Clinical Sports Medicine Update

Management of Recurrent Anterior Shoulder Instability With Bipolar Bone Loss

A Systematic Review to Assess Critical Bone Loss Amounts

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Background: There is increasing evidence to suggest that the amount of glenoid bone loss to indicate bone block procedures may be lower than previously thought, particularly in the presence of a Hill-Sachs defect.

Purpose: To better establish treatment recommendations for anterior shoulder instability among patients with bipolar bone lesions.

Study Design: Systematic review and meta-analysis; Level of evidence, 4.

Methods: A systematic review of the literature was performed with PubMed, EMBASE, Cochrane Library, and Scopus databases according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines. Studies evaluating outcomes of operative management in anterior shoulder instability that also reported glenoid bone loss in the presence of Hill-Sachs defects were included. Recurrence rates, glenoid bone loss, and humeral bone loss were pooled and analyzed with forest plots stratified by surgical procedure. Methods of quantification were analyzed for each article qualitatively.

Results: Thirteen articles were included in the final analysis, with a total of 778 patients. The mean ± SD age was 24.9 ± 8.6 years. The mean follow-up was 30.1 months (range, 11-240 months). Only 13 of 408 (3.2%) reviewed bipolar bone loss articles quantified humeral and/or glenoid bone loss. Latarjet procedures had the greatest glenoid bone loss (21.7%; 95% CI, 14.8%-28.6%), followed by Bankart repairs (13.1%; 95% CI, 9.0%-17.2%), and remplissage (11.7%; 95% CI, 5.5%-18.0%). Humeral bone loss was primarily reported as percentage bone loss (22.2%; 95% CI, 13.1%-31.3% in Bankart repairs and 31.7%; 95% CI, 21.6%-41.1% in Latarjet) or as volumetric defects (439.1 mm^3; 95% CI, 336.3-541.9 mm^3 in Bankart repairs and 366.0 mm^3; 95% CI, 258.4-475.4 mm^3 in remplissage). Recurrence rates were as follows: Bankart repairs, 19.5% (95% CI, 14.5%-25.8%); remplissage, 4.4% (95% CI, 1.3%-14.0%); and Latarjet, 8.7% (95% CI, 5.0%-14.7%). Bankart repairs were associated with significantly greater recurrence of instability in included articles (P = .013).

Conclusion: There exists a need for universal and consistent preoperative measurement of humeral-sided bone loss. The presence of concomitant Hill-Sachs defects with glenoid pathology should warrant more aggressive operative management through use of bone block procedures. Previously established values of critical glenoid bone loss are not equally relevant in the presence of bipolar bone loss.

Keywords: shoulder instability; bipolar bone loss; Hill-Sachs defect; critical bone loss

Since 1855 the Hill-Sachs defect has been described on the posterolateral aspect of the humerus after traumatic anterior shoulder dislocation. Shoulder radiographs, specifically the Stryker notch view, demonstrate the incidence of Hill-Sachs defects to be between 42% and 51% among patients with recurrent anterior instability.[7] Diagnostic arthroscopy has identified an incidence of this lesion as high as 90%[71] among patients undergoing operative treatment for instability symptoms. The advent of advanced imaging modalities in computed tomography (CT) and magnetic resonance imaging (MRI), particularly with 3-dimensional (3D) reconstruction, have improved the detection of this lesion.[16,43] The true incidence, however, is still unknown.[16,43] Despite this, quantification of the Hill-Sachs defect is not standard or commonplace in

The American Journal of Sports Medicine
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DOI: 10.1177/0363546518791555

practice. The Bankart repair is generally the first indicated surgical option for anterior instability, and it consists of a soft tissue–only procedure that addresses the anteroinferior labrum to provide a deeper cup of articulation for the humerus. In cases of increasing severity, a remplissage procedure that involves a capsulotenodesis of the infraspinatus or Latarjet to incorporate the coracoid process with the glenohumeral joint may be used. Both procedures increase the articulation of the glenohumeral joint. For patients with traumatic anterior instability, the Hill-Sachs defect is typically not addressed with soft tissue capsulolabral repair, and there is limited evidence to determine the effect of bipolar defects on outcomes of instability repairs.[51]

The engaging Hill-Sachs defect is a critical bony variable associated with an increased recurrence rate after isolated Bankart repairs that is attributed to a deficit in the articular arc of the glenohumeral joint.[5] The concept of the glenoid track predicts engagement by pairing the articular surfaces of the glenoid and humerus.[66] Hill-Sachs defects that articulate with the glenoid outside this track will engage the anteroinferior glenoid.[66] Biomechanical studies determined that a monopolar humeral bone loss of 20% to 37.5% is required to create engaging Hill-Sachs defects[36,53,68]; however, no clinical corollary exists to date. Glenoid bone loss is directly related to a reduction in the glenoid track and an increased risk of engagement, which would imply that both articular surfaces must be examined together to determine a patient's risk of dislocation.[68]

