The "Bony Bankart Bridge" Technique for Restoration of Anterior Shoulder Stability

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Background: Bony deficiency of the anteroinferior glenoid rim can cause recurrent glenohumeral instability. To address this problem, bony reconstruction is recommended in patients with glenoid bone loss more than 20% to 25%. Recent advances in shoulder surgery techniques allow for the arthroscopic reconstruction of glenoid bone defects to restore stability.

Hypothesis: The all-arthroscopic "bony Bankart bridge" (BBB) technique for bony anterior glenohumeral instability can restore shoulder stability and provide good shoulder function as well as improve patient satisfaction for these difficult-to-treat cases.

Study Design: Case series; Level of evidence, 4.

Methods: A consecutive series of 15 patients with bony anterior shoulder instability were treated using the arthroscopic BBB technique. All patients were assessed with the Disabilities of the Arm, Shoulder and Hand–short version (QuickDASH), American Shoulder and Elbow Surgeons (ASES) score, and Short Form-12 (SF-12) preoperatively and at final evaluation. In addition, a specific questionnaire evaluated patient satisfaction and possible complications.

Results: Two women and 13 men were included in the study, with an average age of 44 years (range, 24-70 years). The average glenoid bone loss was 29% (range, 17%-49%). The mean duration of follow-up was 2.7 years (range, 2.0-4.4 years). At that time, the mean ASES score had improved from 81 (range, 50-98) to 98 (range, 88-100) ($P = .133$). Although this change was not statistically significant because of low patient numbers, the amount of improvement was almost 3 times the minimal clinically important difference of 6.4 points as reported in previous studies. The mean SF-12 (physical component) improved from 46.8 to 56.2 at final follow-up ($P = .015$). The mean QuickDASH score at final follow-up was 2.8 (range, 0-15.9), and the mean Single Assessment Numeric Evaluation score was 99 (range, 95-100). There were 14 (93%) stable shoulders and 1 (7%) failure with redislocation from a fall. Median patient satisfaction at final follow-up was 10 (range, 7-10) out of 10.

Conclusion: The arthroscopic BBB technique for anterior instability with glenoid rim fracture successfully restores shoulder stability with a high median patient satisfaction (10/10) and a very low complication rate.

Keywords: bony Bankart lesion; glenoid rim fracture; shoulder dislocation; arthroscopic repair

Bony deficiency of the anteroinferior glenoid can contribute to recurrent glenohumeral instability.[4] Glenoid bone loss occurs during acute shoulder dislocation or because of erosion and attrition in more chronic cases of anterior instability. The incidence of bony Bankart lesions after shoulder dislocations ranges from 4% to 70% in the literature, with a higher prevalence in men.[21] These injuries have been previously classified by Bigliani et al[1] into 3 types, with type I representing an avulsion fracture with attached capsule, type II a medially displaced fragment malunited to the glenoid rim, and type III an erosion of the glenoid diameter with less (IIIA) or more (IIIB) than 25% deficiency. Burkhart and De Beer[3] also demonstrated that glenoid bone loss is associated with a higher risk of surgical failure after arthroscopic soft tissue repair. A number of biomechanical studies have been performed to determine the critical amount of bone loss that results in recurrent instability.[5,8,28]

Cadaveric studies have helped us understand the consequences of glenoid bone loss. Itoi et al[8] reported that an osseous defect of at least 21% of the glenoid length will significantly decrease stability. Similarly, Yamamoto et al[28] created a model with an osseous defect at 3-o'clock (right shoulder) and concluded that when the defect was equal to or greater than 20% of the glenoid length, there was significantly decreased anterior stability. According to Gerber and Nyffeler,[5] when the length of the glenoid defect was greater than the glenoid radius, resistance to dislocation was reduced by 30%. Furthermore, glenoid bone loss of 20% of the diameter doubles the mean contact pressure in the anteroinferior quadrant and increases peak pressures from 50% to 100%.[6]

