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Arthroscopic Versus Open Anterior Shoulder Stabilization

A Prospective Randomized Clinical Trial With 15-Year Follow-up With an Assessment of the Glenoid Being ''On-Track'' and ''Off-Track'' as a Predictor of Failure

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Background: Recent studies have demonstrated equivalent short-term results when comparing arthroscopic versus open anterior shoulder stabilization. However, none have evaluated the long-term clinical outcomes of patients after arthroscopic or open anterior shoulder stabilization, with inclusion of an assessment of preoperative glenoid tracking.

Purpose: To compare long-term clinical outcomes of patients with recurrent anterior shoulder instability randomized to open and arthroscopic stabilization groups. Additionally, preoperative magnetic resonance imaging (MRI) studies were used to assess whether the shoulders were ''on-track'' or ''off-track'' to ascertain a prediction of increased failure risk.

Study Design: Randomized controlled trial; Level of evidence, 1.

Methods: A consecutive series of 64 patients with recurrent anterior shoulder instability were randomized to receive either arthroscopic or open stabilization by a single surgeon. Follow-up assessments were performed at minimum 15-year follow-up using established postoperative evaluations. Clinical failure was defined as any recurrent dislocation postoperatively or subjective instability. Preoperative MRI scans were obtained to calculate the glenoid track and designate shoulders as on-track or off-track. These results were then correlated with the patients' clinical results at their latest follow-up.

Results: Of 64 patients, 60 (28 arthroscopic and 32 open) were contacted or examined for follow-up (range, 15-17 years). The mean age at the time of surgery was 25 years (range, 19-42 years), while the mean age at the time of this assessment was 40 years (range, 34-57 years). The rates of arthroscopic and open long-term failure were 14.3% (4/28) and 12.5% (4/32), respectively. There were no differences in subjective shoulder outcome scores between the treatment groups. Of the 56 shoulders, with available MRI studies, 8 (14.3%) were determined to be off-track. Of these 8 shoulders, there were 2 surgical failures (25.0%; 1 treated arthroscopically, 1 treated open). In the on-track group, 6 of 48 had failed surgery (12.5%; 3 open, 3 arthroscopic [$P = .280$]).

Conclusion: Long-term clinical outcomes were comparable at 15 years postoperatively between the arthroscopic and open stabilization groups. The presence of an off-track lesion may be associated with a higher rate of recurrent instability in both cohorts at long-term follow-up; however, this study was underpowered to verify this situation.

Keywords: shoulder; anterior instability; arthroscopic Bankart repair; open Bankart repair; on-track and off-track; glenoid track

The incidence of glenohumeral dislocation in the general population[26] is approximately 1% to 2%; however, the incidence is much higher in athletes as well as in the active duty military population.[29] Recurrent shoulder instability results in decreased performance in sporting activities and military-specific occupational demands, and, in some cases, may cause severe disability.[15] A tearing of the anterior capsulolabral attachment, called a "Bankart lesion," is present in 85% to 90% of cases of traumatic anterior shoulder dislocations.[22,28,29,35] Several landmark studies performed within the US military medical system demonstrated that arthroscopic stabilization reversed the natural history of this injury.[2,7,8,37] Many subsequent studies supported these findings.[1,19-21,29] The age and activity level of the patient who sustains an acute dislocation were found to best

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correlate with the risk of recurrence after nonoperative treatment.

Traditional operative shoulder stabilization, the open Bankart reconstruction, affords the ability to perform an open capsular shift and is the standard against which all arthroscopic techniques are compared. The use of arthroscopic stabilization for chronic recurrent anterior instability was initially reported to be less successful than traditional open techniques.[6,11,17,18,30,34] However, with a better appreciation of the arthroscopic pathoanatomy associated with anterior shoulder instability and an improvement in arthroscopic instrumentation, arthroscopic surgical outcomes have continually improved. Numerous studies with 2-year follow-up have demonstrated the comparable efficacy of current arthroscopic techniques with open techniques in restoring anterior shoulder stability.[3,5,10,24,33] A previous report of the present study population showed no statistically significant differences in established shoulder assessment scores.[3] The basis of this long-term study, with minimum 15-year follow-up, is a prospective randomized comparison of arthroscopic and open stabilization of the same consecutive series of 64 patients. Our first goal was to compare surgical failure rates and clinical outcomes between treatment cohorts.

