurrent shoulder instability. The apical oblique view described by Garth et al., the West Point view, and the Didié view are recognized as being the most sensitive radiographs for detecting osseous abnormalities of the glenoid. Magnetic resonance imaging and magnetic resonance arthrography may be used, but they are primarily employed to assess the surrounding soft tissues. If any osseous lesion is discovered on radiographs, or with magnetic resonance imaging, a computed tomography scan can provide valuable information about the extent of the bone loss. Furthermore, a three-dimensional-reconstruction computed tomography scan allows digital subtraction of the humeral head from images of the glenohumeral complex, providing an en face sagittal oblique view of the glenoid. Precise measurements of the percentage of glenoid bone loss can be calculated by modeling the inferior aspect of the intact glenoid as a true circle.

It is preferable to accurately assess glenoid bone loss prior to surgical intervention, as this permits informed consent and shared clinical decision-making with the patient regarding optimal treatment strategies. Once a precise estimation of bone loss is made, decisions regarding the surgical approach to be used, particularly those related to the risk of the recurrence of shoulder instability, can be discussed with the patient. Although the exact treatment for each percentage of glenoid bone loss has yet to be fully defined, the published literature supports the idea that, in patients with less than 15% to 20% glenoid bone loss (usually less than 5 to 7 mm of bone), recurrent instability can be successfully treated with soft-tissue stabilization alone. However, when bone loss is 25% to 30% of the glenoid sphere (more than 6 to 8 mm of bone loss), open repair or bone augmentation procedures should be considered. Osseous reconstruction techniques include the Bristow procedure, the Latarjet procedure, use of iliac crest bone graft, and allografting with use of the femoral head or the distal part of the tibia.

The principles of surgical management are guided by the extent of osseous deficiency, consideration of combined glenoid and humeral bone defects, the surgeon’s personal experience with specific reconstructive techniques, and patient-specific circumstances. Osseous reconstruction techniques include the Bristow procedure, the Latarjet procedure, use of iliac crest bone graft, and allografting with use of the femoral head or the distal part of the tibia.

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Disclaimer: The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, the Department of Defense, or the United States Government.
factors such as work and athletic demands. Techniques for soft-
tissue stabilization, the type and orientation of the glenoid bone
graft, and treatment of concomitant pathologic conditions are all
variables that should be carefully considered to optimize the
likelihood of a well-functioning shoulder joint after surgical
repair.

Source of Funding
No external funds were used for this study.

Diagnosis of Glenoid Bone Loss

Patient History
A thorough orthopaedic history should be recorded for all
patients with recurrent glenohumeral instability, as some
key clues from the shoulder instability history may signal the
finding of glenoid bone loss. The diagnosis of glenoid bone loss
should be suspected when the patient had a high-energy injury,
especially if the arm was abducted $\geq 70^\circ$ and extended $\geq 30^\circ$
at the time of the initial dislocation, or presents with shoulder
instability that occurs within the range of 20° to 60° of ab-
duction (Table I). Patients with glenoid bone loss often note
that it has become progressively easier to subluxate the gleno-
humeral joint and often have a long history of either shoulder
instability symptoms or coping with this injury. Although the
emphasis is likely on instability when the patient is seen, care
must be taken to thoroughly consider other shoulder disorders,
such as rotator cuff tears, particularly in patients over the age
of forty who have instability, a concomitant superior labral
anterior-posterior (SLAP) tear, and cartilage injury.

Physical Examination
A thorough physical examination to compare the affected
shoulder with the contralateral shoulder will confirm the diag-
nosis of instability, but it will also identify other shoulder dis-

<table>
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<tr>
<th>TABLE I Key Clues from the History and Physical Examination That May Herald the Finding of Glenoid Bone Loss</th>
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<tr>
<td><strong>History</strong></td>
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<tr>
<td>High-energy mechanism of injury</td>
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<tr>
<td>Arm was abducted (≥70°) and extended (≥30°) at time of initial dislocation</td>
</tr>
<tr>
<td>Patient reports that most instability occurs in midrange of motion (20°-60° of abduction)</td>
</tr>
<tr>
<td>Patient notes progressive ease of instability</td>
</tr>
<tr>
<td>Prolonged history of instability</td>
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For a West Point axillary view, the beam is directed at the axilla at a 25° angle medially and a 25° angle cephalad, centered inferior and medial to the acromioclavicular joint.
Visual inspection of the shoulder should focus on identifying deformity, rotator cuff atrophy, or scapular dyskinesia. The initial physical examination should always include a careful neurovascular evaluation of the entire upper extremity, testing of active and passive shoulder motion, and assessment of rotator cuff strength. The magnitude and direction of shoulder instability are documented. Special maneuvers such as the Jobe relocation test\textsuperscript{15}, sulcus sign\textsuperscript{16}, Gagey hyperabduction sign\textsuperscript{17}, and apprehension sign\textsuperscript{18} are often useful. To complete the examination specific for glenoid bone loss, the shoulder apprehension test is performed in various degrees of shoulder abduction and external rotation. Although a patient with glenoid bone loss will typically have a positive apprehension test in 90° of shoulder abduction and 90° of external rotation, patients with apprehension findings in 30° to 90° of shoulder abduction and in a lesser amount of external rotation may have glenoid bone loss, as the humeral head is easily subluxated over the glenoid. In addition, the examiner should evaluate anterior translation of the humeral head over the glenoid rim (Table I), which, when strongly positive, may be an additional indication that glenoid bone loss is likely present and should be investigated further with advanced imaging studies.