Therefore, based on the current data, a bony reconstruction procedure is recommended in patients with glenoid bone loss of greater than 20% to 25% to restore the surface area and to avoid high failure rates.[3]

Bony procedures have historically been performed open. However, recent advances in arthroscopic technique have allowed for the reconstruction of glenoid bone defects to restore stability.[9,16,18,20] In 2009, the senior author (P.J.M.) described an all-arthroscopic technique developed for this specific condition named the "bony Bankart bridge" (BBB).[16] The purpose of this study was to investigate the clinical outcomes and complications after arthroscopic

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fixation of anterior glenoid rim fractures using this technique. We hypothesized that the BBB technique would provide good restoration of stability with a high patient satisfaction and a low complication rate.

METHODS

Patient Selection

This study underwent prior institutional review board approval for prospective collection of data that were stored in a data registry and then retrospectively reviewed. From January 2006 to August 2010, a total of 191 patients with anterior shoulder instability and a Bankart lesion received arthroscopic treatment by the senior author (P.J.M.). Fifteen of the 191 consecutive patients with anterior shoulder instability due to a bony Bankart lesion were treated by the senior author using the arthroscopic BBB technique.[15] The indications for the BBB were (1) an acute bony Bankart fracture with recurrent anterior glenohumeral instability or a high risk for recurrence or (2) recurrent anterior glenohumeral instability with a chronic bony Bankart.

The inclusion criteria for this study included patients with traumatic anterior shoulder instability with bony lesions type I or II (according to Bigliani et al[1]) treated with the BBB technique and a follow-up of at least 2 years out from their surgery. Patients with inferior, posterior, or multidirectional instability, including voluntary dislocation, and patients with glenoid erosion (type III),[3] along with any patient younger than 18 years of age, were excluded from the study. Plain radiograph series were taken at initial clinical evaluation and only in postoperative visits when patients reported pain, instability, or weakness. Radiographs were obtained including true AP radiographs of supraspinatus outlet (Y-view) and axial views. Two patients who did not return our questionnaire were contacted by phone and reported no further surgery or episodes of instability. Therefore, minimum 2-year outcome data were available for the remaining 13 of 15 patients (87%).

Quantification of Bone Defects

Glenoid bone loss was evaluated with a 2-dimensional, en face, plain computed tomography (CT) view of the glenoid.[7,14] As described by others, the percentage of bone loss was calculated as the ratio of the width of the defect to the diameter of the assumed outer fitting circle based on the inferior portion of the glenoid contour.[4,13,26] In addition, the maximum depths of potential Hill-Sachs lesions were measured on the axial CT planes as described by Saito et al.[22] To minimize any bias resulting from the location of the maximum depth on the humerus or the size of the humeral head, the maximum depth was expressed as the ratio of the depth of the lesion to the diameter of a best fitting circle drawn around the humeral head (Figure 1). A Hill-Sachs lesion of less than 10% in depth was defined as "not significant." Two independent observers performed the calculations to evaluate interobserver reliability for both the glenoid bone loss and the depth of the Hill-Sachs lesions.