There is increasing evidence suggesting that the amount of glenoid bone loss to indicate bone block procedures may be lower than previously thought.[50] Recent literature reported worse outcomes after Bankart repair, with as little as 13.5% or greater glenoid bone loss,[14,49,55] which is far less than the 20%-25% threshold established through initial cadaveric study.[29,67] The concept of the glenoid track illustrates the arc of the glenohumeral joint, wherein greater glenoid bone loss results in reduced articulating surface and an increased propensity for the Hill-Sachs defect to engage. Treatment algorithms incorporating the glenoid track and humeral bone loss have been developed, although not validated through clinical outcomes.[16,20,36] Further examination of the relationship of glenoid bone loss, humeral bone loss, and the glenoid track must be made to accurately guide clinical decision making.

The purpose of this systematic review is to better establish treatment recommendations of anterior shoulder instability among patients with bipolar bone lesions.

TABLE 1
Boolean Search Criteria for Systematic Review

"Glenoid defect" OR Bankart lesion OR "osseous Bankart" OR "bony Bankart" OR "humeral defect" OR "shoulder instability" OR "bipolar instability" OR "primary instability" OR "recurrent instability" OR "glenoid bone loss" OR "bony defect" OR "humeral bone loss"
NOT "arthroplasty," NOT "replacement"
AND "surgical procedures," "operative" OR "orthopedics" OR "orthopaedics"

METHODS

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines were used to perform a systematic review of the available literature.

Search Strategy

A literature search was performed with the PubMed, EMBASE, Cochrane Library, and Scopus databases. The Boolean search indicated in Table 1 was performed. The initial search was performed on September 5, 2017. The search was reviewed on December 19, 2017, to include newly released articles. During full article review, references of each article were manually reviewed to include any additional articles into final analysis. This search was also performed with ClinicalTrials.gov and the International Clinical Trials Registry Platform to identify ongoing clinical trials relevant to this study.

Selection Criteria

Articles were included that reported operative management with outcomes of recurrent anterior shoulder instability and quantitatively reported bipolar bone loss (regardless of technique). The following study designs were included: case series, prospective and retrospective cohort, case-control, and randomized controlled. Exclusion criteria were as follows: animal or cadaveric subjects, literature reviews, noninstability populations, nonhomogeneous populations, revision surgery, primary dislocations with no bone loss, multidirectional instability, and lack of quantification in glenoid and/or humeral bone loss. Articles with <18-month mean follow-up were excluded, as well as those that did not report clinical outcomes of surgery.

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One or more of the authors has declared the following potential conflict of interest or source of funding: N.N.V. has received research support from Arthrex Inc and Smith & Nephew Inc, intellectual property royalties from Smith & Nephew Inc, stock or stock options from Cymedica Orthopedics, food and lodging from Stryker Corporation, and consulting fees from MEDACTA USA and Wright Medical. M.T.P. has received IP royalties and consulting fees from Arthrex Inc, food and lodging from Smith & Nephew Inc, Stryker Corporation, Wright Medical, Gemini Mountain Medical LLC, Zimmer Biomet, and Sanofi-Aventis.

Quality Evaluation

No randomized trials were found during the literature search, so the MINORS (Methodological Index for Non-randomized Studies) checklist was used to evaluate the quality of nonrandomized surgical studies.[57] Twelve items were evaluated to determine quality, and only the last 4 were applicable to comparative studies. Scoring was scaled from 0 to 2 (0, not reported; 1, reported but poorly done and/or inadequate; and 2, reported well done and adequate). Noncomparative studies had a maximum score of 16, while comparative studies had a maximum of 24. Each study included in the analysis was scored by 2 authors (J.N.L., A.K.G.), who reached consensus if disagreement occurred.

Data Extraction and Analysis

Articles included in this study were evaluated according to the following categories: article details, patient demographics, operative techniques, complications and failures, and bone loss measurements.

Data analysis was performed with the metafor package as part of RStudio software (v 1.0.143; R Foundation for Statistical Computing). The recurrence rate of instability after surgery was used as the primary outcome. This was stratified by different surgical procedures: capsulolabral repair, Latarjet procedure, and arthroscopic remplissage with Bankart repair. Pooled data were reported in forest plots, and the I^2 index was used to measure heterogeneity. Articles with low heterogeneity were modeled with a fixed effects model. For pooled estimates from articles with greater heterogeneity, effect sizes were determined with the random effects model and DerSimonian-Laird estimator.[12,13,19] Random effects models are better suited to incorporate between-article variability while estimating the pooled effect.[2,12,13] Duplicate patient populations were included in this review but withheld from pooled meta-analysis. All outcomes were reported with a 95% CI.

