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Beyond guesswork: how accurate are surgeons at determining the degree of glenoid bone loss in instability surgery?

Caleb A. LaVigne, MD[a], Timothy B. Griffith, MD[b], Zachary C. Hanson, MD[c], Donald D. Davis, MD[d], James S. Kercher, MD[b], Xavier A. Duralde, MD[b,*]

[a]Department of Orthopedic Surgery, Wellstar Health Systems, Marietta, GA, USA
[b]Peachtree Orthopedic Clinic, Atlanta, GA, USA
[c]Department of Orthopedic Surgery, Rush University Medical Center, Chicago, IL, USA
[d]Swedish Medical Group, Seattle, WA, USA

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Background: Accurate measurement of glenoid bone loss (GBL) is critical to preoperative planning in cases of recurrent shoulder instability. The concept of critical bone loss has been established with a value of GBL >13.5% being associated with higher failure rate following arthroscopic Bankart Repair. Advanced imaging, such as magnetic resonance imaging (MRI) scans, can be used to quantify GBL prior to surgery using the best-fit circle technique. Surgeons have traditionally relied on visual inspection of the MRI scan preoperatively or on visual inspection of the glenoid at the time of arthroscopy to determine whether GBL is present. The purpose of this study is to determine if 3 fellowship-trained shoulder surgeons could adequately quantify GBL without using best-fit circle measurements on MRI.

Methods: A retrospective review was performed which included 122 patients over an 8-year period that had an arthroscopic Bankart repair performed by 3 fellowship-trained surgeons. In all patients, preoperative MRI scans were retrospectively measured using best-fit circle technique to determine true GBL and compare that to the surgeons' preoperative and intraoperative estimation of GBL.

Results: GBL was correctly identified in only 36% (18/50) of patients when the preoperative best-fit circle measurements were not made. Critical bone loss was missed in 9.8% (12/122) of patients in the study group. The estimated mean bone loss in that group by visual inspection was 11.3% compared to 16% true bone loss measured on MRI. Even in the 18 patients with some identified bone loss prior to surgery, critical bone loss was missed in 6 patients when using visual inspection of the MRI or intraoperative inspection alone.

Conclusion: Simple visual inspection of glenoid images on MRI scan and visual inspection of the glenoid at the time of surgery are inaccurate in determining the true extent of GBL especially in cases of subtle bone deficiency. Preoperative planning is dependent on the exact degree of bone deficiency and measurement on the MRI scan using the best-fit circle technique is recommended in all cases of instability surgery.

Glenoid bone loss (GBL) has been associated with failure of soft tissue procedures performed for the correction of glenohumeral joint instability. Early clinical and biomechanical studies demonstrated that GBL of more than 20%-25% resulted in a loss in concavity compression that could not be adequately compensated for with soft tissue reconstruction of the anterior capsulolabral complex.[4,5,17,24,28] The degree of bone loss beyond which an isolated soft tissue reconstruction alone is inadequate in reliably restoring shoulder stability has been referred to as critical bone loss.[1,10,29] Burkhardt and DeBeer described the inverted pair configuration of the glenoid with severe glenoid bone loss following recurrent traumatic glenohumeral joint dislocations in collision athletes. This severe degree of bone loss is obvious to visual inspection of the magnetic resonance imaging (MRI) and at the time of arthroscopy. More recent studies have indicated that bone loss even as little as 10%-13.5% results in a higher failure rate following arthroscopic Bankart repair suggesting the need for either additional arthroscopic procedures or alternative surgeries

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*Corresponding author: Xavier A. Duralde, MD, Peachtree Orthopaedic Clinic, 3200 Downwood Circle, NW Suite 700, Atlanta, GA 30327, USA.

E-mail address: Xaduralde@pocatlanta.com (X.A. Duralde).

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such as bone grafting to the glenoid.[32] This subtle degree of bone loss may involve less than 5 mm of bone and may be more difficult to identify with visual inspection alone.