Surgical Technique

The technique was performed as described by Millett and Braun.[16] Patients were placed in the beach-chair position with the index arm in a pneumatic arm holder. After diagnostic arthroscopy was performed, a high anterosuperior portal and an accessory anteroinferior portal were established. Typically, the labrum and inferior glenohumeral ligament (IGHL) complex were attached to the bony fragment (Figure 2, A and B). These attachments were preserved. After the fracture sites were prepared by use of a shaver or bur, a 3.0-mm bioabsorbable suture anchor, loaded with nonabsorbable suture (eg, Biocomposite Suture-Tak anchor, Arthrex, Naples, Florida), was placed medially on the glenoid neck providing the medial fixation point for the Bankart bridge. For this crucial step, the anchor was inserted through the anteroinferior portal. Since correct anchor placement of this medial anchor can be technically challenging, the anteroinferior portal was placed a bit more medial to make this step easier. Furthermore, we visualized medially using a 70° scope and elevated the capsule and labrum from a superior portal using an elevator. Depending on the fragment size, 1 or 2 anchors were used medially. If 1 anchor was used, it was placed medial (axial plane) to the fracture site on the glenoid neck and in the midportion (sagittal plane) of the fracture. Both limbs of the suture were passed through the soft tissues, medial to the bony piece, with a shuttling device (Figure 2B). An alternative method is to use a trocar tip guide for the anchor and to insert this through the capsule penetrating medial to the bone fragment. After the anchor is placed, the guide is then used to pass the sutures around the capsule-labral-bony fragment, thus obviating the need to use a shuttling device. The next step was to place a suture anchor inferior to the bony fragment on the glenoid rim to secure the labrum

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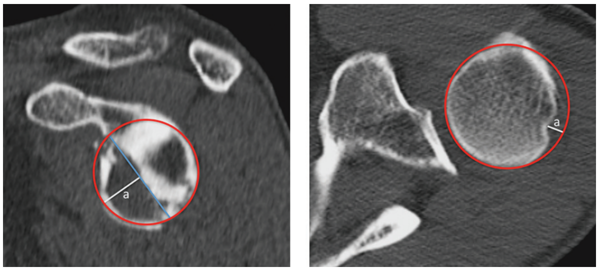

Figure 1. Computed tomography (CT) scan of a left shoulder. (Left) Sagittal plane showing severe glenoid bone loss. The amount of bone loss is calculated as the ratio *a*/*d* of the width of the defect (*a*) to the diameter (*d*) of the assumed outer fitting circle. (Right) Axial plane showing a Hill-Sachs lesion loco typico. The maximum depth of the Hill-Sachs lesion is calculated as the ratio *a*/*d* of the depth of the defect (*a*) to the diameter (*d*) of the assumed outer fitting circle.

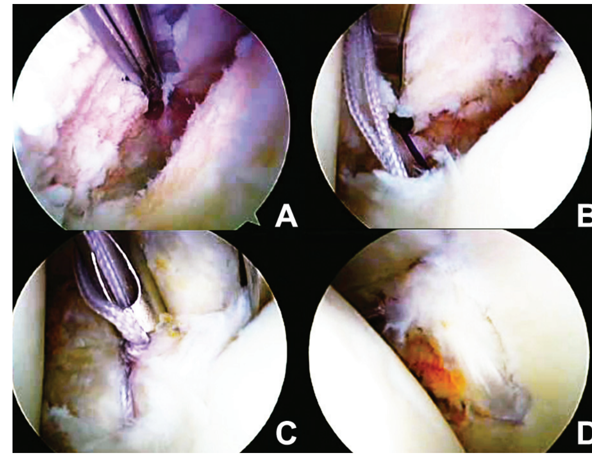

Figure 2. Right shoulder of patient in the beach-chair position, viewing the joint from the posterior. (A) Diagnostic arthroscopy confirms anteroinferior bony Bankart lesion (BBB). The capsulolabral complex is attached to the fragment. (B) The medial anchor is placed, and a shuttling device is used to shuttle the sutures through the soft tissue. (C) The medial anchor sutures are knotted, reducing the fragment together with the soft tissue. (D) Completed stable BBB repair after insertion of the lateral anchor.

