Glenoid Bone Loss in Recurrent Shoulder Instability After Arthroscopic Bankart Repair

A Systematic Review

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Background: Glenoid bone loss has been reported to occur in as many as 86% of patients with recurrent shoulder stability. This systematic review evaluated the amount of glenoid bone loss associated with recurrent shoulder dislocation or subluxation and with worse patient-reported outcomes after arthroscopic Bankart repair. We hypothesized that the percentage of glenoid bone loss associated with recurrent instability after arthroscopic Bankart repair is lower than the previously proposed critical value of 25%.

Methods: The systematic review included 528 patients with glenoid bone loss from 3 clinical studies. The percentage of bone loss was the value quantified and reported in each study. Failure was defined as recurrent dislocation or subluxation. The percentage of glenoid bone loss associated with recurrent shoulder dislocation or subluxation after arthroscopic Bankart labral repair was analyzed with receiver operating characteristic (ROC) curve analysis.

Results: Recurrent dislocation or subluxation occurred in 23.7% (125) of 528 patients in the pooled study cohort. There was a significant difference in age between those in whom the arthroscopic Bankart repair failed and those in whom it did not (22.9 versus 24.3 years; p = 0.009). The ROC curve analysis demonstrated that ≥16.0% glenoid bone loss was predictive of recurrent shoulder dislocation or subluxation (Youden index = 0.59, sensitivity = 80%, specificity = 80%). In patients who did not sustain a recurrent dislocation or subluxation, the ROC curve analysis demonstrated that 20.0% glenoid bone loss was predictive of a Single Assessment Numeric Evaluation (SANE) score of <85% (Youden index = 0.93, sensitivity = 93%, specificity = 100%).

Conclusions: The critical amount of glenoid bone loss associated with an increased risk of persistent instability was found to be less than previously reported. Glenoid bone loss of ≥16.0% was found to place patients at higher risk for recurrent shoulder dislocation or subluxation after treatment with arthroscopic Bankart repair alone.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Risk factors for recurrent shoulder instability include male sex, being a contact athlete, an age of <20 years, and glenoid bone loss[1-5]. In the United States, most patients with anterior shoulder instability are treated with arthroscopic Bankart repair[6-11]. However, glenoid bone loss has been reported to occur in as many as 86% of patients with recurrent shoulder instability[12].

In their landmark study, Burkhart and De Beer analyzed the consequences of glenoid bone loss, reporting that lesions involving >25% bone loss can result in an 89% recurrent instability rate[13]. More recently, Shaha et al. coined the concept of subcritical bone loss. They studied military patients treated with arthroscopic Bankart repair alone and found that those who had had ≥13.5% glenoid bone loss had worse scores on patient-reported outcome measures[14]. Numerous previous studies have evaluated glenoid bone loss and its association with recurrent instability and with worse patient-reported outcomes. However, the studies were underpowered and their methods of measuring bone loss and reporting outcomes were inconsistent.

The primary aim of this systematic review was to evaluate the amount of glenoid bone loss associated with recurrent

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shoulder dislocation or subluxation. The secondary aim was to evaluate the amount of glenoid bone loss that results in worse patient-reported outcomes after arthroscopic Bankart repair. We hypothesized that the percentage of glenoid bone loss associated with recurrent instability after arthroscopic Bankart repair is lower than the previously proposed critical value of 25%.

Materials and Methods

Search Strategy

This systematic review was performed according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) guidelines[15]. Two online databases (MEDLINE and Google Scholar) were searched for literature on the measurement and outcomes of anterior glenoid bone loss, and its association with anterior glenohumeral instability, on April 10, 2021.

The Boolean statement utilized in the MEDLINE search was ((glenoid[Title] OR shoulder[Title]) AND (rim[Title]) OR (bone loss[Title]) OR (critical bone loss[Title]) OR (subcritical bone loss [Title]) OR (osseous bankart[Title])). The statement in Google Scholar was allintitle: glenoid AND "rim fracture" OR "bone loss" OR fracture OR "critical" OR "subcritical" OR "bony bankart."