Glenoid bone loss seen on a three-dimensional computed tomography reconstruction. Bone loss can be either acute (A) or chronic (B).
Imaging
In addition to basic radiographic views of the shoulder, specialized glenoid views in which the radiographic beam is angled oblique to the glenoid face are frequently useful for enhanced visualization of lesions of the osseous glenoid rim. The most useful radiographic views include the West Point view, Didié view, and apical oblique (Garth) view. The West Point view, a variation of the axillary lateral radiograph, is a tangential view of the anteroinferior aspect of the glenoid and is the best view for radiographic detection of osseous Bankart lesions (Fig. 1). However, patient positioning for this radiographic view may be difficult after acute trauma, and the apical oblique radiograph may be utilized instead.

Although proper radiographic technique is important to provide information about the presence of a glenoid bone injury, radiographs alone often fail to detect, or to allow accurate quantification of, glenoid bone loss. Two-dimensional computed tomography and magnetic resonance imaging are helpful in detecting glenoid bone loss and newly formed glenoid rim fragments. However, because of the glenoid’s natural three-dimensional structure and variations in glenoid version among individual patients, these methods may be inadequate for quantifying glenoid bone loss. In standard two-dimensional computed tomography, the degree of glenoid version affects the gantry angle needed to gain an accurate representation of the glenoid. The beam must be exactly perpendicular to the long axis of the glenoid while the glenoid is in a fixed position. A sagittal oblique magnetic resonance image, especially when an arthrogram is also made, may be very helpful if the magnetic resonance imaging magnet is strong enough to provide reasonable resolution to differentiate glenoid bone from soft-tissue injury. Magnetic resonance arthrography allows clearer delineation of the glenoid fossa and en face measurements of glenoid bone loss on the sagittal oblique images (Fig. 2). However, like an axial computed tomography scan, axial magnetic resonance imaging or magnetic resonance arthrography may still underestimate the amount of glenoid bone loss because images are only two-dimensional: scans with a larger interslice distance, or greater gap spacing between cuts, may not provide accurate measurements for bone loss quantification.

A three-dimensional computed tomography scan is considered the gold standard for glenoid imaging because it allows digital subtraction of the humeral head from images of the glenohumeral complex (Fig. 3). The net effect is a precise en face sagittal oblique view of the glenoid surface and vault, which allows free body analysis of the scapula. In order to obtain the en face sagittal oblique view, the humeral head has to be digitally subtracted after the three-dimensional reconstructions are performed by the computed tomography software.

A three-dimensional computed tomography scan provides the most information about the extent and magnitude of glenoid bone loss as well as information about the type of glenoid bone injury or loss—a.e., whether it is due to an acute fracture, partial attritional loss, or complete attritional loss (Table II). Three-dimensional computed tomography also can demonstrate that glenoid bone loss occurs clinically along a line parallel to the long axis of the glenoid from 12 o’clock to 6 o’clock.

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Fig. 4
A: A best-fit circle is drawn on the inferior two-thirds of the glenoid fossa to aid with quantification of the percent bone loss. B: Measurement of glenoid bone loss according to surface area. On an en face view of the glenoid, the surface areas of both a best-fit circle on the inferior two-thirds of the glenoid and the osseous defect are digitally measured. The percent bone loss is quantified according to the indicated equation. (Drawing by Sanjeev Bhatia, MD.)
Quantification of Glenoid Bone Loss

Radiography

It is often difficult to visualize osseous glenoid lesions with use of radiographs. Although specialized views such as the West Point axillary, apical oblique, and Didieé radiographs enhance the detection of osseous Bankart lesions, they are too imprecise for quantification of the percentage of glenoid bone loss. Despite this drawback, Bigliani et al. reported a radiographic classification of Bankart lesions consisting of three basic types21. Type I is a displaced avulsion fracture with an attached capsule; Type II, a medially displaced fragment malunited to the glenoid rim; and Type III, an erosion of the glenoid rim. Type-III lesions are further

Fig. 5 Measurement of glenoid bone loss based on ratios23. An en face view of the glenoid is visualized on a computed tomography scan. With use of the intersection of the longitudinal axis and the widest anteroposterior diameter of the glenoid, the bare spot is approximated on the glenoid fossa. A best-fit circle centered at the bare-spot approximation is then drawn about the inferior two-thirds of the glenoid (red). The distance from the bare spot to the anterior edge (d) is measured and compared with the radius of the best-fit circle (R). The ratio of d/R is inserted into the indicated equation23 for estimation of the percent bone loss. For ease of calculation, a function graph using common values from this equation is frequently utilized. (Drawing by Sanjeev Bhatia, MD.)

Fig. 6 Importance of Bankart fragment length. If the length (x) is greater than half of the widest anteroposterior (AP) diameter (R), the dislocation resistance is ≤70% of that of an intact glenohumeral joint24. (Drawing by Sanjeev Bhatia, MD.)
classified according to whether bone loss is less (Type IIIA) or greater (Type IIIB) than 25%. If glenoid bone loss is detected on any radiographic view, a three-dimensional computed tomography scan should help to better define the amount of the loss.