and IGHL complex inferior to the bony piece. The medial suture limb was passed through the IGHL complex, shifting the IGHL complex and labrum superiorly and medially, thereby tightening the axillary pouch. Sutures were then tied using a sliding-locking Weston knot that was backed up with 2 alternating half-hitches, and the free limbs were cut (Figure 2C). Typically, 1 anchor was placed inferior to the bony fragment. The bony Bankart was then fixed with a bridging technique. The sutures from the medial anchor were retrieved out of the anteroinferior portal. Appropriate tension was assessed to test the fracture reduction and to determine the optimal position for the lateral fixation anchor before a hole was drilled for the lateral anchor on the glenoid face at the cartilage-fracture margin. The 2 free limbs of the medial suture anchor were fed into a knotless suture anchor (eg, 3.5-mm Bio-PushLock anchor, Arthrex), which was then pressed into the drill hole on the glenoid face. The suture limbs were tensioned before final fixation of the anchor, compressing the bony fragment back into its donor bed. This arthroscopic osteosynthesis provided a secure 2-point fixation and compression of the fracture without tilting of the bony piece to prevent over- and underreduction (Figure 2D). Finally, an additional repair of the superior capsule, labrum, and middle glenohumeral ligament superior to the Bankart bridge with at least 1 and usually 2 anchors was performed to provide additional rotational stability. Figure 3 illustrates the final repair.

Arthroscopic Findings

In all patients, diagnostic arthroscopy confirmed the bony lesion of the anteroinferior glenoid rim and the humeral head impression fracture. Furthermore, the labroligamentous complex was detached together with the bony fragment in all shoulders (Figure 2, A and B). There were 10 Bigliani type I lesions and 5 type II lesions. A superior labrum anterior and posterior (SLAP) lesion was found in 14 of the 15 patients (93%) and was treated with biceps tenodesis in 3 cases, with a SLAP repair in 6 cases, and with debridement in 5 cases. Three patients (13%) had full-thickness tears of the supraspinatus that were repaired with an average of 2.5 suture anchors (range, 1-4).

Postoperative Management

Postoperatively, the shoulders were immobilized with a sling for 3 weeks. The rehabilitation program was individualized by fracture and repair characteristics. The patients were encouraged to perform early passive range of motion (ROM) exercises with supervised active motion taking place within 2 weeks. The strengthening program began 6 to 8 weeks postoperatively. At 3 to 4 months postoperatively, all patients were cleared to return to noncontact sport activities. Full return to contact or throwing sports was allowed after an average of 6 months.

Clinical examination in the postoperative period revealed no signs of recurrent instability.

Outcome Measurement

Data were prospectively collected and stored in a data registry and included demographic information, surgical techniques, mechanism of injury, and surgical history. We defined chronic instability as episodes of instability that persisted for more than 3 months prior to surgery. Data were collected on history of shoulder subluxations, number of dislocations, more subtle feeling of subluxations, and activities in which instability occurred both preoperatively and postoperatively. Preoperative and postoperative outcome measurements included the visual analog scale (VAS) for pain (pain with activities of daily living, pain with sport, pain with work, pain with rest, whether patients were able to return to their sport or fitness activity), the American Shoulder and Elbow Surgeons (ASES) score, and physical and mental components of the Short Form-12 (SF-12). Outcome measures collected at final follow-up were the Disabilities of the Arm, Shoulder and Hand–short version (QuickDASH), Single Assessment Numeric Evaluation (SANE) scores, and patient satisfaction, along with surgical complications.

Statistical Analysis

Statistical analysis was done with the use of a statistical package (SPSS version 11.0; SPSS Inc, Chicago, Illinois). The paired Student *t* test was used to compare the differences between the preoperative and postoperative outcome measures. Univariate and nonparametric analyses were performed where appropriate for the outcome variable depending on whether the data were normally distributed. Bivariate analysis was done using a chi-square analysis. The intraclass correlation coefficient was used to measure interrater agreement between the 2 raters. The level of significance was set at $P < .05$.