Inclusion and exclusion criteria were established a priori. Inclusion criteria were human studies and English language. Exclusion criteria were review articles, ill-defined measurement of glenoid bone loss, revision surgery, and osseous reconstruction.

Study Screening

Studies were screened independently by 2 reviewers (K.S.M. and J.P.). Screening was done in stages on the basis of the title, abstract, and finally full text; any discrepancies at the title and abstract stages were resolved by automatic inclusion in the next stage of screening. Any discrepancies at the full-text stage of screening were discussed and resolved through consensus between the reviewers. Any relevant referenced articles in the included articles also underwent review.

Quality Assessment

The methodological quality of nonrandomized studies was evaluated using the Methodological Index for NOn-Randomized Studies (MINORS)[16].

Data Abstraction

The corresponding author of each included article was contacted to request deidentified raw data from the study. Data collected included patient age at surgery, gender, duration of follow-up, percentage of glenoid bone loss, failure (defined as dislocation or subluxation), Single Assessment Numeric Evaluation (SANE) score, American Shoulder and Elbow Surgeons (ASES) score, Rowe score, and Western Ontario Shoulder Instability Index (WOSI).

Statistical Analysis

Logistic regression models were developed to investigate the association of the percentage of glenoid bone loss with failure and with the SANE score, adjusting for age at surgery and duration of follow-up. These models were then used in receiver operating characteristic (ROC) curve analyses, and the performance of the optimal threshold was assessed by the Youden index, sensitivity, and specificity[17]. An interaction between age and the percentage of glenoid bone loss was also investigated in the logistic regression model for failure. The Shapiro-Wilk test indicated that age at surgery had a non-normal distribution, and the median age was therefore compared between the patients with and without failure of the arthroscopic Bankart repair using the Wilcoxon test. All statistical analyses were conducted using SAS (version 9.4; SAS Institute), and the significance level was set at 0.05.

Results

Search Strategy

The initial search identified 538 studies (335 in MEDLINE, 203 in Google Scholar). After removal of duplicates and application of the inclusion and exclusion criteria, 12 studies were included in this review (Fig. 1).

Study Quality

Three of the 12 selected studies were biomechanical and 9 were clinical. The 9 clinical studies included no randomized controlled trials (Level of Evidence I), 1 prospective nonrandomized comparative study (Level II), 5 case-control and retrospective comparative studies (Level III), and 3 case series (Level IV). The MINORS scores of the included studies averaged 16.5 (range, 12 to 22), with the comparative studies averaging 21.25 (range, 20 to 22), the noncomparative studies averaging 13 (range, 12 to 16), and the biomechanical studies all scoring 16.

Biomechanical Studies

Itoi et al. authored the first of the 3 biomechanical studies of the effect of glenoid bone loss on glenohumeral instability[18]. A computer-based model of the average shape of the glenoid was constructed, and the glenoid bone loss was calculated as a percentage of glenoid length (from superior to inferior). Osteotomies were performed at an inclination of 45° to test the effect of glenoid bone loss. The study showed that the translation force in shoulders in which the width of the osseous defect equaled ≥21% of the glenoid length was significantly smaller than the force in shoulders without an osseous defect.

Several years later, Yamamoto, Itoi, and colleagues performed a laboratory study to assess the effect of an anterior glenoid defect on anterior shoulder stability[19]. The defect was created vertically, longitudinal to the long axis of the glenoid, and the estimated defect size was expressed as a percentage of the glenoid length. An osseous defect at the 3 o'clock position with bone loss of ≥20% of the glenoid length or ≥26% of the glenoid width significantly decreased anterior stability.