**Computed Tomography**

In a cadaveric study of forty scapulae, Huysmans et al. demonstrated that the inferior aspect of the glenoid has the shape of a true circle, so this geometric comparison can be used when quantifying glenoid osseous lesions. Glenoid bone loss can easily be quantified on a three-dimensional computed tomography scan by modeling the inferior portion of the glenoid contour as a true circle on an en face view. The dimensions and position of this circle are determined by drawing a best-fit circle about the inferior two-thirds of the glenoid, with the center of this circle roughly at the glenoid “bare spot” (a thinning in the cartilaginous covering and increased subchondral density that overlies the tubercle of Assaki) (Fig. 4, A). The amount of glenoid bone loss is calculated with one of two techniques. The most precise method is a digital surface area calculation that determines the amount of glenoid bone loss or injury on the basis of the amount of glenoid surface area that is involved. The percentage of glenoid bone loss is determined by dividing the surface area of the osseous defect by the surface area of the true circle (Fig. 4, B). A simpler technique to determine glenoid bone loss is a linear measurement in millimeters of the bone missing from the circle.

In 2008, Barchilon et al. described a method for quantification of glenoid bone loss using an en face sagittal oblique three-dimensional computed tomography view. The

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**Table II Indications for Obtaining a Computed Tomography Scan**

<table>
<thead>
<tr>
<th>Indications for Obtaining a Computed Tomography Scan* of Patients with Shoulder Instability†</th>
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<tbody>
<tr>
<td>History of multiple dislocations</td>
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<tr>
<td>History of bilateral shoulder dislocation, especially dislocation on nondominant side</td>
</tr>
<tr>
<td>History of failed stabilization procedure</td>
</tr>
<tr>
<td>Dislocation after trivial trauma (initial episode) or little provocation</td>
</tr>
<tr>
<td>Radiographs or magnetic resonance imaging demonstrating glenoid bone loss</td>
</tr>
<tr>
<td>Instability in midranges of motion</td>
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![Fig. 7](image-url) Estimation of bone loss based on glenoid rim distances. An en face view of the glenoid is visualized on a computed tomography scan. With use of the intersection of the longitudinal axis and the widest anteroposterior diameter of the glenoid, the bare spot is approximated on the glenoid fossa. A best-fit circle centered at the bare-spot approximation is then drawn about the inferior two-thirds of the glenoid (red). The distances from the bare spot to the anterior rim (A) and posterior rim (B) are subsequently measured. The percent bone loss is calculated according to the indicated equation. (Drawing by Sanjeev Bhatia, MD.)
Quantifying glenoid bone loss is provided in Table III. Recurrent shoulder dislocation is of the widest anteroposterior diameter (R), the resistance to osseous lesion has also been described as an important marker percentage of glenoid bone loss (Fig. 5). The length of the osseous lesion has also been described as an important marker of glenohumeral stability. If the length (x) is greater than half of the widest anteroposterior diameter (R), the resistance to recurrent shoulder dislocation is ≤70% of that of an intact glenohumeral joint\(^2\) (Fig. 6).

Perhaps the simplest method for computed tomography measurement of glenoid bone loss relies on the same techniques used during diagnostic arthroscopy. After approximation of the bare spot with use of the intersection of the longitudinal axis and the widest width on an en face view of the glenoid, the distance from the bare spot to the anterior edge (A) and from the bare spot to the posterior rim (B) are measured\(^2\) (Fig. 7). Percent bone loss is calculated as: \((\frac{B - A}{AB}) \times 100\)%\(^6\). A summary of the various methods for quantifying glenoid bone loss is provided in Table III.

### Arthroscopy

Methods for arthroscopic quantification of glenoid bone loss are based on the fact that the inferior two-thirds of the glenoid cavity is circularly shaped\(^7,27\). As shown by Burkhart et al., the glenoid bare spot is consistently equidistant from the anterior, posterior, and inferior glenoid margins and can be regarded as a practical center point for the inferior part of the glenoid circle\(^7\). With use of the glenoid bare spot as a geometrical reference point, the percentage of glenoid bone loss can be calculated during arthroscopy by measuring the anterior and posterior distances to the glenoid rim\(^25,27\) (Fig. 8, A and B).

To effectively utilize the glenoid-bare-spot method for intra-articular quantification, one must understand the optimum circumstances for its use. As we showed previously\(^7\), the glenoid-bare-spot method is most accurate for quantifying Bankart lesions that occur parallel to the long axis of the glenoid. In these situations, arthroscopic measurement from either the 2 o’clock or the 3 o’clock posterior portal is sufficient for true measurement of bone loss. If the glenoid rim defect occurs at a 45° angle relative to the long axis of the glenoid, the glenoid-bare-spot method substantially overestimates the amount of bone loss\(^20\). However, glenoid bone loss does not typically occur