Plain radiographs may demonstrate the presence of a bony Bankart lesion but cannot reliably quantify the degree of GBL.[11,18] Subtle bone loss is also difficult to visualize at the time of arthroscopy due to distorted anatomy and variable visibility of the bare area of the glenoid.[30] Advanced imaging studies including computed tomography (CT) and MRI scans can be used to reliably quantify the degree of anteroinferior GBL in cases of glenohumeral joint instability.[36] The best-fit circle measurement technique relies on the observation that the inferior portion of the glenoid forms a near-perfect circle and the degree of bone loss in the anterior glenoid can be determined by comparing the distance from the anterior bone edge to the center of the circle with the distance from the posterior edge to the center.[2,6,16,21]

Evaluation of patients with instability now routinely includes CT scan or MRI for the evaluation of both soft tissue and bony pathology. Although the best-fit circle technique is now recommended to identify the degree of GBL, it is not universally performed. We reviewed a series of patients in whom formal measurements were not performed, although advanced radiographic studies in the form of MRI scans were available preoperatively. For the purposes of this study, we used the value of >13.5% GBL as the definition of critical bone loss. We hypothesized that the incidence and degree of bone loss in glenohumeral instability cases is underestimated by surgeons unless formal measurements are taken and that critical bone loss will be missed in a significant number of cases.

Materials and methods

We retrospectively reviewed all the cases performed by 3 fellowship-trained surgeons in Sports Medicine and Adult Reconstructive Shoulder/Elbow Surgery in which a Bankart repair was performed arthroscopically between February 2014 and December 2022. All cases with Current Procedural Terminology codes 29806 and 29807 were initially identified and screened to identify those patients who had specifically undergone repair of the anteroinferior glenoid labrum (Bankart Repair) as a portion of their operation. This included 137 sequential cases. Ten patients were excluded due to an inability to find an operative note (n = 2) or loss of preoperative imaging (n = 8). This left 127 patients for review.

During the same time period, a total of 74 open instability repairs were performed on patients with Bankart lesions including 40 open Bankart repairs, 31 Latarjet procedures, and 3 open bone grafting procedures to the anterior glenoid. The indication for open Bankart repair was most often for revision surgery. In the patient group scheduled for arthroscopic Bankart repair, there was an implicit bias by the surgeon that an arthroscopic technique would be adequate based on the visualized bone loss on MRI, and therefore, this patient population was selected for study. Surgeons felt confident in these cases that the additional procedures available arthroscopically including Remplissage, capsular imbrication, and extended labral repair would be adequate if additional pathology was identified given the bone loss or lack thereof observed preoperatively. Surgeons did not convert from an arthroscopic approach to an open approach in any case during this time period.

Preoperative notes and operative reports were reviewed to determine if the surgeon had identified any preoperative GBL and whether measurements were performed to determine the degree of GBL. Operative pathology was recorded including the degree of labral damage, associated capsular laxity, visualization of GBL, and the presence of a Hill-Sachs lesion. When the central bare area could be identified by the surgeon, a probe was used to compare the relative distances from the center of the glenoid to the anterior and posterior glenoid rims, respectively.

Between the preoperative clinical notes and the operative note, a determination could be made as to the surgeon's estimate of the amount of GBL. In 5 patients, formal measurements were made using the MRI scan to determine the amount of GBL present prior to surgery and these patients were additionally excluded from the study. This left 122 patients for inclusion in this study. There were no acute bony Bankart repairs in this series.

All patients had preoperative MRI scans which were later retrospectively reviewed for assessment of GBL 2 separate times by 2 independent reviewers (fourth year orthopedic residents) using the best circle technique. All cases of suspected critical bone loss were further reviewed by the senior author. Any disagreements were resolved by joint evaluation and discussion by reviewers. MRI scans were used to calculate GBL, accepting the premise of excellent intraobserver and interobserver correlations of GBL between CT scans and MRIs established by Lee (21).

Radiographic evaluation

GBL was assessed on preoperative sagittal MRI cuts (4 mm thickness) using the best-fit circle technique with Med Strat Joints Cloud PACS system. The circle was drawn with the perfect circle tool of the imaging software, using the inferior border of the glenoid as a reference following the pattern established in previous studies showing that the inferior glenoid can be modeled as a true circle (6, 16) (Fig. 1).

The diameter of the best-fit circle was calculated automatically with use of the perfect circle-drawing tool from the imaging software. The straight-line function tool was used to determine the width of the defect measured along the same axis as a diameter of the circle at the point of maximum bone loss.