A funnel chart was used to evaluate publication bias with reported recurrence rates of all articles. The funnel chart is a graphic representation of treatment outcomes with respect to effect sizes. Symmetric distribution of the funnel suggests limited bias toward a particular outcome. The estimated treatment effect was plotted on the x-axis, while the size of each study was plotted on the y-axis. Larger studies were plotted at the top and smaller near the bottom. Point estimates were checked to be distributed evenly and symmetrically around the real effect of treatment to determine if no bias exists.[62]

RESULTS

Articles Included

Thirteen studies were included in the final analysis. Given the comparison groups, 23 homogeneous populations with separated outcomes were used in the analysis from these articles. A flow diagram was created to summarize this literature search (Figure 1). Eleven populations were used in meta-analysis of the recurrence rate, and 11 were used in meta-analysis of glenoid bone loss. Seven articles were used in meta-analysis of humeral bone loss by percentage loss, while 6 articles were used in meta-analysis of humeral bone loss by volume (mm^3). From full article review of 408 articles, 395 articles were excluded because they did not report either glenoid or humeral bone defect sizes. In only 13 of 408 (3.2%) articles in which outcomes of shoulder instability are reported, both glenoid bone loss and humeral bone loss were quantified.

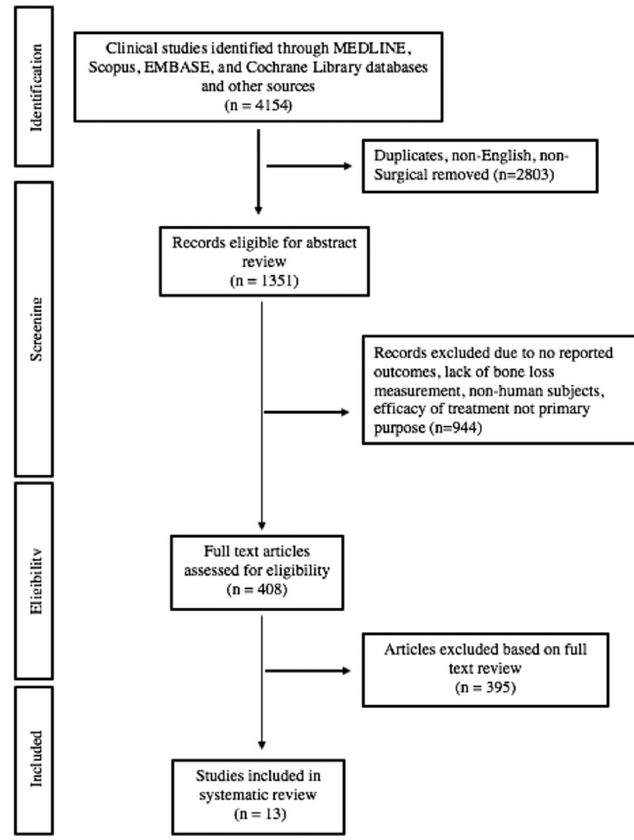
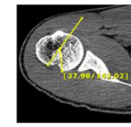
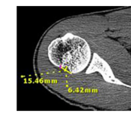
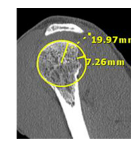
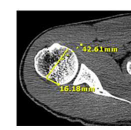
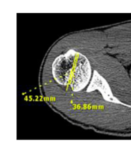
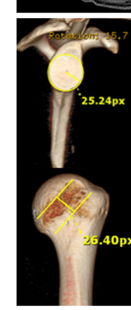
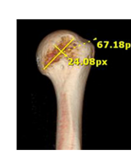


Figure 1. PRISMA (Preferred Reporting Items for Systematic Meta-analyses) flow diagram of included articles in review of bipolar bone loss.

Study Characteristics and Quality

The study design consisted of 6 case series and 7 retrospective comparative cohorts. Comparison groups were composed of either differing techniques of surgery (n = 4) or differing degrees of bone loss (n = 3). All articles used 3D CT to measure bone loss in the humerus and glenoid; however, 2 articles also used MRI (Appendix Tables A1 and A2, available in the online version of this article). The mean ± SD MINORS score for noncomparative studies was 11.8 ± 3.6 out of a possible 16. For comparative studies, the mean MINORS score was 17.6 ± 0.5 out of a possible 24.