RESULTS

The average age was 44 years (range, 24-70 years) in 2 women and 13 men. All patients reported healthy shoulders without pain or signs of instability before the initial trauma. Glenoid trauma was related to a fall while skiing, while snowboarding, or during other recreational activity in 13 of 15 (87%) of the shoulders. In 1 case, the patient was a professional kayaker who dislocated his shoulder while kayaking. All patients had sustained trauma-related dislocations, where the dominant shoulder was affected in 7 of 15 (47%). In 9 shoulders (60%), the arthroscopic repair was performed within 3 months (acute; range, 1-35 days) after initial injury and in 6 shoulders (40%) at a later time point (chronic; range, 120-5023 days). Among the patients within the acute group, 7 of 9 (78%) had a single dislocation, and 2 of 9 (22%) had 2 or more frank dislocations. In the chronic group, 3 of 6 patients (50%) had fewer than 10 dislocations, and 3 of 6 (50%) had 11 or more dislocations. Patients in the chronic group averaged 15 dislocations (range, 1-27) before surgery.

In all patients, an osseous fragment at the anteroinferior quadrant of the glenoid rim was confirmed with CT scan and during diagnostic arthroscopy (Figure 1). There was high interrater reliability in glenoid bone loss (r = 0.968; 95% confidence interval [CI], 0.878-0.991) and depth of the Hill-Sachs lesions (r = 0.971; 95% CI, 0.889-0.992). The mean glenoid bone loss was 29% (range, 17%-49%) of the inferior glenoid diameter. Nine patients (60%) had Hill-Sachs lesions with a depth of greater than 10%, whereas the mean maximum depth was 19% (range, 14%-27%) of the humeral head diameter. Three patients (33%) had lesions greater than 20% of the humeral head diameter.

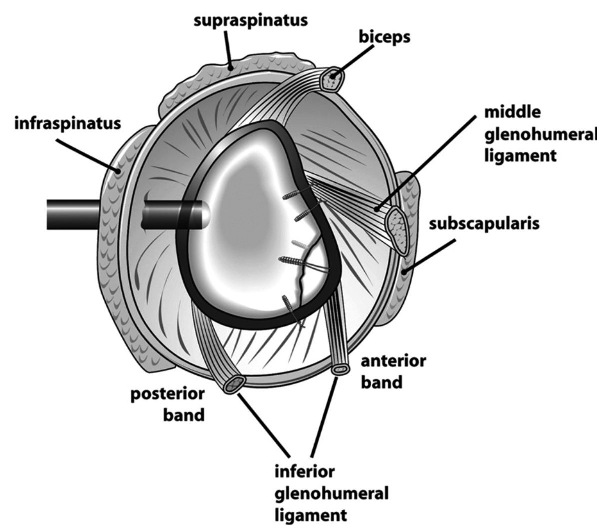

Figure 3. Final bony Bankart bridge repair with reduced bony Bankart piece, repaired labrum, and shifted capsule and inferior glenohumeral ligament complex. (Reprinted with permission from Millett PJ, Braun S. The ''bony Bankart bridge'' procedure: a new arthroscopic technique for reduction and internal fixation of a bony Bankart lesion. *Arthroscopy*. 2009;25(1):102-105. © Elsevier.)

The average number of anchors used per repair to secure the glenoid fragment and labrum back into anatomic position was 5 (range, 4-8).

Preoperative active ROM averages were forward elevation 153° (standard error [SE], 10°), external rotation 63° (SE, 6°), and external rotation at 90° of abduction 78° (SE, 6°). Although not statically significant, there were slight improvements in postoperative averages at a mean of 5.7 months (range, 1-18 months) to forward elevation 168° (SE, 3°) (P = .087), external rotation 70° (SE, 6°) (P = .317), and external rotation at 90° of abduction 86° (SE, 5°) (P = .312).

