

# Glenoid Pathology, Skeletal Immaturity, and Multiple Preoperative Instability Events Are Risk Factors for Recurrent Anterior Shoulder Instability After Arthroscopic Stabilization in Adolescent Athletes



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**Purpose:** To identify risk factors for recurrent shoulder instability after arthroscopic stabilization in adolescent athletes. **Methods:** A retrospective case-control study was undertaken of all patients younger than 18 years undergoing arthroscopic shoulder stabilization for anterior instability between 2009 and 2016. Two patient cohorts were identified: (1) patients with recurrent instability (frank dislocations or subluxations) after arthroscopic stabilization and (2) an age- and sex-matched cohort of patients with no recurrent instability at a minimum of 2 years' follow-up from index surgery. Patient demographic, injury, radiographic, and surgical variables were recorded. Variables with  $P < .10$  on univariate analysis were entered into a binary logistic multivariate regression analysis. **Results:** We identified 35 patients (20.5%) in whom arthroscopic stabilization failed at a mean of  $1.2 \pm 1.0$  years after their index surgical procedure. A separate age- and sex-matched cohort of 35 patients with no evidence of recurrent instability was identified (mean follow-up,  $5.4 \pm 2.0$  years; minimum follow-up, 2 years). Univariate analysis identified increased glenoid bone loss ( $P = .039$ ), decreased glenoid retroversion ( $P = .024$ ), and more than 1 instability event prior to surgery ( $P = .017$ ) as significant risk factors for recurrent instability. Multivariate regression analysis revealed that glenoid retroversion less than  $6^\circ$ , skeletal immaturity, and more than 1 prior instability event significantly and independently predicted future recurrence. The risk of recurrence after arthroscopic stabilization was increased by 3 times in patients with 2 risk factors and by 4 times in patients with all 3 risk factors. **Conclusions:** Anterior glenoid bone loss, glenoid version, skeletal immaturity, and multiple preoperative instability events are risk factors for failed arthroscopic stabilization in adolescent athletes with anterior instability. **Level of Evidence:** Level III, case-control study.

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Shoulder instability is a common problem within the adolescent population. Overall, the incidence of shoulder dislocations is reported to be 11.2 to 23.9 per

100,000 person-years.<sup>1-4</sup> The highest-risk population for shoulder dislocations is young adolescent male individuals, with the incidence in this population an order of magnitude higher, at 164.4 per 100,000 person-years.<sup>5</sup> Among all types of shoulder instability, anterior shoulder instability is by far the most common, accounting for 85% to 95% of cases.<sup>1,2</sup>

Although there are many different approaches to treating anterior shoulder instability, 87% to 91% of surgical shoulder stabilization procedures in the United States are performed through an arthroscopic approach.<sup>6,7</sup> Moreover, a study by Bonazza et al.<sup>6</sup> showed that the absolute number as well as the proportion of arthroscopic stabilization surgical procedures steadily increased yearly from 2008 to 2012, with 9,245 arthroscopic cases in 2008 versus 16,331 cases in 2012.

Although studies have shown that assessments of satisfaction after arthroscopic shoulder stabilization

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have shown predominantly good to excellent outcomes,<sup>8,9</sup> recurrent instability is still a problem, with reported rates between 8% and 51%.<sup>8,10,11</sup> The highest risk of recurrence was reported in a study looking at adolescent contact athletes.<sup>11</sup> Previously reported patient-associated risk factors for recurrent instability after arthroscopic repair in all age groups include an increased number of dislocations prior to surgery, delayed surgery, younger age, off-track lesion, large Hill-Sachs lesion, glenoid bone loss, white ethnicity, bilateral shoulder instability, history of closed reduction prior to repair, and ligamentous laxity.<sup>12-16</sup> Technical factors shown to increase the risk of recurrent instability include the use of fewer suture anchors, absorbable suture anchors, and standard knotted suture anchors.<sup>17</sup> Although it is likely that many of the risk factors previously studied in the adult population would apply to the adolescent and/or pediatric population, the goal of our study was to elucidate this.