There is a recently established scientific concept called "glenoid tracking," which was introduced to measure and quantify combined glenoid and humeral head bony defects and to predict their potential effect on shoulder stability. A cadaveric study by Yamamoto et al[38] determined that the glenoid track, or the amount of articular cartilage that contacts the humerus throughout its motion, is 84% of the glenoid width, while Di Giacomo et al[9] concluded this value was 83% among live participants. In a retrospective radiographic review of patients with clinical engagement on examination under anesthesia, Metzger et al[23] demonstrated that the glenoid track method may predict shoulders prone to engagement. Several studies confirmed the use of magnetic resonance imaging (MRI) to accurately and reproducibly measure the glenoid track in shoulders with bipolar bone loss.[9,12,26,31]

Therefore, the second goal of this study was to utilize the preoperative MRI studies in the same cohort of patients who had undergone arthroscopic or open stabilization to ascertain whether the shoulders were "on-track" or "off-track" based on established criteria. Since the concept of tracking was only recently proposed, we hypothesized that a retrospective review of the radiographic studies would allow a prediction of clinical failure for those shoulders found to be off-track. Our hypothesis was as follows: arthroscopic and open stabilization would yield comparable outcomes at long-term follow-up, but recurrent instability or clinical failure could be predicted by ascertaining which shoulders were off-track at the time of the index operation.

METHODS

Study Design and Setting

The index study was approved by our institutional review board, and all participants consented to randomization of surgical technique and magnetic resonance arthrography. The subsequent long-term follow-up study with retrospective review of the MRI studies was also approved by our institutional review board. Between April 2001 and September 2002, 64 consecutive patients with recurrent anterior shoulder instability were randomized to either arthroscopic or open stabilization (Figure 1).[3] This same cohort of patients was our target population for minimum 15-year follow-up assessment.

Randomized Controlled Trial

Patients aged $\geq$18 years with unidirectional recurrent anterior glenohumeral instability and at least 6 months of supervised rehabilitation that failed to resolve the condition were given the option to participate in the randomized controlled trial. Inclusion criteria of this trial consisted of unidirectional anterior instability and physical examination findings consistent with instability. Exclusion criteria consisted of any previous surgery, multidirectional instability, and the inability to return for clinical assessments. Randomization of patients was performed by study design to either the open or arthroscopic stabilization group. All procedures were performed by a single sports medicine fellowship–trained orthopaedic surgeon at our institution.

Surgical Technique

Open and arthroscopic techniques are described in our index article.[3] To summarize, for the arthroscopic procedure, the patient was placed in the lateral decubitus position, and 3 portals were established (2 anterior, 1 posterior). The anteroinferior labrum was elevated from the glenoid, and a bioabsorbable anchor was inserted at the articular margin of the glenoid. The permanent suture from the anchor was used to secure the labrum to the glenoid using a combination of an arthroscopic knot and alternating half-hitches. For the open technique, the patient was placed in the beach-chair position, and

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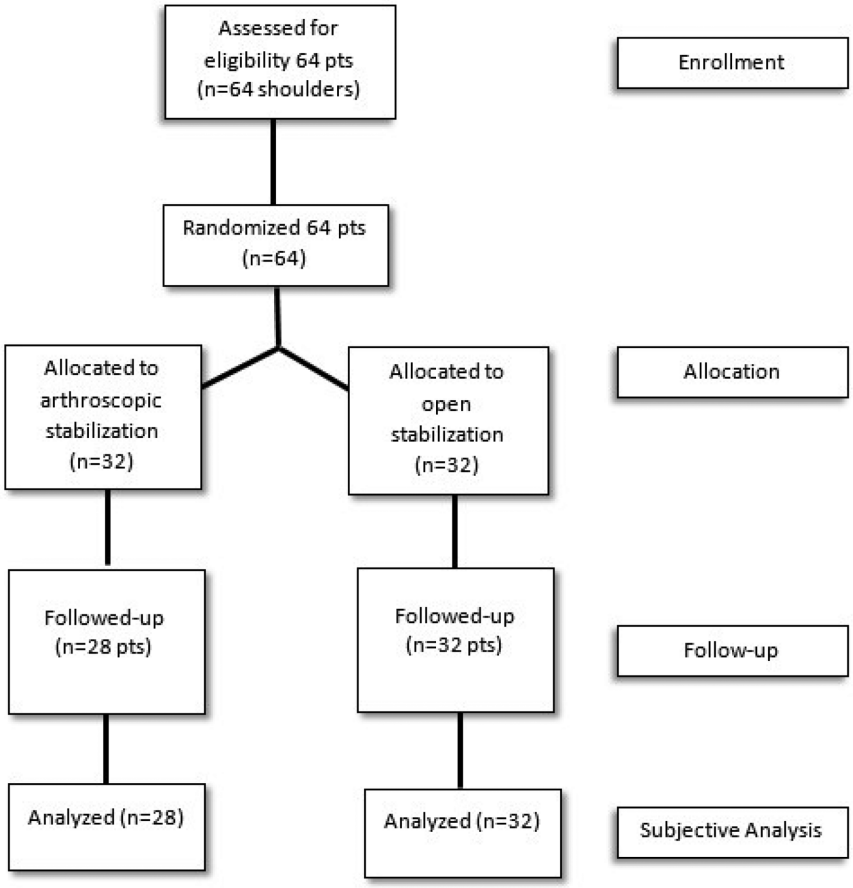