The cadaveric study by Shin et al. expressed glenoid bone loss relative to the largest anterior-posterior diameter (width) of the glenoid instead of glenoid length[20]. Cadaveric shoulders with soft-tissue Bankart lesions, with and without Bankart repairs, involving various percentages of glenoid bone loss were tested. The soft-tissue Bankart repair failed to restore normal glenohumeral kinematics in shoulders with glenoid defects of ≥15%.

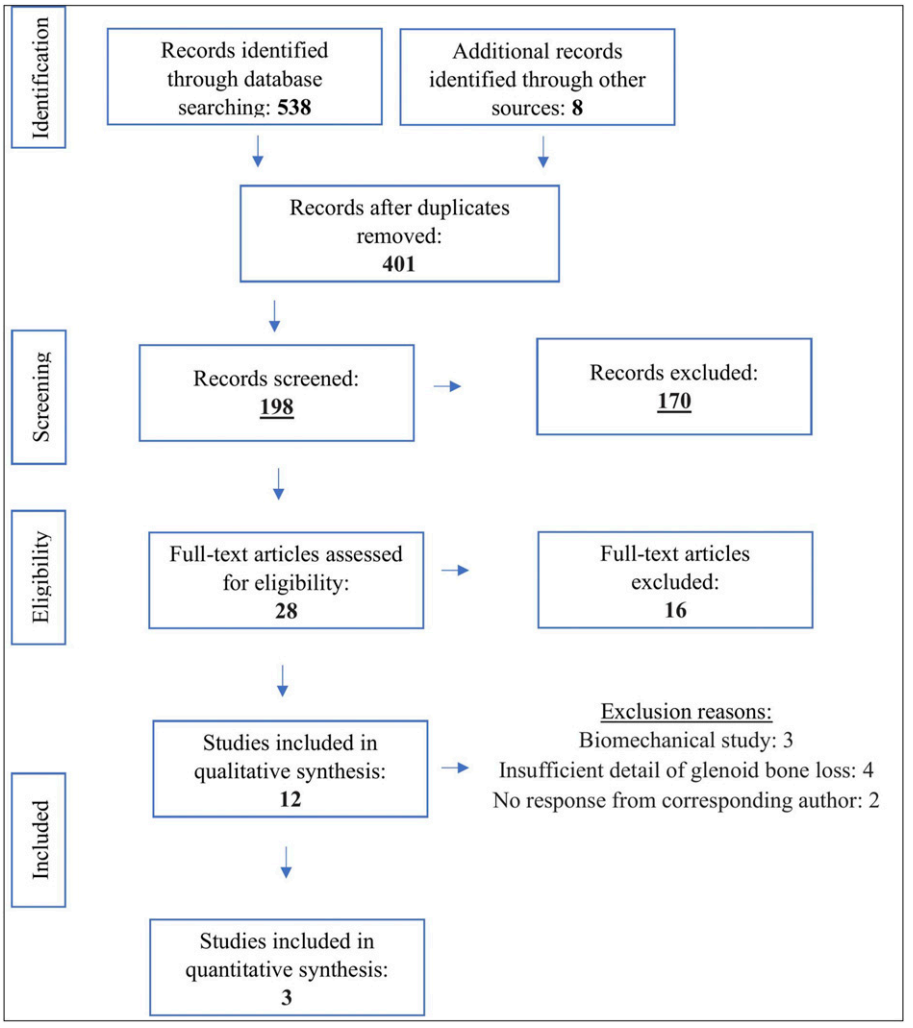

Fig. 1
PRISMA flowchart for the search procedure and study selection.

Non-Comparative Studies

The 5 non-comparative studies are summarized in Table I. They identified the following risk factors for recurrent glenohumeral instability after arthroscopic Bankart repair: glenoid bone loss (10% to 20%), an off-track lesion, patient age of <22 years, an intact anterior articular arc of <150°, hyperlaxity, and <4 anchors used for the Bankart repair[14,21-24].