Percent bone loss was determined by dividing the width of the glenoid bony defect by the diameter of the inferior glenoid perfect circle multiplied by 100. Hill-Sachs lesions were also measured, and calculations were made using previously described techniques to determine on-track and off-track classification[23,25] (Fig. 2).

Results

Fourteen patients had quantified estimated bone loss documented in the operative report. In an additional 4 patients, bone loss was mentioned but an estimated amount was not given (Table I). The mean bone loss estimated by visual inspection was 11.28% (range: 5%-33%). This compares to the actual mean bone loss measured on MRI report was 15.92% in this patient group (range: 6.4%-31.0%) (Table II).

In the 104 patients with no perceived bone loss, 72 (69.2%) had no bone loss measured on MRI (Table III). Therefore, 32 patients (30.8%) of the patients with no perceived bone loss prior to surgery did have some bone loss noted on preoperative advanced studies using best circle measurements. The mean bone loss measured retrospectively on advanced imaging studies in the no perceived bone loss group was 3.15% (range: 0%-22.7%) (Table II). Six of these 32 had bone loss >13.5%. Therefore, of the patients with no perceived bone loss prior to surgery, 6/104 (5.8%) had critical bone loss (Table III).

Looking at the entire group of 122 patients, 104 had <13.5% bone loss measured on MRI including 72 with no bone loss, 32 who had between 0% and <13.5% GBL, and 6 patients with perceived bone loss prior to surgery whose best-fit circle measurement was less than that (Table IV). Of the entire study group, 18 of the 122 patients (14.8%) had bone loss >13.5%. Of these 18 patients with critical bone loss, only 3 were definitively identified preoperatively/intraoperatively using visual inspection alone without the benefit of best-fit circle measurements (patients 14, 17, 18, Table V). In the