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flow diagram. pts, patients.

a standard deltopectoral approach was utilized. After the subscapularis tenotomy, a longitudinal and then horizontal capsulotomy was made to expose the Bankart lesion. The lesion was repaired with bioabsorbable anchors; a laterally based capsular shift was performed to eliminate redundancy; and a "pants-over-vest" technique completed the capsular repair. The subscapularis tendon was subsequently repaired with a No. 5 Ethibond suture. Both techniques utilized the same bioabsorbable anchor (BioFASTak; Arthrex Inc).

Data Collection

Our primary outcome assessments for surgical failure were a single redislocation event, surgery for recurrent anterior instability, or subjective instability of the operative shoulder. To better define a successful operative outcome, we included secondary outcome measures utilizing the following patient-reported outcome shoulder scores: Single Assessment Numeric Evaluation (SANE), Simple Shoulder Test (SST), and University of California Los Angeles (UCLA) shoulder score. The SANE score consists of a single subjective evaluation score from 1 to 100 and includes 3 domains: function, stability, and range of motion. The SST is a series of 12 yes/no questions regarding function of the involved shoulder. The UCLA score assesses pain, motion, function, and overall satisfaction on a 35-point scale. Outcome assessments were obtained by telephone, email surveys, or in person when available.

MRI Retrospective Evaluation of Glenoid Tracking

Unless contraindicated, all patients underwent magnetic resonance arthrography preoperatively. Patients consented separately to this procedure. Each shoulder was injected under fluoroscopic guidance with 12 mL of a solution containing a 1:200 dilution of gadolinium and Omni 180 nonionic contrast. The MRI examinations were performed with a 1.5-T magnet (Signa LX; GE Medical Systems) using a receive-only shoulder phased array coil (Medrad). The following sequences were obtained: axial, oblique sagittal, and oblique coronal spin echo T1 weighted with frequency-selective fat suppression (800/20 [repetition time, ms / echo time, ms]); oblique sagittal spin echo T1 weighted (800/20); and axial, oblique sagittal, and oblique coronal fast spin echo T2 weighted with frequency-selective fat suppression (4000/70). A 16- to 18-cm field of view, 256 $\times$ 192 matrix, and 4-mm slice thickness with

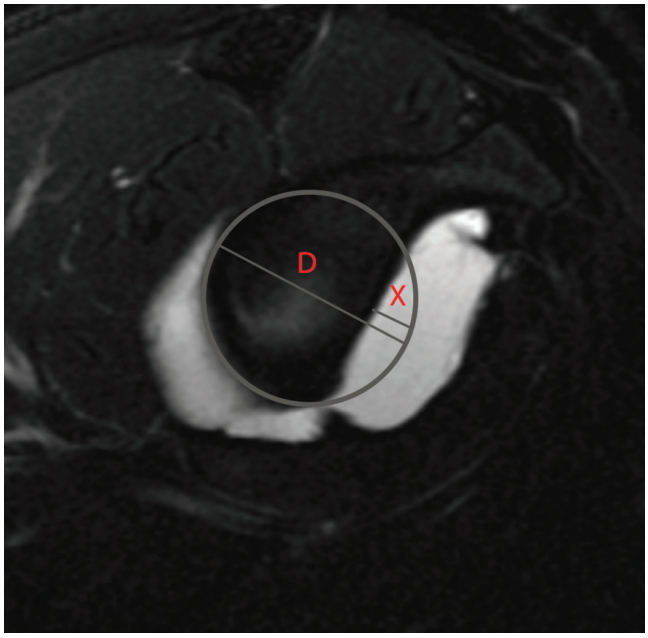

Figure 2. Sagittal cut of the glenoid en face. A perfect circle was drawn using the posteroinferior border of the glenoid to approximate the normal contour of an intact glenoid. The diameter of the glenoid, *D*, was measured, and the bone loss, *X*, was measured by a line from the anterior glenoid to the edge of the circle. The glenoid track was calculated as 0.83 × *D* – *X*. *Am J Sports Med.* 2015;43(7):1719-1725.