Comparative Studies

The 4 comparative studies that looked at the effect of glenoid bone loss on shoulder instability are summarized in Table II[25-28]. Iizawa et al. found that among patients with >20% glenoid bone loss, those treated with bone grafting had a significantly lower recurrence rate of shoulder instability (2.9% versus 48.5%)[26]. Shin et al. retrospectively reviewed patients who had been treated with arthroscopic Bankart repair and found that those with glenoid bone loss of >17.3% had a higher rate of recurrent instability (42.9% versus 3.7%) and worse SANE scores (83.8% versus 92.9%)[27]. Yamamoto et al. retrospectively reviewed recurrent shoulder instability events in patients who had undergone arthroscopic Bankart repair[28]. The overall recurrence rate was 7%, but patients who had 17% to 25% glenoid bone loss had a recurrence rate of 18.6% and worse WOSI values than those with lower percentages of bone loss.

Dekker et al. performed a comparative study showing that patients with loss of >15% of the glenoid area had 4 times greater odds of recurrent instability after arthroscopic Bankart repair compared with those with less glenoid bone loss[25]. However, measuring glenoid bone loss as a percentage of glenoid area has been shown to result in lower values than measuring linear bone loss, since the area measurement takes into consideration the curvature of the glenoid. Areal glenoid bone loss of 15% is equivalent to linear bone loss of 20.7%[29].

Pooled Data

Five of the 9 clinical studies reported the methods of bone loss measurement, quantity of bone loss in the patient cohort, failure rates, and patient-reported outcomes[14,22,24,25,27]. The

TABLE I Non-Comparative Clinical Studies Included in the Systematic Review*

First Author	Year	Summary
Yian[24]	2020	Symptomatic recurrent instability occurred in 30.3% of patients undergoing primary arthroscopic Bankart repair. In a scoring system, patients received 1 point for age, 1 point for off-track lesions, 2 points for an intact anterior articular arc of <150°, and 4 points for glenoid bone loss of >10%. The system could predict instability with moderate accuracy in patients who scored >2 points.
Rossi[22]	2021	Competitive rugby players with glenohumeral instability and glenoid bone loss of >20% underwent arthroscopic Bankart repair or an open Latarjet procedure; most athletes in both groups returned to sports. However, the recurrence rate was 20% after Bankart repair versus 4% after the Latarjet procedure. The reoperation rate was 16% after Bankart repair versus 4% after the Latarjet procedure.
Shaha[14]	2015	In a military population with high levels of mandatory activity, glenoid bone loss of >13.5% was associated with worse WOSI values.
Su[23]	2018	42% of patients who underwent revision arthroscopy had recurrent instability at 2.3 years after surgery. The presence of an off-track lesion, age of <22 years, and ligamentous hyperlaxity were independent predictors of recurrence.
Boileau[21]	2006	The presence of glenoid bone loss combined with inferior hyperlaxity led to a 75% recurrence rate. Patients with ≤3 suture anchors had a higher risk of recurrent instability.

*WOSI = Western Ontario Shoulder Instability Index.

corresponding author of each of the 5 studies was contacted, and the raw (deidentified) data were obtained from 3 of the studies[14,24,27].

After curation of the data, the pooled sample size for the 3 studies (total number of patients with failure data) was 528 patients. In all 3 studies, the glenoid bone loss was measured as the linear defect. The mean follow-up duration in the pooled sample was 54.3 months, the mean age at surgery was 24.0 years, and the mean percentage of glenoid bone loss was 10.9% of the glenoid width. The 528 patients had a total of 125 failures (23.7%), defined as recurrent dislocation or subluxation.

Among the 221 patients who also had postoperative SANE scores, the mean follow-up duration was 41.2 months, the mean age at surgery was 24.2 months, the mean percentage of glenoid bone loss was 12.5%, and the mean SANE score was 83.0. These 221 patients had 28 failures (12.7%). The I^2 statistic was 0.0%, demonstrating no heterogeneity.