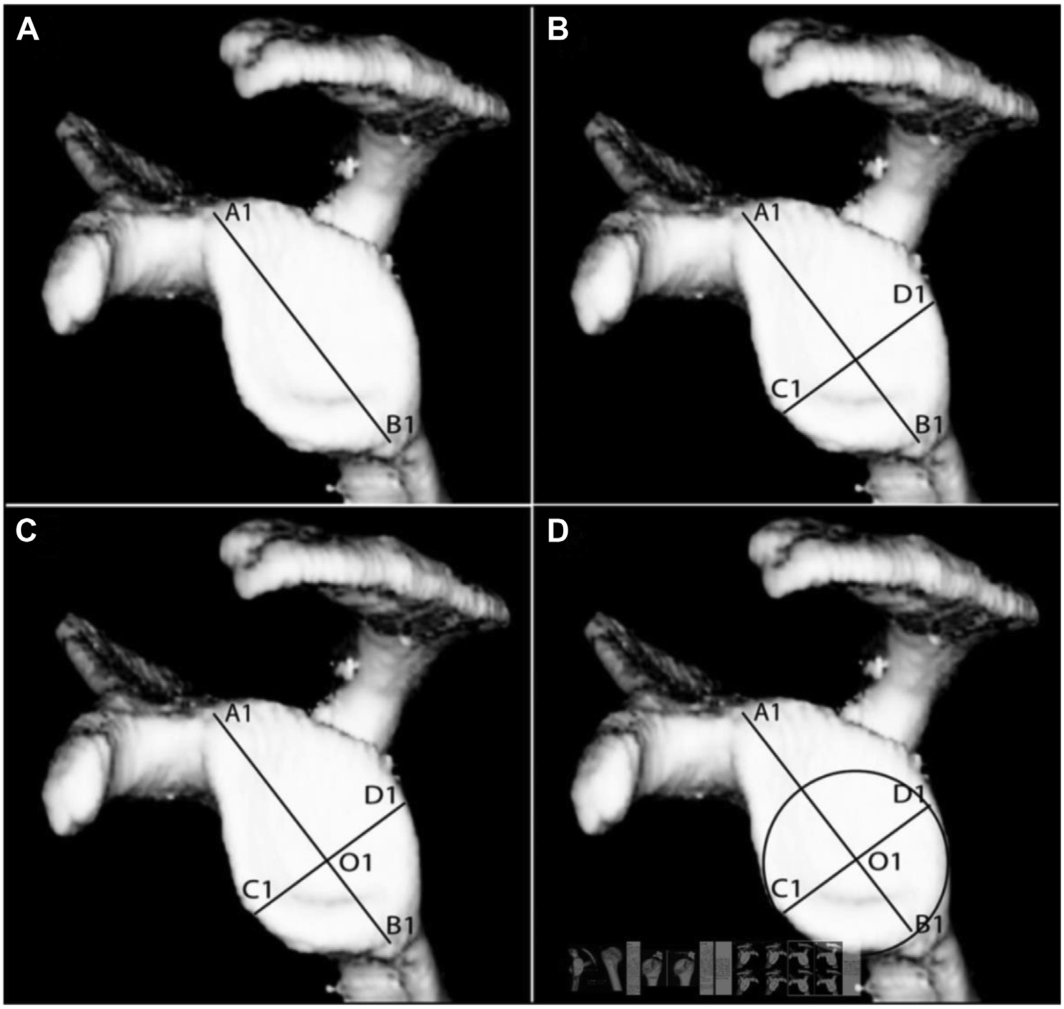

Figure 1 The normal glenoid. (**A**) The long axis of the glenoid is defined by the line A1B1. (**B**) The widest portion of the inferior glenoid is line C1D1, which is perpendicular to the line A1B1. (**C**) The intersection of lines A1B1 and C1D1 is labeled O1, and it represents the geometric Center of the inferior glenoid circle (**D**). Image courtesy of Chuang et al.[6]

4 patients who had observed bone loss without a quantitative estimate by the surgeon, 3 had critical bone loss and 1 did not. It is not possible to determine in those cases whether the surgeon suspected critical bone loss or not. Therefore, in the entire group of 122 patients, critical bone loss was missed in 9.8% (12/122). This includes 6 patients in whom some bone loss was noted preoperatively and 6 patients in whom no bone loss was perceived. Surgeons correctly identified only 18/50 (36%) patients with GBL and 3/15 (20.0%) patients with critical bone loss (>13.5%) by visual inspection without formal measurements prior to surgery.

Off-track and on-track Hill-Sachs lesions

The total number of patients with Hill-Sachs lesions in patients with GBL was 26 of 50 (52.0%). The number of on-track lesions was 9 (34.6%) and off-track lesions was 17 (65.4%). The number of patients who had Hill-Sachs lesions in the critical GBL group was 11 of 18 (61.1%). The number that had on-track lesions was 1 (9.1%) and off-track lesions was 10 (90.9%) (Tables VI and VII).

Discussion

The most important finding in this study is that fellowship-trained surgeons underestimated the degree of glenoid bone deficiency in a series of patients undergoing arthroscopic surgery for recurrent instability when relying on visual inspection alone without formal measurements using the best circle method. GBL was identified in only 18/50 (36%) patients prior to surgery and critical bone loss was correctly identified in only 3/15 (20.0%) cases where the bone loss was quantified. The average underestimation of bone loss was 4.6% in patients in whom some obvious bone loss was noted. Even in these patients, critical bone loss was missed in 15/18 when formal measurements were not made. In patients without any perceived bone loss, more than 30% of patients did indeed have some GBL and in 5.8% of patients this bone deficiency attained a level commonly accepted in the range of critical bone loss (>13.5%). This study emphasizes the importance of preoperative best-fit circle measurements on advanced radiographic studies prior to all instability surgery.

Burkhart and DeBeer first described the impact of glenoid bone defects on the results of arthroscopic Bankart surgery in a study of 194 contact athletes in the year 2000 noting a 6.5% recurrence rate in contact athletes without significant bone defects compared to an 89% recurrence rate in those with a significant glenoid bone defect (5). Itoi made the first attempt to quantify critical bone loss using a cadaveric model and defined critical GBL as 21% loss of bone (17). Further clinical and anatomic studies have steadily lowered this number to 17%, 15%, 13.5%, and even 10% glenoid bone defect after