### TABLE III Computed Tomography Methods\(^*\) for Quantification of Glenoid Bone Loss\(^8,22-4,26,47\)

<table>
<thead>
<tr>
<th>Quantification Method</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Surface area method(^22)</td>
<td>• Three-dimensional computed tomography image of glenoid with humeral head subtraction is obtained</td>
</tr>
<tr>
<td>Superimposed circle method(^8)</td>
<td>• Best-fit circle is drawn on inferior 2/3 of pear-shaped glenoid</td>
</tr>
<tr>
<td></td>
<td>• Osseous deficiency is measured directly on circle with use of digital means</td>
</tr>
<tr>
<td>Pico method(^47)</td>
<td>• Best-fit circle centered at bare-spot approximation is drawn on injured glenoid and contralateral, uninjured glenoid</td>
</tr>
<tr>
<td></td>
<td>• Glenoid circle on normal shoulder is superimposed on injured-shoulder circle</td>
</tr>
<tr>
<td></td>
<td>• Preinjury size and amount of bone loss are calculated</td>
</tr>
<tr>
<td>AP distance from bare area method(^26)</td>
<td>• Best-fit circle is drawn on inferior portion of contralateral, uninjured glenoid with use of MPR (multiplanar reconstruction) software, and its surface area (A) is digitally calculated</td>
</tr>
<tr>
<td></td>
<td>• Circle is superimposed onto injured glenoid, and surface area of defect (D) is calculated</td>
</tr>
<tr>
<td></td>
<td>• Percent bone loss = (\frac{D}{A} \times 100)%</td>
</tr>
<tr>
<td>Bankart length measurement(^24)</td>
<td>• Bare area is approximated on computed tomography with use of intersecting lines</td>
</tr>
<tr>
<td></td>
<td>• Distances are measured from bare area to anterior edge of osseous lesion (A) and from bare area to posterior aspect of glenoid rim (B)</td>
</tr>
<tr>
<td></td>
<td>• Percent bone loss = (\frac{B - A}{2B} \times 100)%</td>
</tr>
<tr>
<td>Ratio method(^23)</td>
<td>• Best-fit circle with radius (R) drawn on inferior 2/3 of glenoid</td>
</tr>
<tr>
<td></td>
<td>• Length of osseous lesion (x) is measured</td>
</tr>
<tr>
<td></td>
<td>• If x &gt; R, dislocation resistance is ≤70% of that of an intact joint</td>
</tr>
<tr>
<td></td>
<td>• Best-fit circle with radius (R) is drawn on inferior 2/3 of injured glenoid</td>
</tr>
<tr>
<td></td>
<td>• Distance is measured from center of circle to anterior edge of osseous lesion (d)</td>
</tr>
<tr>
<td></td>
<td>• Percentage bone loss found with use of ratio d/R and specialized graph expressing percent bone loss as function of (d) and (R)</td>
</tr>
</tbody>
</table>

\(^*\)A three-dimensional computed tomography scan with digital subtraction of the humeral head is best for accurate quantification.
at a 45° angle. Rather, it occurs along a line parallel to the long axis of the glenoid, and the measurement from the posterior rim to the anterior rim of the glenoid provides reasonable and accurate depiction of glenoid bone loss (Fig. 9).

Other authors have described additional problems with the glenoid-bare-spot method that pertain to its reliance on the glenoid bare spot. Kralinger et al. used computed tomography verification to show that the glenoid bare spot is approximately
1.4 mm anterior to the true center point, a finding that implies that the glenoid-bare-spot technique overestimates bone loss. Huysmans et al., despite pioneering the notion that the inferior aspect of the glenoid can be compared with a true circle, demonstrated that the glenoid bare spot is not identifiable in all shoulders. In order to circumvent problems associated with

\[ FN = (DE \times \frac{ME}{NE}) - NE \]

Fig. 10
The secant method for quantification of bone loss. A: A secant is a straight line that intersects the circumference of a circle twice and extends beyond the radius. When two secants share an end point outside of a circle, the products of their lengths and external segments are equal. The formula \( FN = (DE \times \frac{ME}{NE}) - NE \) can be derived from this relationship. B: To estimate glenoid bone loss, the lengths of segments DE, ME, and NE are determined as shown. Next, the theoretical value of FN (\( FN_{calc} \)) is calculated with use of the formula \( FN_{calc} = (DE \times \frac{ME}{NE}) - NE \). The actual value of FN (\( FN_{meas} \)) is then measured intra-articularly with use of a calibrated probe. The percent bone loss is estimated as \( \left( \frac{FN_{calc} - FN_{meas}}{FN_{calc}} \right) \times 100\% \). (Drawings by Sanjeev Bhatia, MD.)

Fig. 11
Losses of <15% of the width of the glenoid (<3 to 4 mm from the anterior rim) are probably unimportant in most patients. Defects of 15% to 30% (between 4 and 9 mm of bone remaining anterior to the bare spot) are relevant in some patients. Finally, losses of >30% (<4 mm of bone left anterior to the bare spot) are likely to be important in most patients. A: A summary of critical bone defects. B: A typical glenoid seen in most patients with >30% bone loss. The posterior slope of the defect results in a narrower inferior glenoid width, leading to the so-called inverted-pear glenoid (when viewed superiorly through the anterosuperior portal). (Reprinted, with permission, from: Piassecki DP, Verma NN, Romeo AA, Levine WN, Bach BR Jr, Provencher MT. Glenoid bone deficiency in recurrent anterior shoulder instability: diagnosis and management. J Am Acad Orthop Surg. 2009;17:482-93.)
the glenoid-bare-spot method, Detterline et al. developed a new technique for glenoid bone loss quantification that relies on the secant chord theory. Simply put, a secant is a straight line that intersects the circumference of a circle twice and extends beyond the radius. With use of simple geometry of chords and secants, the percentage of glenoid bone loss can be calculated with a simple formula (Fig. 10, A and B).

**Amount of Glenoid Bone Loss**
The anterior-to-posterior dimension of the glenoid at the level of the bare spot is between 23 and 30 mm, and in most patients it ranges from 24 to 26 mm. Thus, a 25% glenoid bone injury or loss comprises about 6 to 8 mm of the glenoid. This underscores the finding that only a relatively small amount of bone loss is required for clinical relevance. As an additional diagnostic and treatment aid, one can consider the glenoid in 5% increments, with each 5% increment comprising about 1.5 to 2.0 mm of bone (Fig. 11).