ROC Curve Analyses

An ROC curve analysis was performed on the 528 patients with failure data to determine the critical glenoid bone loss, defined as the percentage associated with an elevated failure rate of the arthroscopic Bankart repair. The critical bone loss was found to be 16.0%, with a Youden index of 0.59 (sensitivity = 80%, specificity = 80%). The interaction between age and the percentage of glenoid bone loss was not significant ($p = 0.94$).

Another ROC curve analysis was performed on the 221 patients with a SANE score to determine the subcritical glenoid bone loss, defined as the percentage associated with a SANE score of <85%. After excluding the patients with failure of

TABLE II Comparative Clinical Studies Included in the Systematic Review*

First Author	Year	Summary
Iizawa[26]	2020	The dislocation rate in patients with glenoid bone loss of >20% was only 2.9% after arthroscopic Bankart repair with bone graft augmentation versus 48.5% after arthroscopic Bankart repair without bone graft augmentation.
Shin[27]	2017	The optimal critical value of glenoid bone loss was 17.3%. Patients with >17.3% glenoid bone loss had significantly worse shoulder functional scores and SANE scores.
Yamamoto[28]	2019	17% to 25% glenoid bone loss was determined to be subcritical bone loss. Male patients and patients involved in contact sports were more likely to have worse scores as measured by the sports/recreation/work domain of the WOSI value.
Dekker[25]	2020	Patients with any glenoid bone loss had 4 times greater odds of recurrence after arthroscopic stabilization. Glenoid bone loss of >15%, symptoms for >5 months, and age of <20 years were risk factors that increased the risk of recurrent instability.

*SANE = Single Assessment Numeric Evaluation, and WOSI = Western Ontario Shoulder Instability Index.

TABLE III Impact of the Percentage of Glenoid Bone Loss on Failure and the SANE Score

		SANE < 85%	
	Failure	Failures Excluded	Failures Included
No.	528	193	221
Glenoid bone loss	16.0%	20.0%	15.2%
Sensitivity	80%	93%	74%
Specificity	80%	100%	90%
Youden index	0.59	0.93	0.64

the arthroscopic Bankart repair (dislocation or subluxation), subcritical glenoid bone loss in the remaining 193 patients was found to be 20.0%, with a Youden index of 0.93 (sensitivity = 93%, specificity = 100%). In addition, a separate ROC curve analysis was performed that also included the patients with failure of the arthroscopic Bankart repair. That analysis of all 221 patients with SANE data found 15.2% glenoid bone loss to be the optimal cutpoint for subcritical bone loss, with a Youden index of 0.64 (sensitivity = 74%, specificity = 90%) (Table III).

Age

The mean age was 22.9 years (median, 21 years) in the patients who experienced failure of the arthroscopic Bankart repair and 24.3 years (median, 22 years) in those without recurrent instability. The ages in the 2 groups differed significantly (p = 0.009; Wilcoxon test).

Discussion

This study indicated the critical amount of glenoid bone loss predictive of recurrent instability in patients treated with arthroscopic Bankart repair to be 16.0%, and the subcritical amount of glenoid bone loss predictive of worse patient-reported outcomes (SANE score of <85%) to be 20.0% in those without recurrent instability. This is in contrast to previously accepted values of 25% for critical bone loss[30] and 13.5% for subcritical bone loss[14].

The data suggest that patients treated with arthroscopic Bankart repair have a higher rate of recurrent instability if they have ≥16% anterior glenoid bone loss. Moreover, among patients treated with arthroscopic Bankart repair who did not have recurrent instability, those with ≥20% anterior glenoid bone had significantly worse patient-reported outcomes.

The risk factors for recurrence after arthroscopic Bankart repair were age at the first dislocation, the number of dislocations, activity level (contact athlete), osseous defects (osseous Bankart, Hill-Sachs), defect size (glenoid bone loss, engaging Hill-Sachs lesion, off-track lesion), an intact anterior articular arc of <150°, hyperlaxity, and <4 anchors used for the Bankart repair (Table I)[14,21-24,31,32].