Given the high prevalence of anterior shoulder instability in the adolescent population and the increasing popularity of arthroscopic repair, the purpose of this study was to identify risk factors for recurrent shoulder instability after arthroscopic stabilization in adolescent athletes. Our hypothesis was that bony morphologic changes, such as the degree of glenoid bone loss, would be predictive of recurrent instability after arthroscopic stabilization surgery.

## Methods

After obtaining approval from the institutional review board, we performed a retrospective review of charts and magnetic resonance imaging (MRI) scans, including concurrent prospective data collection on patient outcomes. Current Procedural Terminology codes (29806) were used to identify patients who underwent arthroscopic shoulder stabilization from 2009 to 2016 performed by the 2 senior authors (A.T.P. and E.W.E.). All patient charts were reviewed for any evidence of recurrent instability, defined for this study as redislocation or recurrent subluxation after surgery, including subjective feelings of subluxation. The exclusion criteria included age 18 years or older at the time of the initial surgical procedure, underlying syndromes affecting the musculoskeletal system, absence of shoulder MRI of sufficient quality for radiographic measurements, and any clinical or arthroscopic evidence of posterior or multidirectional instability.

After identification of a cohort of patients with recurrent instability, the remaining patients were organized by sex and surgeon and then ordered by operative date. A sequential set of age- and sex-matched patients was identified to serve as the control group. All patients in the control group were questioned directly and confirmed that they did not have any recurrent instability with a minimum of 2 years'

follow-up. The recurrent dislocation group was not questioned because once we had documented evidence of recurrent instability, we did not believe this was necessary. Patient charts were then reviewed for age at the time of the initial surgical procedure, time to surgery from initial injury, and number of dislocations prior to surgery. Operative reports were reviewed for the number and location of suture anchors, tear size, and tear location based on a clock face.

All radiographic measurements were performed by a single reviewer (T.T.C., orthopaedic surgery chief resident) with the patient order randomized and the reviewer blinded to the patient's failure status. Anatomic measurements were recorded from the most recent MRI scan prior to the initial stabilization surgical procedure. Measurements obtained included glenoid bone loss, Hill-Sachs lesion size, and glenoid version. Glenoid bone loss was measured using the best-fit circle method as previously described for MRI.<sup>18</sup> Hill-Sachs lesion size in this study was defined as the maximum Hill-Sachs lesion size measured on an axial MRI scan. For each shoulder, calculations were also made to calculate the glenoid track and classify the lesion as an on- or off-track lesion based on the formula from Di Giacomo et al.<sup>19</sup> and validated for MRI by Gyftopoulos et al.<sup>20</sup> Each patient was also classified as having open, closing, or closed proximal humeral physes identified on MRI.

Univariate analysis was performed using analysis of variance (ANOVA) for continuous variables and the  $\chi^2$  test for categorical variables. Statistical analysis was performed with SPSS software (IBM SPSS Statistics for Windows, version 25.0 [released 2017]; IBM, Armonk, NY). ANOVA was used given statistician preference to use the univariate general linear model ANOVA function within the SPSS program because it allows for automatic saving of the standardized residuals of the dependent variable to produce a quantile-quantile plot to evaluate the distribution. From these results, all variables with  $P < .10$  were entered into a backward stepwise conditional binary logistic regression to evaluate which of these variables was an independent predictor of failure, with  $P < .05$  required for a variable to meet the criteria to remain in the final regression model. For continuous variables on regression analysis, the lower bound of the 95% confidence interval (CI) for the group with no failure and the upper bound of the 95% CI for the group with failure were used to determine a cutoff to create a categorical variable. This was then assessed by the  $\chi^2$  test.

## Results

A total of 171 patients underwent arthroscopic shoulder stabilization for anterior shoulder instability during the study period performed by the 2 senior authors (A.T.P. and E.W.E.). Among this group, 35

patients (20.5%) were identified as having recurrent instability after arthroscopic shoulder stabilization. The average age of this cohort was  $15.9 \pm 1.4$  years at the time of the initial surgical procedure, and 29 of these patients (83%) were male adolescents. The average time to failure was  $1.2 \pm 1.0$  years. An age- and sex-matched control group consisting of 35 patients was also evaluated. The average age of the control cohort was  $16.4 \pm 1.3$  years ( $P = .16$ ), and 29 of these patients (83%) were male adolescents ( $P = .99$ ). The average follow-up period in this group was  $5.4 \pm 2.0$  years (minimum of 2 years' follow-up). Table 1 shows patient demographic characteristics of the failure and control groups.