**Glenoid Bone Loss Treatment Algorithm**
The degree of glenoid bone injury or loss, patient expectations, and the anticipated postoperative activity level are the three most important factors to consider when selecting treatment for patients with recurrent shoulder instability. Other factors to consider are listed in Table IV. Nonsurgical treatment may be appropriate for patients with <20% glenoid bone loss who have low activity demands, are sedentary, or are older as well as for those with a high surgical risk or a history of voluntary glenohumeral dislocation. If nonoperative management fails or if the patient is a highly active individual with glenoid osseous deficiency, surgery is generally indicated. In patients with a previous failure of a surgical repair that was done to address shoulder instability who currently have recurrent instability, it is imperative to rule out glenoid bone loss as a contributing factor prior to considering further surgical treatment.

As shown in Figure 12, the decision-making regarding surgical treatment of a patient with recurrent shoulder instability and glenoid bone loss may be aided by the following recommendation. In patients with 0% to 20% (and even up to 25%)
glenoid bone loss, it may be possible to treat the instability successfully with arthroscopic repair. Multiple anchors may be used, and a posterior repair may help to balance the repair. Although these patients have only minor bone loss, incorporation of the Bankart fragment has been shown to potentially improve the outcome. However, some authors have advocated bone augmentation procedures even in those with little or no glenoid bone loss and have reported excellent clinical outcomes.

Patients with between 15% and 25% glenoid bone loss may still be treated with arthroscopic techniques, but these techniques should be used more cautiously, as instability-related failure has been associated with this amount of glenoid bone loss. In these patients, sound osseous fragment fixation is imperative and open capsulolabral repair is still considered the gold standard for surgical treatment. If the osseous Bankart fragment has either partially or fully resorbed, which is often the case with attritional bone loss seen in association with chronic instability, bone augmentation techniques may be needed. In addition, patients’ expectations and desires should be thoroughly addressed when treatment is being discussed for any amount of glenoid bone loss, as the risk of recurrent instability after open repair or glenoid bone augmentation procedures is clearly decreased compared with that after arthroscopic repair, especially with an increased percentage of glenoid bone loss.

In patients with greater than 20% to 25% bone loss, open bone augmentation procedures such as the Latarjet, iliac crest bone-grafting, or allograft technique should be considered primarily to reconstitute the glenoid osseous arc. Transfer of the coracoid has been used for more than fifty years, with excellent results in terms of shoulder stability and function. However, there are concerns about postoperative arthritis and limitations in shoulder motion after the nonanatomic coracoid reconstruction. Other bone graft options, including the use of autogenous iliac crest graft and various frozen and fresh osteochondral allografts, have also been described. Ultimately, the patient’s wishes

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**Fig. 13**

Arthroscopic repair of an osseous Bankart lesion. A: Anterior labral bone fragment attached to the glenoid labrum. B: A combination of an arthroscopic bone-cutting shaver (<3.5 mm in diameter so that it can easily fit between the bone fragments) as well as a small arthroscopic burr or arthroscopic rasp is very helpful to adequately prepare the glenoid prior to fixation. C: Sutures being passed through the fragment-labral interface. D: The final repair construct. (Reprinted, with permission, from: Piasecki DP, Verma NN, Romeo AA, Levine WN, Bach BR Jr, Provencher MT. Glenoid bone deficiency in recurrent anterior shoulder instability: diagnosis and management. J Am Acad Orthop Surg. 2009;17:482-93.)
Surgical Options for the Treatment of Glenoid Bone Loss

Arthroscopic Repair

If the osseous defect is less than 20% to 25%, the Bankart fragment may be reliably repaired with use of an arthroscopic technique (Fig. 13). Several techniques utilizing suture anchors and a variety of suture configuration constructs to repair the osseous injury have been described. Arthroscopic methods may be used for an acute glenoid fracture as well as in patients who have attritional or partial attritional glenoid bone loss. The main goal is to incorporate any remaining bone fragment into the repair and to restore the tension in the capsulolabral soft-tissue structures. Bankart lesion fixation is accomplished with suture anchors introduced through a posterolateral, transsubscapularis, or midglenoid portal. The posterolateral portal allows ease of access to the inferiormost aspect of the glenoid, especially if the patient is in the lateral decubitus position.

Preparation of the native glenoid and osseous surfaces is imperative for a successful repair. A combination of an arthroscopic bone-cutting shaver (<3.5 mm in diameter so that it can easily fit between the bone fragments) as well as a small arthroscopic burr or arthroscopic rasp is very helpful to adequately prepare the glenoid osseous surface prior to fixation (Fig. 13, B). Adequate preparation of the anterior aspect of the glenoid neck is signified by visualization of the posterior subscapularis fibers through the capsule, which has been elevated subperiosteally off the glenoid.

Arthroscopic repair techniques continue to evolve, and special instruments such as sharp penetrators, sharp suture hooks, or other curved suture devices or punches may be utilized in order to punch through the mid-aspect of the glenoid bone fracture or bone injury. If the glenoid bone loss is partially attritional in nature or chronic, the glenoid bone fragment is usually relatively soft, and standard arthroscopic repair devices will usually penetrate the bone. A variety of anchors and suture configurations—both standard and knotless—may be utilized for effective surgical repair in this scenario (Fig. 13, C and D).