0.4-mm gap were used. One excitation was obtained for the T1-weighted images and 2 were obtained for the fat suppressed fast spin echo T2-weighted images. The studies were evaluated in soft copy format on a PathSpeed PACS workstation (General Electric Medical Systems) on 5MP CRT monitors (Barco NV). The available preoperative MRI studies of the patients from the long-term follow-up cohort were used to assess for the glenoid track. Using a digital Centricity picture archiving and communication system (General Electric), glenoid bone loss was quantified on sagittal cuts using a perfect-circle technique as described by Huysmans et al.[16,27]

The glenoid bare spot was used as a central reference point to draw a perfect circle that aligned with the intact posteroinferior glenoid rim. The circle diameter, drawn from the 9 to 3 o'clock position, provided the expected width before bone loss. Bone loss was then calculated by drawing a line overlapping the diameter of the defect area. The glenoid track was calculated as 83% of the diameter minus the bone loss (Figure 2). Hill-Sachs lesions were quantified by length as measured on axial cuts, using the slice with the largest lesion. An engaging or off-track lesion was defined as one in which the calculated glenoid track was narrower than the size of the Hill-Sachs lesion. The biceps angle was measured using a line from the bicipital groove to the center of the humeral head, and another line was drawn tangentially to the medial-most margin of the Hill-Sachs lesion, as described by Gyftopoulos et al.[12] Two fellowship-trained musculoskeletal radiologists and an orthopaedic surgeon trained in this technique reviewed and calculated the data independently to ensure accuracy of measurements.

TABLE 1
Combined Patient Demographics of Arthroscopic and Open Treatment Groups at 15-Year Follow-up

Age, y, mean (range)	40 (34-57)
Sex: male, %	96.7
Follow-up, y, mean (range)	15 (15-17)
Treatment, No. of patients	
Arthroscopic	28
Open	32

Statistics

Descriptive statistics were summarized for demographic data. A 2-way analysis of variance with repeated measures over time was used to analyze each subjective score (SANE, SST, and UCLA) to compare differences between the patient groups (open vs arthroscopic techniques). All statistics were performed using SPSS for Windows (Version 14.0 or higher; IBM), with significance verified by SAS (SAS Institute). The alpha level for all statistical tests was set at .05. A post hoc power analysis using the distribution of glenoid tracking within this study was performed to calculate the required number of patients needed to achieve 80% power in detection of clinical differences in instability rate.

RESULTS

Patient Characteristics

Of the 64 eligible patients from the initial study cohort, 60 were reached for follow-up. We obtained follow-up for all 32 patients in the open stabilization cohort, including the 3 patients originally lost to follow-up in the index 32-month study.[3] However, in the arthroscopic cohort, 3 patients were lost to follow-up and 1 was killed in combat, leaving 28 patients. Therefore, in the current evaluation with minimum 15-year follow-up (range, 15-17 years), we achieved 94% follow-up (60/64 patients) from the initial study cohort. The mean age at surgery was 25 years (range, 19-42 years), while the mean age at the time of this assessment was 40 years (range, 34-57 years). Of the total patients, 58 were men (96.7%) and 2 were women (3.3%) (Table 1).

Clinical Outcomes

There were 8 total clinical failures (4/28 arthroscopic and 4/32 open) by the defined criteria, resulting in arthroscopic and open long-term failure rates of 14.3% and 12.5%, respectively. Subjective shoulder outcome scores between the treatment groups were similar at the 32-month and 15-year follow-up periods (Table 2). The mean overall postoperative SANE scores at 32 months and 15 years were

TABLE 2
Mean Scores on Subjective Assessments: SANE, SST, and UCLA[a]

	Preoperative	Postoperative		*P* Value[b]
		32 mo	15 y	
SANE				.13
Total	53.0	92.3	83.1	
Open	52.7	90.6	85.7	
Arthroscopic	53.3	93.5	86.4	
SST				.11
Total		11.1	10.3	
Open		10.9	9.6	
Arthroscopic		11.4	10.8	
UCLA				.10
Total		31.4	28.6	
Open		30.6	29.9	
Arthroscopic		32.1	27.7	

[a]SANE, Single Assessment Numeric Evaluation; SST, Simple Shoulder Test; UCLA, University of California Los Angeles.
[b]15-year open vs arthroscopic.