Additionally, Table 1 evaluates the patient factors for both groups. On univariate analysis, the number of prior dislocations showed the only significant difference between the failure and control groups. Ninety percent of patients who had failure of operative stabilization reported more than 1 dislocation prior to surgery compared with 65% of the controls ( $P = .017$ ). There was no difference between the groups when we compared tear size ( $P = .45$ ), number of anchors ( $P = .68$ ), or participation in collision sports ( $P = .47$ ).

Table 1 also shows the radiographic factors that were evaluated for both groups. Radiographic measurements showed significantly increased glenoid bone loss and loss of glenoid retroversion in the failure group on univariate analysis. Glenoid bone loss measured  $3.2 \pm 3.9$  mm in the failure group compared with  $1.6 \pm 2.5$  mm in the control group ( $P = .039$ ). Glenoid retroversion was  $5.1^\circ \pm 3.4^\circ$  in the failure group compared with  $6.9^\circ \pm 3.1^\circ$  in the control group ( $P = .024$ ). The presence of an open proximal humeral physis did not

reach significance, with open physes in 63% of patients in the failure group versus 43% in the control group ( $P = .094$ ). There were no off-track lesions in either group, and the Hill-Sachs lesion size was not a significant predictor of recurrent instability ( $P = .30$ ).

For the regression analysis, glenoid retroversion less than  $6^\circ$  was used as a cutoff for categorical variables based on frequency distribution and CI plots (Fig 1). On regression analysis, an open physis (odds ratio [OR], 3.9; 95% CI, 1.1-13.9;  $P = .04$ ), more than 1 dislocation prior to surgery (OR, 7.7; 95% CI, 1.6-38.7;  $P = .01$ ), and glenoid retroversion less than  $6^\circ$  (OR, 9.1; 95% CI, 2.5-33.3;  $P < .001$ ) were shown to be independent predictors of recurrent instability. We found that having 0 of the aforementioned variables and 1 variable showed failure rates of 25% and 21%, respectively. The failure rate increased to 65% with 2 predictive variables and to 82% with 3 variables (Figs 2 and 3).

## Discussion

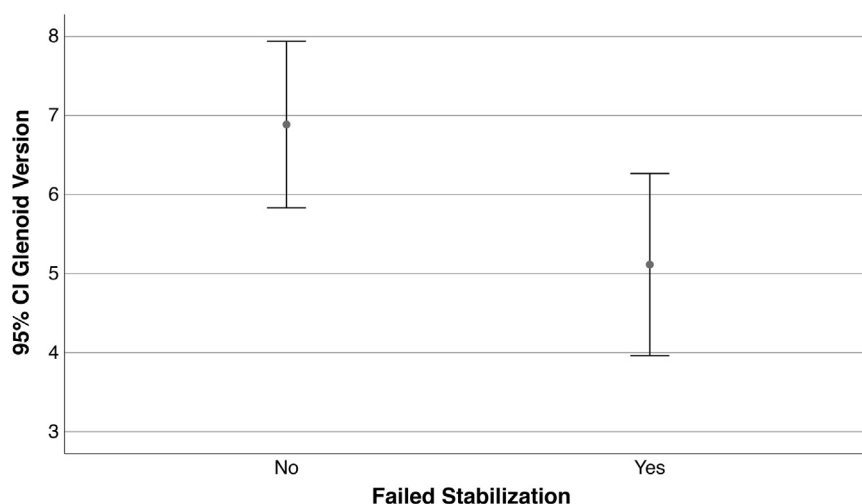
The results of this study show that young patients in whom arthroscopic shoulder stabilization failed were more likely to have more than 1 dislocation prior to surgery, increased glenoid bone loss, decreased glenoid retroversion, and open proximal humeral physes. Furthermore, regression analysis showed that a history of more than 1 dislocation, decreased glenoid retroversion, and open physes were the most important independent risk factors. Having 2 of the aforementioned risk factors increased the chance of recurrent instability by 3 times and having 3 risk factors increased it to 4 times the baseline of 21%. Arthroscopic stabilization for shoulder instability remains a common procedure for the adolescent population. Rates of recurrent instability