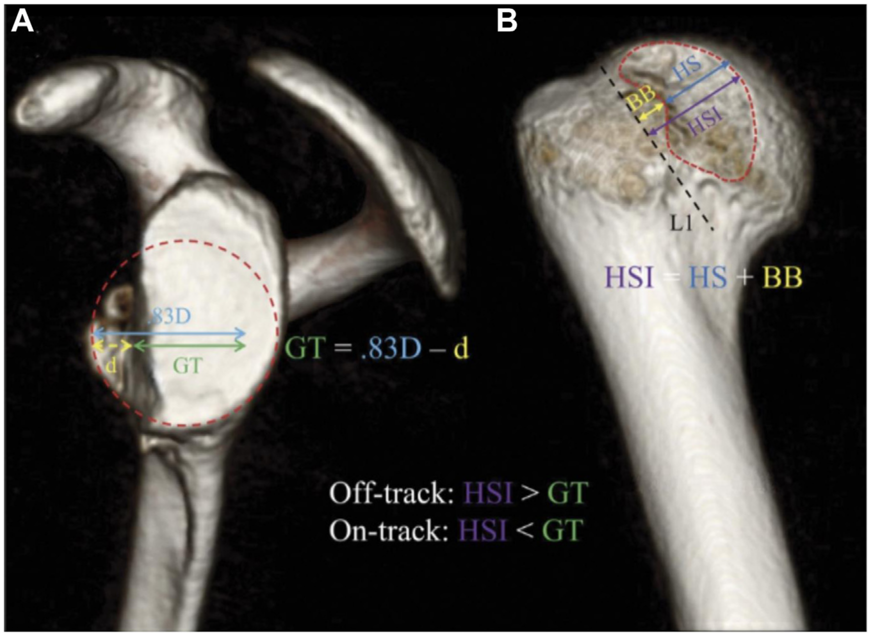

Figure 2 Calculating the glenoid track (GT) and and Hill-Sachs interval for determining on-track and off-track lesions, as described by Di Giacomo et al (**A**), a circle is superimposed over sagittal view of the glenoid, using the inferior border of the glenoid as a reference. The diameter of the best fit circle (D) and the width of the glenoid defect (d) are measured and entered into the above equation to calculate the GT. (**B**) The HSI is measured adding the width of the bony bridge between the insertion of the rotator cuff and the width of the HS lesion. HSI, Hill-Sachs interval. Image provided courtesy of Makhni et al.[23]

Table I
Number and percentage of patients that had perceived bone loss identified preoperatively/intraoperatively.

Number of patients with perceived bone loss	
# Perceived bone loss by surgeon	18 (14.8%)
Total Patients	122

Table II
The mean bone loss measured visually during surgery vs. measured utilizing the perfect circle technique on MRI.

Preop/Intraop vs. MRI bone loss	
Intraop % bone loss mean, perceived BL group	11.28%
MRI % Bone Loss Mean, Perceived BL Group	15.92%
MRI % Bone Loss Mean, No Perceived BL Group	3.15%

BL, bone loss; *MRI*, magnetic resonance imaging.

Table III
Number and percentage of patients that did not have perceived bone loss identified preoperatively/intraoperatively.

True bone loss in patients without perceived bone loss by surgeon		
Criteria	Count	Percentage
0%	72	69.2%
<13.5%	26	25.00%
>13.5%	6	5.8%
Total	104	

Table IV
Number and percentage of patients with above and below critical bone loss in the total group.

Bone loss in patient sample		
Criteria	Count	Percentage
0%	72	59.02%
<13.5%	32	26.23%
>13.5%	18	14.75%
Total	122	

which an isolated arthroscopic Bankart repair results in a higher recurrence rate, worse functional results, and abnormal joint mechanics.[3,7,10,32,33] The significance of a glenoid bony defect can be further compounded by a Hill-Sachs lesion on the humeral head creating bipolar lesions which increase the risk of recurrent instability.[8,34] These lesions are extremely common in patients with instability and can be found in 60%-84% of patients.[9,14,26] In this study, Hill-Sachs lesions were identified in 26/50 (52.0%) patients with GBL and 10/11 (90.9%) patients with critical bone loss had off-track lesions. As the risk of recurrent instability following surgery is even higher in these patients, the importance of identification of critical bone loss is further magnified.