TABLE 2
Techniques to Quantify and Determine Engagement of Humeral Bone Loss[a]

Quantification Method	Description	Measurement of Engagement	Sample Measurement
Hall (1959)[24]	• Axial CT/MRI • Measure degrees of involvement in single slice (Z) • Z/180 × 100	Not reported	
Rowe (1984)[52]	• Axial CT/MRI • Measure depth and width of lesion on single slice • Mild: $<2 \times 0.3$ cm^2 • Moderate: 2-4 × 0.3-1 cm^2 • High: $>4 \times 1$ cm^2	Not reported	
Charousset (2010)[8]	• Axial CT scan • Circle drawn at greatest depth of lesion • Width and depth measured • Width/diameter and depth/diameter measured as percentage of diameter	Dynamic arthroscopy	
"P/R depth ratio index": Cho (2011)[11]	• AP shoulder in internal rotation • Circle created to contour humeral head • Depth of lesion (P) as ratio of radius (R)	Not reported	
"Flatow method": Flatow (1998)[18]	• Clinically insignificant <20% • Variable significance: 20%-40% • Clinically significant: >40%	Not reported	
Di Giacomo (2014)[16]	• Not reported	• Perfect circle method for glenoid defect to measure diameter (D) and bone loss (X) • Width of glenoid track (GT) = 0.83D – X • Hill-Sachs (HS) measured from articular insertion of rotator cuff to medial margin of lesion • HS > GT: off-track • HS < GT: on-track	
Ozaki (2014)[43]	• 3D reconstruction with DICOM images • Major axis, L, and minor axis, W, measured on reconstruction • Depth measured on axial slice CT • Calculated as percentage of diameter	Dynamic arthroscopy	

[a]3D, 3-dimensional; AP, anterior-posterior; CT, computed tomography; MRI, magnetic resonance imaging.

Quantification of Humeral Bone Loss

Seven techniques of measuring humeral bone loss were referenced from in vivo studies. These are the only measurements used to determine a percentage of humeral bone loss (Table 2).

Patient Characteristics

A total of 778 patients were included in the analysis: 442 male, 90 female, and 246 not reported. The mean age was 24.9 ± 8.6 years. The mean follow-up was 30.1 months (range, 11-240 months).

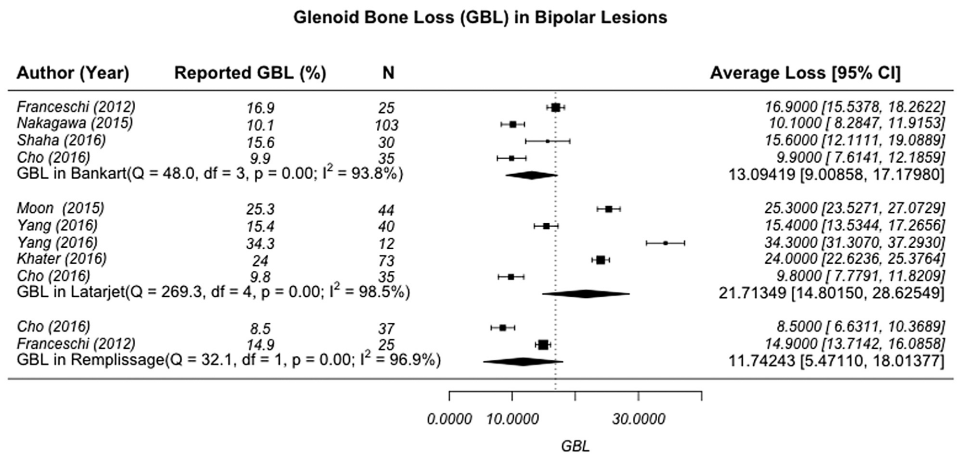


Figure 2. Glenoid bone loss reported in series with bipolar defects. Heterogeneity: Q value = 48.0, df = 3, $P < .001$, I^2 = 93.8% (Bankart repair); Q value = 269.3, df = 4, $P < .001$, I^2 = 98.5% (Latarjet); Q value = 32.1, df = 1, $P < .001$, I^2 = 96.9% (remplissage with Bankart repair).