**Table 1.** Univariate Comparisons Between Failures and Controls: Demographic Characteristics, Follow-up Information, Patient Factors, and Radiographic Factors

	Failure Group	Control Group	P Value
N	35	35	—
Male patients	29 (83)	29 (83)	.99
Average age at surgery, yr	$15.92 \pm 1.44$ (15.4-16.4)	$16.37 \pm 1.27$ (15.9-16.8)	.162
Time to failure, yr	$1.19 \pm 0.99$ (0.84-1.5)		
Final follow-up, yr		$5.38 \pm 2.01$	
Tear extent, °	$156.86 \pm 59.60$ (136.4-177.3)	$170.14 \pm 83.83$ (141.4-198.9)	.447
No. of anterior anchors	$3.74 \pm 0.78$ (3.5-4.0)	$3.83 \pm 0.92$ (3.5-4.2)	.676
No. of posterior anchors	$0.83 \pm 1.34$ (0.4-1.3)	$1.03 \pm 1.77$ (0.4-1.6)	.596
Patients in collision sports	19 of 35 (54.3)	22 of 35 (62.9)	.467
Patients with >1 dislocation	27 of 30* (90)	22 of 34* (64.7)	.017
Glenoid bone loss, mm	$3.24 \pm 3.87$ (1.9-4.6)	$1.61 \pm 2.48$ (0.8-2.5)	.039
% Bone loss	$10.07 \pm 11.73$ (6.0-14.1)	$5.03 \pm 7.65$ (2.4-7.7)	.037
Glenoid version, °	$5.11 \pm 3.31$ (3.9-6.3)	$6.89 \pm 3.07$ (5.8-7.9)	.024
Patients with glenoid version < 6°	23 of 35 (65.7)	10 of 35 (28.6)	.001
Hill-Sachs lesion size, mm	$13.8 \pm 4.62$ (11.9-15.6)	$13.12 \pm 4.86$ (10.3-14.5)	.3
Open physes	22 of 35 (62.9)	15 of 35 (42.9)	.094

NOTE. Continuous variables are reported as mean  $\pm$  standard deviation (95% confidence interval), whereas categorical variables are reported as absolute number (percentage).

\*The information was not available for all patients.



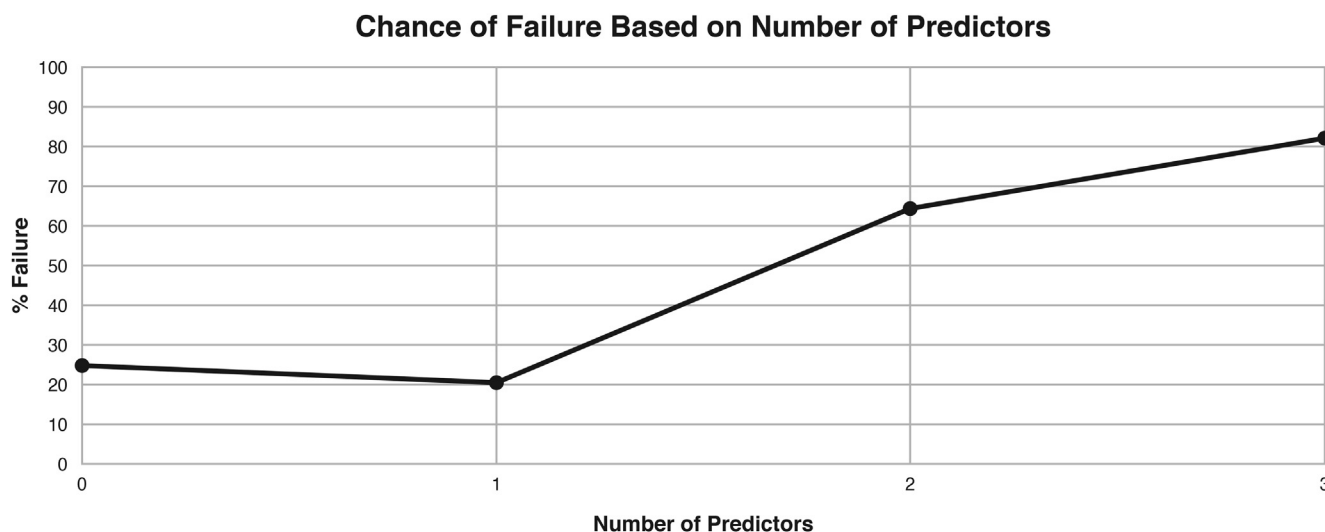
**Fig 1.** The 95% confidence intervals (CIs) for glenoid version for patients who had successful versus failed stabilization procedures were used to choose a cutoff of 6°.