The addition of the Remplissage procedure to the arthroscopic Bankart repair has markedly improved the results of instability surgery in patients with 10%-15% GBL.[13,22,35] These results have been reproduced in patients with both of on-track and off-track lesions with the results in terms of recurrence rates equivalent to the Latarjet procedure but with a fraction of the complications related to that bony procedure.[15,27] The surgeon's ability to diagnose GBL in the 10%-15% range is therefore critical to operative planning as the addition of some type of posterior restraint surgery such as a Remplissage or posterior capsular imbrication will be indicated. The addition of the Remplissage procedure may alter postoperative rehabilitation, return to sport and possibly ultimate range of motion, and will require preoperative counseling.[12,20] Therefore, the possible need for this technique should be determined preoperatively through accurate measurement of GBL and determination of on-track and off-track status.

A systematic and reproducible method of diagnosing this subtle bone loss is therefore imperative in the preoperative planning process prior to shoulder instability surgery. Visualization at the time of arthroscopic surgery is relatively unreliable.[19] Recent

Table V
Patients identified by the surgeon to have bone loss and the estimated bone loss value vs. measurement on MRI.

Patients w/ Identified bone loss: Estimated vs. MRI measurement		
Patient	EBL	MBL
1	5.0%	6.4%
2	10.0%	7.9%
3	10.0%	9.0%
4	Unspecified	9.3%
5	5.0%	11.2%
6	15.0%	11.3%
7	Unspecified	13.6%
8	5.0%	13.8%
9	5.0%	15.4%
10	5.0%	15.5%
11	10.0%	16.4%
12	10.0%	19.2%
13	10.0%	19.3%
14	33.0%	19.4%
15	Unspecified	22.0%
16	Unspecified	24.0%
17	15.0%	27.1%
18	20.0%	31.0%

EBL, estimated bone loss; *MBL*, measured bone loss on MRI; *MRI*, magnetic resonance imaging.

Table VI
Total number of on-track and off-track Hill-Sachs lesions in patients with glenoid bone loss.

Total on-track vs. off-track Hill-Sachs lesions with glenoid bone loss	
On-track HSL	9
Off-track HSL	17
Total	26

HSL, Hill-Sachs lesion.

Table VII
Number of on-track and off-track Hill-Sachs lesions in patient with measured glenoid bone loss greater than 13.5%.

On-track vs. off-track Hill-Sachs lesions in patients with critical bone loss	
On-track HSL	1
Off-track HSL	10
Total	11

HSL, Hill-Sachs lesion.

studies have demonstrated that CT and MRI can both accurately detect GBL, whereas plain radiographs can only recognize them poorly. MRI has the added benefit of avoiding radiation exposure.[31] Inspection of the MRI without taking direct measurements as seen in this study results in a failure of diagnosis of subtle bone loss in more than 60% of the patients treated. Although critical bone loss of >13.5% was missed in only 9.8% of patients, improvement in operative planning and execution of the procedures in the small subgroup will improve overall results of the treatment cohort. This study emphasizes the importance of taking best-fit circle measurements prior to all instability surgeries.

This study has multiple limitations including the fact that surgeries were performed by 3 separate fellowship-trained surgeons and the data were collected retrospectively. Surgeons in our group have become more aggressive in performing additional procedures during arthroscopic Bankart repair such as extended labral repair, posterior capsular imbrication, and Remplissage procedure due to the high failure rate noted and the growing understanding of additional pathology requiring treatment in these patients. Therefore, the implications of this diagnostic failure cannot be evaluated in terms of treatment decisions at the time of surgery and the final impact of this on final outcomes. In cases where surgeons do not typically perform additional procedures to augment the Bankart repair, the impact of GBL underestimation would be more significant with a higher failure rate documented in the literature for isolated Bankart repair in the face of critical bone loss (4, 22). Very few patients were excluded due to loss of operative note or preoperative MRI scans. This is a sequential group of patients and includes all the patients treated surgically with Bankart repair for 3 relatively high-volume surgeons. Despite the recent literature discussing the importance of determining true GBL for optimal surgical planning in cases of recurrent instability, it is interesting that it had not become the routine of these 3 high-volume shoulder surgeons. This most likely indicates that the routine measurement of best circle may not be the standard in the community.

Conclusion

Simple visual inspection of glenoid images on MRI scan and visual inspection of the glenoid at the time of surgery are inaccurate in determining the true extent of GBL especially in cases of subtle bone deficiency. Preoperative planning is dependent on the exact degree of bone deficiency and measurement on the MRI scan using a perfect circle technique is recommended in all cases of instability surgery.

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