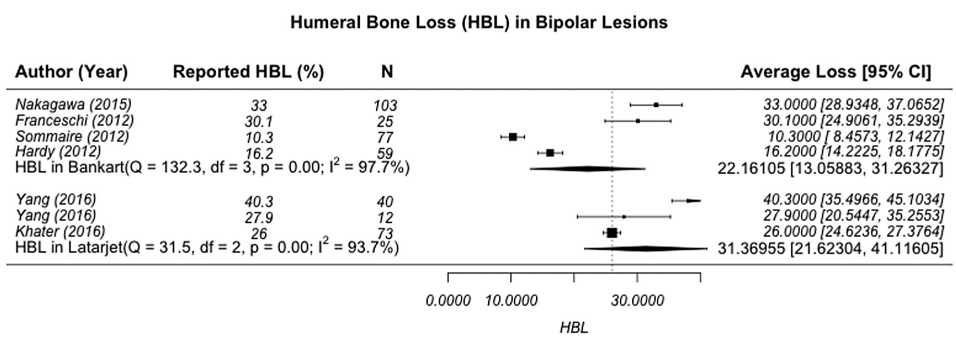


Figure 3. Humeral bone loss reported by percentage. Heterogeneity: Q = 132.3, df = 3, $P < .001$, I^2 = 97.7% (Bankart repairs); Q = 31.5, df = 2, $P < .001$, I^2 = 93.7% (Latarjet).

Glenoid Bone Loss

Glenoid bone loss was measured in 9 included articles, although 2 did not report exact amounts. The bare area method was used 4 times, ratio method once, and surface area method once, and 3 articles did not specify a technique. Eight articles identified these defects with 3D CT, 2 with MRI, 2 with radiographs, and 1 with arthroscopy. Patients treated with arthroscopic remplissage with Bankart repair reported the least glenoid bone loss (11.7%; 95% CI, 5.5%-18.0%), while those who underwent Latarjet reported the greatest bone loss (21.7%; 95% CI, 14.8%-28.6%) (Figure 2). There was a statistically significant difference in the bone loss of Latarjet in comparison with remplissage with Bankart and Bankart only (P = .035).

Humeral Bone Loss

Mean humeral bone loss was pooled among all patients with bipolar lesions. Among studies that quantified humeral bone loss, there was no difference in humeral bone loss between Bankart repairs and Latarjet procedures. Four studies reported humeral bone loss by percentage (Figure 3), 3 by volume (Figure 4), and 2 by depth. Humeral defect depth for a series of Bankart repairs was 6.0 ± 1.5 mm; Latarjet, 6.4 ± 2.4 mm; and remplissage, 6.8 ± 1.7 mm. Each measurement modality of humeral bone loss (percentage, volume, and depth) was analyzed separately. From 13 included articles, only 6 reported whether lesions were engaging the glenoid. Three articles did so from dynamic arthroscopy and 2 from MRI, and 1 did not report a methodology.

Recurrence Rates

The recurrence rate of instability among patients with bipolar lesions was reported as 19.5% (95% CI, 14.5%-25.8%) in Bankart repairs, 8.7% (95% CI, 5.0%-14.7%) in Latarjet procedures, and 4.4% (95% CI, 1.3%-14.0%) in arthroscopic remplissage with Bankart repair. Bankart repairs had a statistically greater recurrence rate when compared with remplissage (P = .013) and Latarjet (P = .008) (Figure 5). Mean follow-up for the remplissage group was 25.0 months (range, 19-31); for Latarjet, 31.5 months

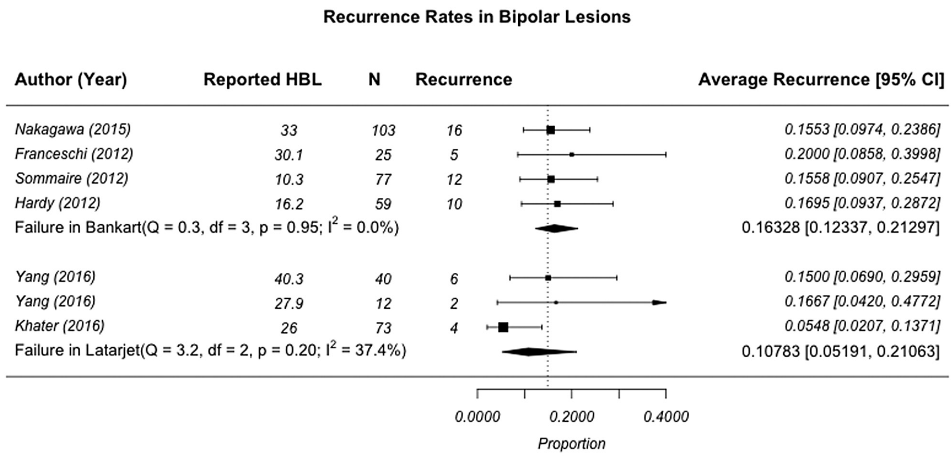


Figure 4. Humeral bone loss reported by volume (mm^3). Heterogeneity: $Q = 8.1$, $df = 2$, $P = .02$, $I^2 = 75.3\%$ (Bankart repairs); $Q = 8.6$, $df = 2$, $P = .01$, $I^2 = 76.8\%$ (remplissage).