after surgery as high as 51% have been reported in the adolescent population. Given this high-risk group, it is important to determine risk factors for recurrent instability after arthroscopic shoulder stabilization in the adolescent population.

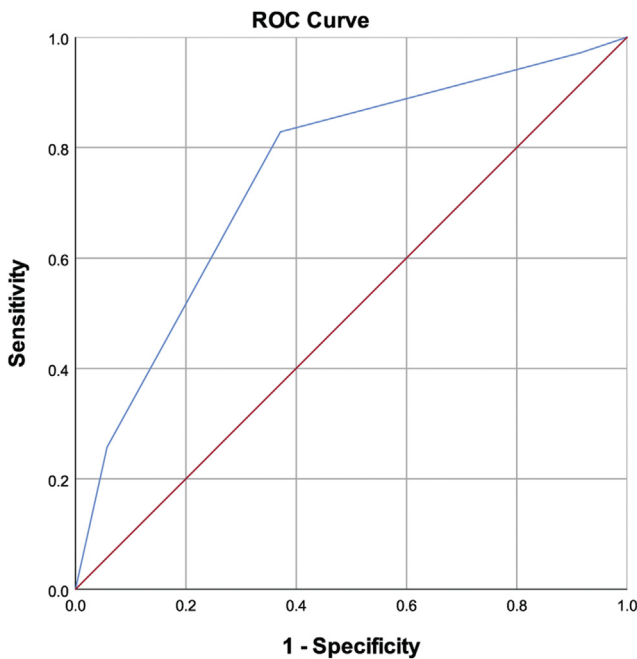
Multiple studies have shown that patient age is an independent risk factor for failure of arthroscopic shoulder stabilization.<sup>11,13,15,16</sup> Waterman et al.<sup>21</sup> evaluated a military population and reported that for every 1-year increase in age, patients showed a 7% decrease in failure rate. Torrance et al.<sup>11</sup> evaluated recurrent instability in an adolescent population and found that patients younger than 16 years at the time of index surgery had over double the risk of recurrent instability. In our study, we did not find a significant difference in age between the 2 groups. The presence of an open physis, which is often used as a surrogate for

age in the adolescent and pediatric populations, showed a higher incidence in the recurrent failure group, although it did not reach significance on univariate analysis. On multivariate regression, however, this was shown to be a significant independent predictor of recurrent instability.

Our study showed that patients with more than 1 dislocation prior to surgery were over 7 times more likely to have recurrent instability. This result confirms the findings of 2 prior studies showing that an increased number of dislocations prior to surgery is a risk factor for shoulder instability recurrence.<sup>12,14</sup> A study by Marshall et al.<sup>14</sup> showed that patients with more than 1 dislocation prior to arthroscopic stabilization had a greater than 4 times higher risk of needing a repeated surgical procedure to address instability (32% vs 7%,  $P < .001$ ). Currently, it is unclear what incremental



**Fig 2.** Chance of recurrent instability based on number of preoperative predictive factors including open physes, less than 6° of glenoid retroversion, and more than 1 dislocation preoperatively.



**Fig 3.** Receiver operating characteristic (ROC) curve based on number of predictors of failed arthroscopic stabilization.

increase in risk each additional preoperative instability event has on future recurrence rates. Our data, along with those of previously published studies, do show that the risk of recurrent dislocation after arthroscopic Bankart repair is higher when additional preoperative dislocations occur. What effect this information should have on surgical indications and the timing of interventions is currently an important topic of discussion. With early surgery, we can reduce the risk of recurrent postoperative instability. If we were to operate on every patient with a first-time traumatic anterior shoulder dislocation, however, we would likely be treating patients who may not need an operation. This point highlights the importance of identifying potential risk factors to better guide surgical decision making and should play a role in the discussion of treatment options with patients.