Postoperatively, patients wear a shoulder abstraction sling for four to six weeks to allow the osseous injury and capsular repair to heal. Passive shoulder flexion and abduction in the scapular plane as well as gentle passive pendulum exercises and isometric strengthening of the scapular musculature are allowed during this time. At six weeks after the surgery, patients use more progressive shoulder motion, coupled with a comprehensive strengthening program. By four to five months, patients may return to competitive sports and most activities, although those who engaged in contact sports and those whose shoulder is routinely in a provocative instability position of abduction and external rotation might wait for six months until they fully return to activities.

Open Stabilization

As described by Pagnani, open stabilization is a simple and effective means for improving glenohumeral joint stability. Through a standard deltopectoral approach, the subscapularis tendon is transected approximately 1 cm medial to its insertion on the lesser tuberosity. The interval between the subscapularis tendon and the underlying anterior aspect of the capsule is developed. It is helpful to isolate the underlying capsule more medially and to bluntly dissect toward the lesser tuberosity prior to completing the subscapularis tenotomy.

The capsule is divided transversely, allowing placement of a humeral head retractor. If a labral lesion is encountered, the detached labrum is elevated from the glenoid neck with angled liberator devices. The glenoid neck is abraded with a rasp or mechanized burr to healthy bleeding bone, and anchors are placed into the glenoid at the anterior glenoid cartilage margin.

The anchor sutures are utilized to imbricate the inferior aspect of the divided capsule into the Bankart repair. Capsulorrhaphy is performed by one of two methods. If there is <5 mm of overlap between the inferior and superior aspects of the divided capsule, the edges are imbricated by suturing the superior aspect of the capsule over the inferior aspect of the capsule with the same sutures. If the overlap exceeds 5 mm, then a vertical capsular incision is made at the articular margin of the humeral neck to facilitate a larger capsular shift. The

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T-capsular incision (Fig. 14) allows the inferior aspect of the capsule to be shifted superolaterally, while the superior aspect of the capsule can be closed inferomedially (Fig. 15). The capsular repair and shift are done with the glenohumeral joint in 45° of abduction and external rotation.

The subscapularis is repaired with nonabsorbable suture, and the deltopectoral interval is loosely reapproximated.

Latarjet Procedure

In the Latarjet procedure, a locally harvested coracoid autograft is positioned to become an extra-articular platform that acts as an extension of the articular arc of the glenoid. Three processes work together to improve anterior shoulder stability. First, the osseous block serves to extend the glenoid rim and enhances the “safe arc” available for translation prior to dislocation. Second, the conjoined tendon functions as a sling to resist anterior humeral translation when the arm is abducted and externally rotated. Finally, the transferred coracoid and conjoined tendon over the lower subscapularis tendon create a tenodesis effect that reinforces a deficient anteroinferior aspect of the capsule. There are numerous methods with which to perform a Latarjet osseous reconstruction of the glenoid—ranging from utilizing the coracoid as a free intra-articular graft to employing the triple-blocking effect of the graft and soft-tissue sling. Suture anchors may be utilized on the anterior-most aspect of the native glenoid at the coracoid-glenoid interface in order to repair the native capsule that has been previously dissected off the glenoid neck. Typically, two 3.5-mm metal screws are utilized to fix the coracoid in position as flush as possible with the native glenoid. The native capsule is then repaired to the native glenoid via suture anchors or bone tunnels so that the coracoid is extra-articular, or the capsule is repaired to the anterior aspect of the coracoid so that the coracoid is intra-articular. Some authors have advocated limited capsule and labral repair, believing that the majority of the stability is provided by restoration of the glenoid arc.

Although the Latarjet procedure has been advocated for many years and has undergone several variations, there have been very few studies that have addressed optimal graft placement and orientation. In a recent biomechanical study, Ghodadra et al. evaluated variations in contact pressure and area in a glenoid bone-loss model with varied placement and orientation of iliac crest autograft and Latarjet graft. Those authors demonstrated optimal normalization of glenohumeral contact pressures with flush placement of the iliac crest autograft and the Latarjet graft oriented with the inferior aspect of the coracoid congruent with the face of the glenoid. In addition, Ghodadra et al. determined that grafts placed 2 mm medial to the glenoid face led to increased edge loading and grafts placed 2 mm lateral to the glenoid face resulted in an increased shift of contact pressure to the posterosuperior quadrant of the glenoid. These authors also found that the coracoid placed with the inferior surface as the glenoid face in an anterior 30% glenoid defect provided a
mean of 9.6 ± 0.1 mm of glenoid diameter reconstruction whereas coracoid placement with the lateral surface as the glenoid face led to a mean addition of 7.3 ± 0.2 mm to the glenoid diameter.

Long-term studies of the Latarjet procedure have confirmed its efficacy and lasting benefits. In a retrospective review of fifty-eight shoulders treated with a Latarjet procedure and followed for an average of 14.3 years, Allain et al. noted an "excellent" result in 88% of the shoulders and no recurrent dislocations. At the time of final follow-up, thirty-four of the fifty-eight shoulders had glenohumeral arthritis, with the majority (twenty-five) having grade-1 changes. Hovelius et al., in a prospective study of 118 shoulders treated with a Bristow-Latarjet repair and followed for an average of 15.2 years, noted an overall satisfaction rate of 98% of the patients. However, in a follow-up study of the radiographs in this population, the authors found moderate-to-severe dislocation arthropathy in 14% of the patients. In perhaps the longest follow-up study on patients treated operatively for anterior shoulder instability (mean duration of follow-up, 26.4 years), Schroder et al. found a nearly 70% rate of

Fig. 16
good-to-excellent results in forty-nine patients who had undergone a modified Bristow procedure. Fifteen percent of the shoulders, however, eventually had recurrent instability, with a mean time to the recurrent dislocation of seven years.