One of the most studied risk factors is the size of the glenoid bone defect. However, many of the landmark studies commonly referenced in guiding clinical judgement are inconsistent with modern measurement modalities. For example, the commonly cited landmark study by Burkhart found patients with >25% glenoid bone loss to have a recurrence rate of 86%[13], but bone loss was measured arthroscopically using the bare spot as a landmark[33]. That method of bone loss measurement has since been found to be inaccurate[34].

Modern PACS (picture archiving and communication system) software allows surgeons to preoperatively plan and measure the amount of glenoid bone loss. Methods of measurement of glenoid bone loss include imaging methods based on the Pico best-fit circle, the glenoid area, and the chord defect[35] as well as arthroscopic measurement. Most commonly, surgeons measure the linear defect of the glenoid using the Pico method[36,37]. As previously noted, the calculated areal defect is smaller than the corresponding linear length defect[29]. For example, a glenoid defect measuring 13.2% of the area was reported to correspond to a 19.1% defect on the basis of length (a difference of 5.9%). Because of such variability resulting from differences between methods, published values can inaccurately guide the surgeon if they are based on methods that do not give comparable results to the surgeon's assessment method. The studies in the present systematic review all used the same glenoid bone loss measurement, the linear defect.

Based on historical data on recurrent shoulder instability, we calculated that a minimum of 96 patients would be required to achieve a power of 0.9 to detect an effect size of 0.5 with an alpha value of 0.8. The sample size in this systematic review (528) was considerably larger, and was the largest among all published studies. Furthermore, the patient cohort was wide-ranging, including those patients treated in the military[14], community health systems[24], and university-based health systems[27], making the results more generalizable.

The results differed somewhat from those of previous studies with smaller sample sizes. The critical bone loss that was found to place a patient at risk for failure following arthroscopic Bankart repair was 16.0%, which is substantially less than the commonly accepted 25%. In addition, the subcritical bone loss that was found to place a patient at risk for worse patient-reported outcomes was 20.0%, which is substantially greater than the commonly accepted 13.5%[14]. The difference in the calculated subcritical bone loss value may be due to the study population. Whereas our systematic analysis included patients in the military and community settings, the study by Shaha et al. included only military service members, who are a higher-risk population[14]. Furthermore, our findings are supported by the biomechanical study performed by Shin et al.[20]. They found that a Bankart repair in the setting of ≥15% bone loss failed to restore glenohumeral translation, decreased rotational range of motion compared with patients with no bone loss, and led to abnormal humeral-head positioning; these factors may be the cause of the worse patient-reported outcomes.

As such, this study suggests that patients who have ≥16.0% glenoid bone loss and are <23 years old should not be treated with arthroscopic Bankart repair alone, and that patients with >20.0% glenoid bone loss, regardless of age, should not be treated with arthroscopic Bankart repair alone. However, there may be a subset of patients who have <20.0% glenoid bone loss

and no additional risk factors (i.e., an off-track lesion, contact athletics, hyperlaxity) who can be successfully treated with arthroscopic Bankart repair alone.

Limitations

This study has several limitations. It was a systematic review of Level-II, III, and IV retrospective studies. Although the method of glenoid bone loss measurement was consistent across the included pooled data, there can be variability in measurement between surgeons. The number of patients with documented patient-reported outcomes was substantially less than the number with data regarding failure; however, the sample with SANE data was still sufficiently powered. Failure was defined as dislocation or subluxation; however, the data provided did not specify the mode of failure. As the definition of subluxation can vary, this may have affected the results. Finally, we were unable to analyze the results on the basis of patient gender because the genders of the individual patients were not specified.

Conclusion

The magnitude of critical glenoid bone loss was found to be less than previously reported. Glenoid bone loss of ≥16.0% was found to place patients at higher risk for recurrent shoulder dislocation or subluxation after arthroscopic Bankart repair alone. ■

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