Glenoid version has been evaluated as a factor in posterior shoulder instability<sup>22,23</sup> but, until now, has not been shown to be a significant factor in recurrent anterior shoulder instability. This study showed a significant difference in retroversion between our cohort groups on both univariate analysis and multivariate regression analysis. Patients with glenoid retroversion less than  $6^\circ$  were 9.1 times more likely to have recurrent instability. Biomechanically, there are several explanations for why decreased glenoid retroversion may be a risk factor for recurrent instability. First, increased glenoid anteversion changes the forces and vectors acting on the humeral head, in turn decreasing the force needed to shift the humeral head anteriorly.

Second, although loss of glenoid retroversion may biomechanically predispose patients to anterior shoulder instability, it is also possible that this measurement is a surrogate measure of anterior bone loss given the curvilinear nature of the glenoid face (lacking the anterior aspect of the face would falsely measure more anteversion). With additional dislocation events, attritional wearing of the anterior glenoid could lead to changes in this measurement.

On univariate analysis, glenoid bone loss was significantly greater in patients with recurrent instability, but this was not shown to be an independent predictor of failure on multivariate regression. In previous studies, the findings on glenoid bone loss as a predictor of recurrent instability are mixed, with some studies showing it to be a significant risk factor<sup>15</sup> but others showing it not to be a risk factor.<sup>11,12</sup> Additionally, multiple prior studies have reported findings similar to our findings with glenoid bone loss showing significance on univariate analysis but not on multivariate regression,<sup>16</sup> likely because it is encapsulated in both loss of glenoid retroversion and multiple preoperative dislocations, thus making it not an independent predictive variable.

Arthroscopic stabilization for anterior shoulder instability continues to be a common procedure, and the adolescent population is the highest-risk group for this pathology. This study highlights that having more than 1 dislocation prior to surgery, having glenoid retroversion less than  $6^\circ$ , and having open physes are all independent risk factors for having recurrent instability after arthroscopic stabilization. Teenagers with 0 or 1 of these risk factors have a baseline risk of recurrence of just over 20%. Those with 2 of the aforementioned risk factors have a 3-fold increased risk of recurrence, and adolescents with all 3 risk factors have a 4-fold increased risk. This information can be useful in counseling patients regarding treatment options, as well as surgical outcomes, and to begin a conversation related to life choices after surgical recovery.

### Limitations

This study has a number of limitations, the primary one being its retrospective nature. For most control patients, the data were obtained by phone calls made several years after the index operation, subjecting these data to recall bias. For the failure group, we accepted subjective postoperative instability and subluxation events as a marker of recurrence. Although this may have overestimated our recurrence rate compared with objectively documenting all cases of recurrent instability with imaging, it does provide an accurate clinical measure for recurrent instability. Additionally, although the failure group represents a consecutive series of patients, the control group does not. As a result, we could not calculate the incidence rate. As a



retrospective study, this study is limited to the number of failures within our study period, which limits the power. This lack of power may have led to a type II error and to some significant risk factors not being identified. Another limitation related to the retrospective nature of this study is that only patients who were identified as having failure on routine follow-up or identified by follow-up phone call during creation of the control group were included in the failure cohort. This could introduce selection bias if the variables identified as risk factors were actually tied to the likelihood of patients presenting for follow-up after failure. The most likely scenario for this would be open physes as a risk factor because younger patients may be more likely to follow up with their treating surgeon after failure. Finally, all radiographic measurements were made on MRI scans and not computed tomography scans, which would be the ideal modality for osseous measurements. MRI, however, has been used and validated in multiple prior studies to measure glenoid dimensions and bone loss.<sup>20</sup> Additionally, MRI is more routinely obtained in patients with anterior shoulder instability, potentially making it more important in the assessment of recurrent instability risk. It is also worth noting that the quality of all MRI studies was not uniform and thus could introduce some variability to the results.

## Conclusions

Anterior glenoid bone loss, glenoid version, skeletal immaturity, and multiple preoperative instability events are risk factors for failed arthroscopic stabilization in adolescent athletes with anterior instability.

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