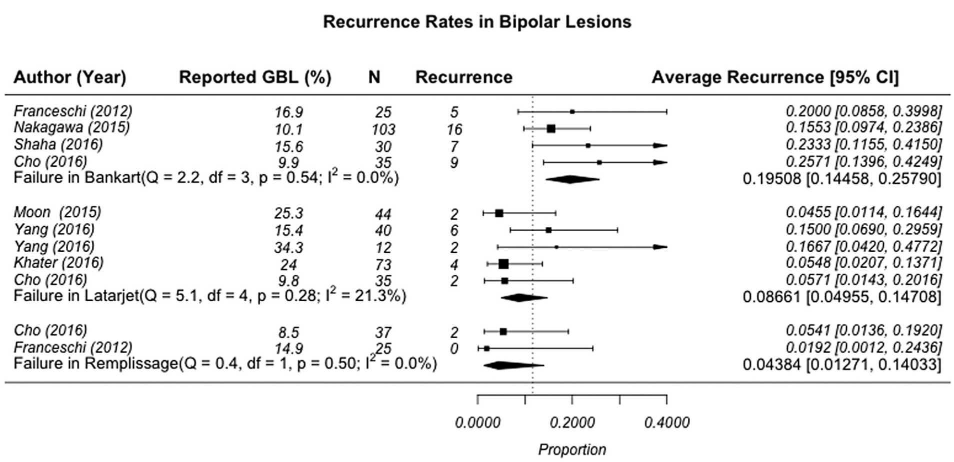


Figure 5. Recurrence rates reported in case series with bipolar lesions. Heterogeneity: $Q = 2.2$, $df = 3$, $P = .54$, $I^2 = 0.0\%$ (Bankart repairs); $Q = 5.1$, $df = 4$, $P = .28$, $I^2 = 21.3\%$ (Latarjet); $Q = 0.4$, $df = 1$, $P = .50$, $I^2 = 0.0\%$ (remplissage).

(range, 19-240 months); and for Bankart, 30.2 months (range, 11-58 months).

A funnel plot was created from the recurrence rates of instability, as this outcome was shared among all articles. No significant publication bias was observed according to the resultant funnel plot (Figure 6).

DISCUSSION

The principal findings of this study demonstrate inconsistent reporting of the size of Hill-Sachs defects, with only 3.1% of the reviewed clinical studies quantifying humeral lesions, despite a previously reported high incidence of Hill-Sachs defects (up to 90%) in recurrent anterior shoulder instability.[71] In the presence of verified bipolar defects, Bankart repair had significantly higher recurrence (19.5%) when compared with Latarjet (8.7%) or Bankart repair with remplissage (4.4%). It is noted, however, that included patients with Latarjet exhibited higher degrees

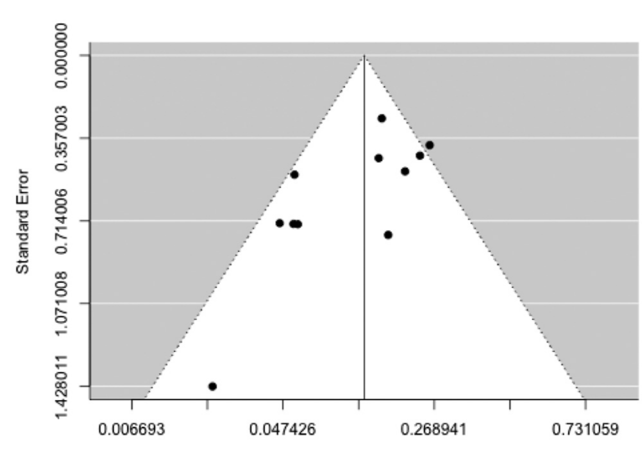


Figure 6. Publication bias funnel plot of all studies with respect to the recurrence rate of instability in bipolar lesions.

of glenoid bone loss (21.7%). Despite inconsistent reporting of engaging lesions (46% articles), measurable bipolar bone lesions were shown to affect recurrence and must be routinely assessed during any instability procedure.