After a Latarjet procedure, patients are treated with a rehabilitation program similar to that used after an arthroscopic repair, although the surgical technique employed for the subscapularis dominates the postoperative protocol. If the subscapularis was taken down either partially or completely, patients should have internal rotation strengthening and passive external rotation protected for at least six weeks. If a subscapularis split was utilized for the Latarjet procedure, patients may be more aggressive in their internal rotation strengthening with less protection of external rotation. However, the subscapularis split is part of the “sling” component of the Latarjet procedure as the conjoined tendon is draped over the subscapularis tendon.

**Iliac Crest Bone-Grafting**

Iliac crest bone graft has also been employed to augment anterior glenoid defects and in some instances may result in a better articular arc match than the coracoid transfer; this is due to the anatomic orientation of the iliac crest graft, which allows the inner table of the iliac crest to become congruent with the glenoid surface. The inner table of the iliac wing is concave and fits the native glenoid curvature well. The iliac crest bone graft has been described as both an intra-articular and an extra-articular construct. The iliac crest bone graft is especially helpful in patients with extensive glenoid bone deficiency as the iliac crest provides an adequate supply of bone to reconstruct large defects (Fig. 16).

**Future Directions for the Treatment of Glenoid Bone Loss**

In order to avoid the potential morbidity of an autograft coracoid and conjoined tendon transfer, various allografts

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**Fig. 17**

A: The lateral aspect of the distal part of the tibia is an excellent fit for the glenoid, providing a nearly anatomic match of the radius of curvature, glenoid and tibial cartilage thickness, and dense corticocancellous weight-bearing bone. B: Acute osseous glenoid deficiency as seen on a three-dimensional computed tomography scan. C: A three-dimensional computed tomography scan of the glenoid obtained shortly after bone augmentation with use of distal tibial allograft. D: The final distal tibial allograft as seen on a postoperative axial computed tomography scan. Note the good incorporation of the allograft into host bone. E: Final postoperative three-dimensional computed tomography scan.
have been identified for use in the treatment of glenoid bone deficiency. Fresh osteochondral glenoid, frozen humeral head, frozen femoral head13, and fresh distal tibial osteochondral grafts have been described14. Although the most logical reconstruction is to replace the missing glenoid bone with similar glenoid bone, these glenoid allograft specimens have been difficult to obtain because of issues with graft contamination, donor consent, and availability14. The lateral aspect of the distal tibial allograft is an excellent fit for the glenoid, providing a nearly anatomic match of the radius of curvature, glenoid and tibial cartilage thickness, and dense corticocancellous weight-bearing bone14 (Fig. 17). In addition, because this allograft is processed fresh and is available without freezing, the normal subchondral osseous architecture is preserved.

Use of a distal tibial allograft for reconstruction of the glenoid surface arc has many potential advantages. In addition to potentially recreating the glenoid articular surface, the distal tibial bone stock is composed of dense corticocancellous bone. The size of the distal tibial allograft can be customized for an individual patient, and the grafts are readily available from allograft distributors.

**Distal Tibial Allograft Technique**

A distal tibial glenoid allograft is applied15 through a deltopectoral approach with the subscapularis split longitudinally. The capsule is exposed and is dissected subperiosteally as medial as possible; it is then tagged with a number-2 nonabsorbable suture. The glenohumeral joint is then exposed, and the amount of glenoid bone loss is assessed.

The glenoid is prepared to receive the allograft. It is important to attempt to maintain any remaining labral tissue, as this will be repaired after osseous augmentation. Occasionally,
as a result of chronic instability, there is attrition of the labral tissue and it cannot be repaired. A high-speed burr is then used to create a uniform glenoid graft bed by making a recipient site that is perpendicular to the articular surface of the glenoid.

Allograft preparation takes place on the back table and begins with measurement of the appropriate width (Fig. 18, A). The lateral aspect of the distal part of the tibia is the ideal portion of the plafond for use, and usually between 8 and 11 mm at the articular surface is required. A 0.5-mm sagittal saw is employed to make the cuts while an assistant secures the graft with pointed reduction clamps or towel clips. The corners of the graft can be rounded with the sagittal saw to closely mimic the morphology of the native glenoid. The allograft is cut with adequate depth, with sufficient subchondral bone to allow placement of 3.5-mm screws to secure the graft to the glenoid (Fig. 18, B).

Prior to fixation of the allograft onto the glenoid, two 1.6-mm Kirschner wires are placed at a 45° angle to the articular surface of the graft (Fig. 18, C) for provisional fixation of the allograft to the glenoid. It is important to plan where the 3.5-mm screws will be placed for final fixation of the graft and to avoid placing the Kirschner wires in these locations. The graft is provisionally fixed with the articular surface of the allograft congruent with the native glenoid (Fig. 18, D). After provisional fixation, the graft is secured to the native glenoid with a lag technique and use of a 3.5-mm fully threaded cortical screw. Typically, these screws measure 34 to 38 mm in length. Washers can be added for additional fixation and dissipation of surface-area forces at the screw-graft interface.

The labrum and capsule are repaired. Prior to final screw tightening, the suture used to repair the labral and capsular tissue is passed under the screw head or washer for secure fixation. After final screw tightening and capsular repair, the wound is closed in the typical fashion. An abduction sling is applied, and the patient gradually returns to active motion over four to six weeks. This is followed by a strengthening program.