92.3 and 83.1, respectively. The mean SANE preoperative score (53.0) for all shoulders was well below the 32-month and 15-year postoperative scores. The mean SST was 11.1 and 10.3 at 32 months and 15 years, respectively. The mean UCLA postoperative scores were 31.4 and 28.6 at 32 months and 15 years, respectively. There were no statistically significant differences between treatment cohorts in all measured outcome scores at the 15-year postoperative assessment ($P > .05$)

MRI Assessment of Glenoid Bone Loss and Tracking

Of the 60 patients, 56 (93.3%) had perioperative MRI scans available for review (29 open, 27 arthroscopic). All patients had an anterior labral tear (Bankart lesion). The mean glenoid bone loss was 8.5% (range, 0%-30.3%), and the mean Hill-Sachs lesion measured 12.9 mm in width (range, 0-29.8 mm). The average glenoid track was 23.0 mm (range, 16.3-28.9 mm). The mean biceps angle was 152° (range, 112°-227°). Measurements separated by surgical outcome are listed in Table 3. There were no statistically significant differences in the amount of glenoid bone loss, size of Hill-Sachs lesions, and biceps angle between patients who progressed to surgical failure and those who did not (P = .54, .78, and .67, respectively).

As previously noted, there were 8 clinical failures: 4 in the open stabilization group and 4 in the arthroscopic stabilization group. Of the 56 patients for whom MRI was available, 8 (14.3%) demonstrated an off-track shoulder, while 24 shoulders in each treatment group were on-track (Figure 3). Of the 8 off-track shoulders, 2 (25.0%) were clinical failures (1 treated arthroscopically, 1 treated open) while 6 remained stable (4 treated arthroscopically, 2 treated open). Of the remaining 48 on-track shoulders, there were 6 surgical failures (12.5%; 3 treated arthroscopically, 3 treated open [P = .280]). However, a post hoc power analysis showed a minimum sample size of 113 per cohort was needed to achieve 80% power to detect a difference between these proportions. Interobserver reliability for glenoid track status was 0.92.

TABLE 3
Magnetic Resonance Imaging Analysis of Surgical Successes and Failures at 15-Year Follow-up[a]

	Glenoid Bone Loss, %	Glenoid Track, mm	Hill-Sachs Lesion, mm	Biceps Angle, deg
Combined data	8.5	23.0	12.9	152.0
Surgical successes	8.8	23.0	13.0	154.6
Surgical failures	6.6	24.3	11.4	151.6

[a]Values are presented as means.

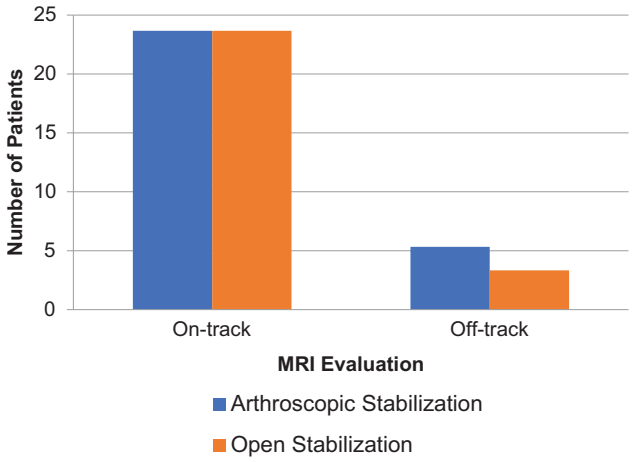

Figure 3. Glenoid track comparison by patient cohort. MRI, magnetic resonance imaging.

DISCUSSION

Early studies of arthroscopic stabilization demonstrated less favorable outcomes when compared with the traditional open Bankart technique. However, with better understanding of the arthroscopic pathoanatomy and the tools available for surgery, published results gradually improved. Many studies over the past 15 years have shown outcomes of arthroscopic stabilization comparable with those of open techniques. However, there have been no prospective randomized comparisons between arthroscopic and open stabilization techniques published with long-term follow-up. In this study, we found no statistically significant differences in the clinical failure rates between arthroscopic and open shoulder stabilization after a minimum of 2 years and again at a minimum of 15 years. There were 2 clinical failures in the open group and 1 in the arthroscopic group at short-term follow-up. However, after 15 years, the clinical failure rate doubled at 8 cases, 4 each in the open and arthroscopic groups. This is noteworthy

since studies reporting results at 2 years may significantly overestimate the long-term success of a surgical technique. This study suggests that longer follow-up is necessary to accurately determine the long-term stability and success of an operative technique. Despite the increase in the total number of surgical failures in this study over time, there were no statistically significant differences in failure rates between treatment groups.