Soft tissue Bankart repair provides no correction of osseous defects in the glenoid and humerus; therefore, it is not surprising that recurrence rates are higher versus Latarjet and remplissage.[9,10,21,33,34,41] The concept of the glenoid track emphasizes the importance of both sides of defects in predicting engagement of a Hill-Sachs defect, as this reduces the articular arc.[1,16,23,37,42,66] Over the past decade, our understanding of the engaging Hill-Sachs defect has grown substantially. All Hill-Sachs defects were previously believed to engage the glenoid in abduction-external rotation, as this was thought to be the mechanism of occurrence.[5,66] However, some lesions are formed because of ligamentous insufficiency that allows the humerus to translate anteriorly.[30] The osseous interaction between the Hill-Sachs defect and engaging glenoid will further exacerbate both poles of bone loss on each subsequent instability event and thereby potentially worsen symptoms. The concept of the glenoid track has improved our understanding of this concept, has provided a practical preoperative mode of assessment, and has been validated clinically to predict worse outcomes in engaging Hill-Sachs defects.[16,42,54,66] Clinical validation of the glenoid track demonstrated that Bankart repairs with off-track lesions failed significantly more than on-track lesions (75% off-track vs 8% on-track dislocated; failures were 60% off-track vs 4% on-track; positive predictive value, 75%; negative predictive value, 92%).[54] These recent studies, with the present review, emphasize the importance of measuring Hill-Sachs defects and determining engagement preoperatively. Seven articles within this review failed to report engagement, and 3 were published after the article by Di Giacomo et al[16] that popularized glenoid track measurement. Failure to address the engaging Hill-Sachs defect, through extending the articular arc with bone block or the remplissage procedure, will predispose recurrence of instability and subsequent increased attritional bone loss that may exacerbate patient symptoms.

The concept of the critical glenoid threshold is commonly used by surgeons to determine whether adjunct or bony procedures are necessary. Recent literature warrants an update to the previously held notion of a critical glenoid bone loss of 25% requiring the bone block procedure.[17,50] The biomechanical literature initially reported glenoid bone loss of 20% to 25% to significantly reduce glenohumeral stability[29,65]; however, recent evidence suggests increased glenohumeral translation contact pressures with glenoid bone loss >10%.[47,56] In recent clinical studies, thresholds as low as 13.5% to 17% were suggested to necessitate additional procedures above and beyond isolated Bankart repair.[14,32,40,47,55] Clinically, bone loss >13.5% was associated with increased risk of dislocation among intercollegiate football players.[14] Within nonathletic populations, although the 13.5% level was not associated with increased failure, patients above this level of bone loss had reduced mean outcome scores for Western Ontario Shoulder Instability and Single Assessment Numeric Evaluation.[55] The present study found that Bankart repairs in the presence of a reported Hill-Sachs defect had a pooled failure rate of 19.5%, although the pooled glenoid bone loss was reported as 13.1%. This exceeds the reported recurrence of instability in prior systematic reviews (6.6%-15.0%).[4,27,28,48] Although a true comparison among studies is limited by heterogeneity, this seems to suggest that the presence of a Hill-Sachs defect should reduce a surgeon's threshold to employ a bone block procedure. Although humeral lesions are seldom considered in operative management, a medium-sized defect classified by Rowe et al[52] (>1.47 cm^3) paired with a 2-mm glenoid defect (<10%) requires significantly less translational force to cause instability. The study by Arciero et al[1] emphasizes the consideration of bipolar lesions in glenohumeral instability, which is corroborated by the findings of the present study.

Preoperative imaging and quantification of both glenoid and humeral bone loss are thus critical in the treatment of recurrent instability as concomitant humeral-sided lesion may change the preferred operative procedure. Radiographs such as the Stryker notch view are able to measure Hill-Sachs defects. However, because this view must be specifically ordered, it may not be an ideal method of quantification. The Stryker notch visualizes glenohumeral articulation but is dependent on the patient to abduct and internally rotate the arm behind the head, which may cause apprehension for patients with recurrent instability. This view also frequently misses Hill-Sachs defects visualized by arthroscopy.[6] CT allows for the visualization of osseous defects regardless of patient positioning, and the advent of 3D reconstructions allows for the most reproducible measurements.[3] Three-dimensional reconstructions from MRI have recently become viable, providing an alternative to protect from high levels of radiation.[61] MRI also demonstrates increased signal intensity attributed to humeral head marrow elements.[60] Three-dimensional MRI showed findings equivalent to those of 3D CT, which suggests that either may be used and that the clinical decision to order one over the other should include consideration of radiation, cost, or concomitant injuries.[70] Given that bone loss measurements were so seldom reported in clinical research, it is reasonable to assume that these measurements are rarely performed in the clinical setting. This may allude to the lack of time to perform them in high-volume centers, the overwhelming number of techniques in measurement, the lack of advanced imaging ordered, or the lack of knowledge given the recency of published articles. Overall, radiographs have largely become outdated in measuring these defects, as noted by the lack of this modality in articles after 2012. Although radiographs serve a purpose to screen patients for obvious defects and dislocation, advanced imaging through CT or MRI should be evaluated in suspicion of osseous defects.