Outcome Assessment

The mean subjective follow-up was 2.7 years (range, 2-4.4 years) in 13 of 15 (87%) patients. At final evaluation, the mean ASES score improved from 81.4 (range, 50-98) preoperatively to 98.3 (range, 88-100) postoperatively (P = .133). Although not statistically significant because of low patient numbers, the amount of improvement is almost 3 times the minimal clinically important difference of 6.4 points as reported by Michener et al.[15] The mean SF-12 (physical component) improved from 46.8 (range, 36-55.0) to 56.0 (range, 46.8-60.5) (P = .015). Preoperative pain with activities of daily living, recreation, and sleep significantly improved for each ($P < .05$) postoperatively. The mean QuickDASH score at final follow-up was 2.8 (range, 0-15.9) and the mean SANE score was 99 (range, 95-100). Overall, median patient satisfaction at final follow-up was 10 out of 10 points (range, 7-10). One patient who redislocated because of a recent fall reported a lower satisfaction—7 out of 10.

Univariate analysis showed that patients with acute injuries had significantly more dislocations than patients with a median of 11 versus 1 ($P = .015$). The chronic injury group was younger (31 vs 50 years; $P = .005$) and had less bone loss on their CT scan with chronic injuries of 22.8% versus 31.9% ($P = .038$). A correlation was found between age and glenoid bone loss ($r = 0.587$; $P = .013$), and a negative correlation was found in Hill-Sachs depth and amount of glenoid bone loss ($r = -0.627$; $P = .042$). Preoperative forward elevation was significantly correlated with glenoid bone loss ($r = -0.714$; $P = .009$), which indicated that increasing bone loss was associated with a decrease in forward elevation. Younger patients had an increased number of dislocations ($r = -0.624$; $P = .007$). A glenoid defect greater than 30% or a Hill-Sachs lesion greater than 10% did not have a negative influence on the outcomes measured.

Return to Sports

Among the 13 patients who actively participated in sports preoperatively, 9 (69.2%) patients had returned to their sport at a level equal to or better than their preinjury level, and 2 (15.4%) had returned with minimal restriction; 2 patients over the age of 60 years did not answer the sports questions. The overall rate of return to a full fitness program was 12 of 15 (80%). Only 2 of 13 (15.4%) patients indicated that they had modified their recreational or sports activity since their surgery.

Failures and Complications

Only 1 patient (6.6%) sustained a traumatic redislocation postoperatively from a fall. There were no intraoperative complications related to this technique. However, care must be taken when inserting the knotless (Bio-PushLock) anchors to ensure that they are inserted at the same angle as the drill so they will seat properly.

DISCUSSION

The results of the present study support our hypothesis that the arthroscopic BBB technique can successfully restore shoulder stability in patients with bony Bankart lesions types I and II,[1] yield successful clinical outcomes, and provide high patient satisfaction. We found a significant improvement in our postoperative outcome scores and significant pain relief; only 1 patient (6%) sustained traumatic redislocation from a fall.

It has been described that glenoid bone loss is associated with a higher risk of surgical failure after arthroscopic soft tissue repair.[3] Furthermore, several biomechanical studies have shown the negative influence of glenoid bone loss on glenohumeral stability.[6,8,28] Therefore, in patients with bone loss of greater than 20% to 25% of the inferior glenoid diameter, a bony reconstruction procedure is recommended to avoid high failure rates.[3] Bony procedures historically have been performed open; however, recent advances in arthroscopic surgery allow reconstruction of glenoid bone defects to be performed arthroscopically to restore glenohumeral stability.[9,16,18,20,25] In this context, arthroscopic bone graft repairs,[23,27] coracoid transfer procedures,[2,11,12] and suture anchor repairs[||] have been described.

Regarding suture anchor repair techniques similar to the current study, several case reports and technique papers exist, but only a few studies are available reporting on outcomes in larger case series.[19,21,25] The suture anchor techniques, as described in the literature, range from traditional Bankart techniques with the anchors placed deep into the glenoid fracture site[19,21,25] to 2-point[16] and 3-point[9] fixation techniques.

In 2005, Sugaya et al[25] reported on an arthroscopic anchor repair in 42 cases with a mean anterior glenoid bone defect of 25% (with 52% showing >25% bone loss) using a traditional Bankart repair technique. In all cases, the bony fragment was mobilized and incorporated in the repair. Patient outcomes were good and excellent in 93% and fair in 2%. Two patients (5%) suffered from a redislocation during sporting activities and were rated to have poor outcomes.