Functional outcome scores decreased slightly over time and with increasing patient age; however, this decline was not significantly different from the 2-year outcomes for all scores (SANE, SST, and UCLA). Specifically, the SANE score remained well above the preoperative baseline (83.1 vs 53), suggesting a lasting subjective assessment 15 years postoperatively.

Osseous deficits of the glenoid and compression fractures of the humeral head are common in patients who have chronic anterior shoulder instability.[14,32] Sugaya et al[31] found a 90% incidence of glenoid bone loss in patients with anterior glenohumeral instability. An "engaging Hill-Sachs lesion" is defined as one in which the long axis of the defect is parallel to the anterior glenoid with the shoulder in a functional position of abduction and external rotation.[9] The engagement of the glenoid into the humeral defect results in apprehension, guarding, or a perception of shoulder instability. Engagement can be evaluated in 2 ways. Arthroscopically, an engaging Hill-Sachs lesion can be confirmed by observing the humerus while the arm is slowly moved into a position of abduction and external rotation. If the glenoid falls into the humeral defect, engagement is confirmed. Radiographically, the glenoid humeral defects can be measured to predict failure of arthroscopic stabilization attributed to engagement of the defect. In a retrospective study by Metzger et al,[23] the glenoid track theory was applied clinically using MRI as compared with examination under anesthesia as a reference standard, with a patient at a high risk for engagement if the width of the Hill-Sachs lesion was greater than that of the glenoid track. The technique demonstrated an accuracy of 85%. However, no study before the current study has applied this concept as a predictor of long-term clinical failure rate after surgery. Our analysis of patients at a mean 15-year follow-up yielded a 25.0% failure rate for off-track lesions as compared with 12.5% rate in on-track lesions. However, given that our sample size is underpowered, conclusions from the data are limited.

The debate between efficacy of arthroscopic and open shoulder stabilization techniques is well documented in the literature, with several studies showing improved outcomes, rate of recurrent instability, and subjective assessment scores of either technique.[3,10,13,25,33,36] The results of our long-term follow-up coincide with recent meta-analyses and systematic reviews that demonstrate no difference in failure rates between arthroscopic and open anterior shoulder stabilization.[4] Burkhart and De Beer[4] reported inferior results with arthroscopic management in the setting of engaging Hill-Sachs lesions, suggesting reconstruction with alternative techniques when significant glenoid bone deficits are quantified. However, there were only 3 patients with this defect in their study, and follow-up was limited to 27 months. In our combined long-term analysis of treatment modality with glenoid track evaluation, arthroscopic stabilization was not associated with higher failure rates in off-track shoulders, as there was an even distribution in stabilization methods between the surgical failures within this group (1 arthroscopic, 1 open). Furthermore, the majority of shoulders that remained stable in the presence of an off-track lesion were treated arthroscopically (4 of 6). Meanwhile, in patients with on-track lesions, there was an even distribution of surgical failures between stabilization techniques (3 arthroscopic, 3 open).

Limitations

Our study is not without limitations. Glenoid tracking assessment was retrospective and therefore subject to the inherent biases of the study design. Additionally, while we discovered a noticeably higher failure rate among shoulders that were off-track, a post hoc power analysis demonstrated that our sample size was statistically underpowered. A sample size of 113 patients per cohort would be required to make any definitive conclusions regarding failure rates between on-track and off-track lesions.

CONCLUSION

Our study demonstrated that open and arthroscopic Bankart repairs are safe and reliable in returning the majority of young athletes to full preinjury activities, even at 15 years postoperatively. An increase in surgical failures was noted between the 2- and 15-year follow-up periods in both treatment cohorts. Likewise, at long-term follow-up, the presence of an off-track lesion appeared to be associated with a higher rate of recurrent instability in the arthroscopic and open shoulder stabilization cohorts; however, this study was underpowered to answer this question. In both circumstances, failure was independent of the method of surgical stabilization. Larger studies are needed for further validation.

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