**Arthroscopic Glenoid Bone-Grafting**

Performing the Latarjet procedure with use of an all-arthroscopic technique allows the orthopaedic surgeon to improve glenohumeral joint stability while using a minimally invasive approach. First described by Lafosse et al., the arthroscopic Latarjet procedure consists of five stages: exposure, coracoid preparation, coracoid drilling and osteotomy, coracoid transfer, and finally fixation of bone graft. Because an arthrooscope is used, the procedure allows excellent visualization of the coracoid graft’s position, thereby decreasing the risk of anterior bone-block overhang. In theory, this should reduce the risk of rapid-onset osteoarthrosis, a common complication associated with open Latarjet procedures. However, an arthroscopic Latarjet or coracoid transfer technique is a difficult operation with a steep learning curve, even for skilled arthroscopists. In a prospective review of 100 consecutive shoulders that had undergone an all-arthroscopic Latarjet procedure, Lafosse and Boyle noted excellent scores in 91% of those followed at twenty-six months. The mean time until the patients returned to work was two months, and the mean time until they returned to sports was ten weeks. Computed tomography imaging demonstrated that 80% of the patients had a coracoid graft that was placed flush, 8% had a graft that was too medial, and 12% had a graft that had lateral overhang. It is notable that 69% of the patients had no arthrosis at the time of final follow-up.

**Concomitant Pathologic Conditions**

To avoid problems with recurrent instability after shoulder stabilization, patients should be thoroughly evaluated for concomitant shoulder disorders prior to any surgical management. Magnetic resonance imaging or magnetic resonance arthrography is often useful in identifying associated injuries such as glenoid labrum articular disruptions (GLAD lesions),

<table>
<thead>
<tr>
<th>Pathologic Condition</th>
<th>Pearls: How to Treat</th>
</tr>
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<tbody>
<tr>
<td>Rotator cuff tear</td>
<td>Recognize partial tears and look for common tear patterns:</td>
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<tr>
<td></td>
<td>Crescent</td>
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<tr>
<td></td>
<td>U-shaped</td>
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<tr>
<td></td>
<td>L-shaped</td>
</tr>
<tr>
<td></td>
<td>Note: intact cuff confers stability</td>
</tr>
<tr>
<td>Acromioclavicular</td>
<td>Consider a distal clavicle excision vs.</td>
</tr>
<tr>
<td>joint pain</td>
<td>preoperative acromioclavicular joint</td>
</tr>
<tr>
<td>Extensive labral tear</td>
<td>Visualize entire glenoid labrum</td>
</tr>
<tr>
<td>SLAP lesion</td>
<td>Tackle at time of surgery</td>
</tr>
<tr>
<td>ALPSA lesion</td>
<td>Search for concomitant biceps lesion</td>
</tr>
<tr>
<td>HAGL lesion</td>
<td>Search for tear of anterior band of inferior glenohumeral ligament</td>
</tr>
<tr>
<td></td>
<td>Remember labrum and scapular periosteal sleeve are detached</td>
</tr>
<tr>
<td></td>
<td>medially and inferiorly on glenoid neck</td>
</tr>
<tr>
<td>Bankart lesion</td>
<td>Visualize from posterior portal with 30° arthroscope in axillary</td>
</tr>
<tr>
<td></td>
<td>pouch in external and internal rotation</td>
</tr>
<tr>
<td></td>
<td>Repair in both inferior-to-superior and medial-to-lateral</td>
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<tr>
<td></td>
<td>directions</td>
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<tr>
<td>Hill-Sachs lesion</td>
<td>Dissect labrum medially until muscle fibers of subscapularis are</td>
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<tr>
<td></td>
<td>visible</td>
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<tr>
<td></td>
<td>&lt;15% bone loss → labral and capsular repair</td>
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<tr>
<td></td>
<td>15%-25% bone loss → incorporate osseous fragment into repair</td>
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<td></td>
<td>&gt;25% bone loss → glenoid bone reconstruction</td>
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<tr>
<td></td>
<td>If engaging, consider remplissage or bone augmentation</td>
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</table>

* A thorough preoperative work-up should aim to identify concomitant shoulder injuries.
anterior labral periosteal sleeve avulsions (ALPSA lesions), and humeral avulsions of the glenohumeral ligaments (HAGL lesions). Tips for addressing concomitant pathologic conditions are listed in Table V.

Overall, there are multiple well-supported approaches for the operative management of shoulder instability. Optimal treatment should be guided by the extent of glenoid bone loss and anticipated patient activity levels. Tips for avoidance of common surgical complications are listed in Table VI.

Conclusions

The diagnosis and management of glenoid bone loss in patients with recurrent shoulder instability continue to evolve. The finding of glenoid bone loss should be suspected in a patient with a prolonged history of instability, multiple dislocations, a progressive ease of dislocation, and symptoms of humeral head engagement. Multiple radiographic studies for evaluation of glenoid bone loss are available; however, the three-dimensional reformatted computed tomography scan provides the most accurate assessment of bone deficiency or combined glenoid and humeral head defects. Multiple procedures, ranging from arthroscopic to open repair to open bone-grafting techniques, have been successfully employed in the management of glenoid bone defects.


consistent landmark for shoulder arthroscopy? A study of 20 embalmed glenoids

Kralinger F, Aigner F, Longato S, Rieger M, Wambacher M. Is the bare spot a

Burkhart SS, Debeer JF, Tehrany AM, Parten PM. Quantifying glenoid bone loss