The lack of a standard approach in measuring these lesions is also problematic in reporting measurements. Universal bone loss measurements are necessary to create meaningful recommendations and algorithms. The ideal measurement should be able to be performed quickly during the preoperative clinic visit and without any barriers in accessing technology. Preoperative values are significantly different from those obtained through diagnostic arthroscopy and were shown to influence clinical decision making.[44]

Methodology that combines the techniques of Ozaki et al[43] and Di Giacomo et al[16] to measure Hill-Sachs dimensions and engagement, respectively, demonstrated high interrater reliability for these variables and was the authors' recommended technique for reporting universal measurements.[26]

Article heterogeneity from varying measurements of bone loss, different surgical procedures, and inconsistent reporting resulted in insufficient evidence on which to base a precise bone loss algorithm. Still, results of this review suggest that surgeons should not overlook humeral defects in management of recurrent instability given the high recurrence rates after Bankart repair in the presence of a Hill-Sachs defect. Surgeons may find the need to be more aggressive in application of bony augmentation or humeral adjunct procedures. The senior author's (N.N.V.'s) preferred treatment algorithm for bipolar bone loss, based on the available evidence and the general findings of this review, is as follows (Figure 7). Adjunctive remplissage should be considered with all engaging lesions as determined preoperatively by the glenoid track.[66] In cases of bipolar bone loss, more aggressive procedures should be considered with glenoid bone loss >15%. This threshold was decided in part from support of recent evidence[14,55] and the fact that recurrence rates within our review were significantly higher, although the mean glenoid bone loss was 13.1%. In the presence of bipolar lesions, the threshold to perform bony augmentation must be further reduced to account for reduction in articular arc.[1,23,37] As previously emphasized, glenoid bone loss increases the susceptibility of the Hill-Sachs defect to engage, in which case it must be addressed.[16] Engaging Hill-Sachs defects increase the propensity for failure and further attritional bone loss, so it is critical that this be addressed. From this review, recurrent instability in bipolar bone loss is approaching an unacceptably high level of 20%, which indicates that anterior soft tissue repair is insufficient. The combination of bone loss >15% with engaging Hill-Sachs defects necessitates addressing the humeral and glenoid sides with either remplissage or osteochondral allograft.[17,35,58] Additional considerations not addressed with this treatment algorithm include patient age, male sex, and athletic activity, as these factors are associated with increased risk of recurrent instability.[14,15,64]

Limitations

Analysis of systematic reviews allows for broad conclusions to be made, based on recurrent patterns of results. However, this analysis does not take into account the heterogeneous populations among studies, and it assumes that these populations are comparable. Variability in reporting of humeral bone loss, follow-up data, limited sample size, number of studies, and related risk factors (age, medical history, and recreational activity) cannot be addressed and is likely responsible for the high levels of heterogeneity among reported outcomes. Randomized controlled clinical trials with glenoid bone loss and humeral bone loss as dependent variables for recurrent instability are ideal articles for meta-analyses; however, such studies cannot be feasibly performed. There was no universally standard method of measuring humeral bone loss, which may cause subtle variances in bone loss measurements. Case series were the predominant study design used in this meta-analysis, which creates bias from analyzing inherently heterogeneous data. Nevertheless, the MINORS criteria, as a common tool for evaluating bias in nonrandomized studies, demonstrated these studies to be of adequate quality, and funnel plot indicated minimal associated publication bias.

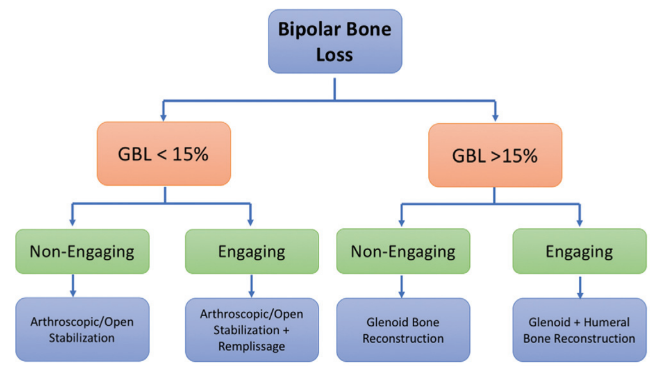


Figure 7. The authors' bipolar bone loss operative management algorithm, with glenoid bone loss (GBL) as defined by the pico method. The presence of humeral bone loss is defined as a Hill-Sachs defect identifiable on preoperative computed tomography imaging.

CONCLUSION

There exists a need for universal and consistent preoperative measurement of humeral-sided bone loss. The presence of concomitant Hill-Sachs defect with glenoid pathology should warrant more aggressive operative management through use of bone block procedures. Previously established values of critical glenoid bone loss are not equally relevant in the presence of bipolar bone loss.

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