Porcellini et al[21] reported on long-term outcomes after arthroscopic treatment of 65 patients with less than 25% glenoid bone loss using a similar technique. The investigators found good clinical results for patients who underwent surgery within 3 months after the first dislocation. In contrast to Sugaya et al,[25] Porcellini et al found that patients with chronic lesions had significantly less favorable outcomes. The investigators indicated that histopathological bone, capsule, and ligament changes, as well as a longer interval until surgery (resulting in spontaneous healing of the fracture and the capsulolabral complex on the scapular neck), might account for this finding.

In the present study, 15 patients with a mean glenoid bone loss of 29% (range, 17%-49%) were treated using the arthroscopic BBB technique for creation of a stable 2-point compressive fixation. Comparable with the studies by Sugaya et al[25] and Porcellini et al,[21] in the present study the bony fragment was mobilized and incorporated into the repair in all patients. The advantage of the BBB technique is that there is no hardware at the bone-bone interface where healing occurs. Furthermore, the fragment is cerclaged, minimizing the risk of comminuting the bony Bankart fragment, as can happen with any technique requiring passage of an instrument through the fragment. Finally, having fixation points medially and laterally minimizes the risk of tilting, overreducing, or underreducing the fragment (Figure 3). Our outcomes showed good and excellent clinical outcomes in 94% of the patients and 1 (6%) poor result in a patient after traumatic redislocation. These results are somewhat better than what has been reported previously.[19,21,25] In contrast to Porcellini et al,[21] we did not find significantly inferior outcomes for the chronic group (delay of surgery >3 months).

A study by Mologne et al[19] emphasized the importance of mobilization, reduction, and incorporation of the bony

[||]References 3, 9, 10, 16, 19, 21, 24, 25, 29.

fragment when an arthroscopic suture anchor repair is used in patients with bony Bankart lesions. These investigators reported recurrent instability in 14.3% (3/21) of their patients. However, all failures occurred within the group that had attritional bone loss (n = 10) and none in patients with the presence of a bony fragment (n = 11).

Therefore, the BBB is a reliable arthroscopic repair technique even for patients with larger (>25%) glenoid rim fractures and additional Hill-Sachs lesions. The essential indication for this technique is the presence of a reducible bony fragment in acute or chronic Bankart fractures. However, for chronic cases with attritional bone loss, an open or arthroscopic coracoid transfer or bone graft procedure may be necessary to restore the glenoid anatomy.[17]

Although this is one of the largest series discussing treatment of the bony Bankart, this study is still limited by the relatively small number of patients, which is attributable to the infrequent nature of this injury. Another limitation is that we do not have radiographic confirmation of the glenoid fracture healing postoperatively at the time of final subjective follow-up on all patients, although the minimum 2-year follow-up period appeared to be appropriate in all cases to evaluate subjective postoperative stability and success of the procedure. However, radiographs (including true AP radiographs in supraspinatus outlet [Y-view] and axial views) were obtained at 3 to 4 months postoperatively on all patients and did show incorporation of the fragment. A strength of this study is that the data were collected prospectively and reviewed retrospectively using strict inclusion criteria; another strength is the reproducibility of the surgical technique performed by a single surgeon (P.J.M.). Furthermore, in addition to the glenoid bone loss, the depth of the Hill-Sachs lesions was measured in all patients, establishing a method using the ratio between Hill-Sachs depth and humeral head diameter. Certainly, further investigation will be necessary to report on long-term results after the BBB technique.

CONCLUSION

The arthroscopic BBB technique for anterior instability with glenoid rim fracture can restore shoulder stability, yield successful clinical outcomes, and provide high patient satisfaction in the presence of a bony fragment that can be subsequently reattached. Larger patient populations with longer follow-up are needed to draw more definite conclusions.

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