

Arthroscopic Stabilization of Shoulder Instability in Children and Adolescents With Open Physes: Minimum Two-year Follow-up Portends Unsatisfactory Recurrence Rates

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Background: Outcomes following shoulder instability events suggest high rates of recurrence for the pediatric population. Previous studies have not focused on those with open physes at the proximal humerus, and longer-term surgical outcomes have not been evaluated for this population. The purpose of the current study is to evaluate patient-reported outcomes and recurrence rates in skeletally immature children and adolescents undergoing arthroscopic stabilization procedures.

Methods: A retrospective review of all skeletally immature patients who underwent arthroscopic shoulder stabilization between 2009 and 2021 from 2 pediatric hospitals was performed. Demographic, injury, imaging, and intraoperative data were recorded. Patient-reported outcomes, including the Pediatric/Adolescent Shoulder Survey (PASS), return to sport, instability recurrence, and need for revision surgery, were documented. Statistical analysis was performed to assess risk factors for recurrence.

Results: One hundred one skeletally immature patients met the inclusion criteria. The mean age at the time of surgery was 14.8

± 1.4 years, and 74% were males. The majority of patients had anterior instability (78%), 17% had posterior instability, and 5% had multidirectional instability. Contact sports were responsible for 47% of injuries. The average number of dislocations before surgery was 2.6 ± 3.4. At a mean follow-up of 5.1 ± 2.9 years, the mean PASS score was 88 ± 14. A total of 35 patients (34.7%) experienced recurrent instability, and 10 patients (10%) had a revision procedure. Patients with recurrent instability were found to be younger, had longer clinical follow-up duration, and had a lower final PASS score. Direction of instability was not associated with recurrence rate. Other factors such as sex, number of dislocations before surgical intervention, and participation in contact sports were not significantly associated with recurrent instability.

Conclusions: While the majority of skeletally immature children and adolescents undergoing arthroscopic shoulder stabilization can achieve favorable outcomes, recurrent instability remains a problem, as ~1 in 3 patients may experience recurrent instability with younger patients being at particular risk.

Level of Evidence: Level IV—retrospective case series prognostic study.

Key Words: shoulder instability, adolescent, open growth plate, skeletally immature

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Shoulder instability is a common clinical problem in the adolescent patient population, with incidence rates estimated as high as 164 per 100,000 person-years, and with ~20% of all shoulder dislocations occurring in those younger than 20 years old.^{1–3} While treatment remains controversial and has evolved over the past several decades, many patients will undergo an initial attempt at nonoperative treatment, including physical therapy, activity modifications, and potential bracing.^{3–5} Despite this, a large percentage of adolescents with shoulder instability will go on to have recurrent subluxations or dislocations of the shoulder joint.^{4–7} In these scenarios, the vast majority of providers will recommend surgical

stabilization. For most patients, an attempt at arthroscopic stabilization is performed initially, with the knowledge that subsequent open or bony procedures may be necessary in the future or in select situations involving bone loss.^{4,5,8,9}

Currently, there is a paucity of literature in the skeletally immature population regarding how children and adolescents fare with arthroscopic stabilization, as longer-term surgical outcomes have not been evaluated.¹⁰ With nonoperative treatment, this population has a high chance of recurrence, but surgical outcomes after arthroscopic stabilization have not been well defined.⁷ Therefore, the purpose of this study was to investigate patient-reported outcomes and recurrence rates at long-term follow-up in skeletally immature children and adolescents undergoing arthroscopic stabilization.

METHODS

International review board approval was obtained. A retrospective chart review of all skeletally immature patients who underwent arthroscopic shoulder stabilization from 2009 to 2021 was performed. Surgeries were performed at 2 pediatric hospitals by one of 3 board-certified pediatric orthopaedic surgeons. Patients were included if they had an open physis at the proximal humerus, as seen on preoperative magnetic resonance imaging, as well as a minimum of 2-year follow-up or a documented failure before 2 years of follow-up.

All patients underwent either a preoperative magnetic resonance imaging (MRI) or MR arthrogram to assess skeletal maturity and evaluate soft tissue and osseous pathology. Skeletal maturity was assessed by evaluating the status of the proximal humeral physis on MRI, with an open physis defined by the presence of a hyperintense cartilage layer between the metaphysis and epiphysis. The proximal humeral physis typically fuses between ages 12 and 19 in females and 15.75 and 20 in males.^{11–13} Demographic, injury, imaging, intraoperative, and follow-up data were recorded. An imaging subanalysis was performed, which included quantification of glenoid bone loss percentage (CITE), anterior Hill-Sachs lesion width in the axial plane in millimeters (mm; CITE), on-track versus off-track classification (CITE), and identification of humeral avulsion of the glenohumeral ligament (HAGL) lesions (CITE).^{14–23} Patients with MDI in this study did not routinely have capsular closure. Our surgery included an anterior and posterior capsulorrhaphy with anchors.

Patient-reported outcomes were documented utilizing the Pediatric/Adolescent Shoulder Survey (PASS), which is a validated and reliable youth-focused 13-item assessment of shoulder-specific outcomes with significant correlation of scores to other commonly used measures such as QuickDASH (Disabilities of Arm, Shoulder, and Hand) and SANE (Single Assessment Narrative Evaluation).²⁴ Return to sport, instability recurrence, and the need for revision surgery were also recorded. Recurrent instability after initial surgery was

patient-reported. Statistical analysis was performed with the primary aim to assess patient-reported outcomes and recurrence rates, and the secondary aim to assess risk factors for recurrence. Alpha was set at $P < 0.05$ to declare significance. All analyses were performed utilizing SPSS v. 28.

RESULTS

A total of 101 skeletally immature children and adolescents met the inclusion criteria and underwent analysis. The mean age at the time of surgery was 14.8 ± 1.4 years, and 74% of patients were males (Table 1). Of the 101 patients, a subset of 64 patients had MRI data available to the authors. Eight (8/64, 12.5%) underwent a standard MRI, and 55 (55/64, 86%) underwent MR arthrogram before surgery. Notably, contact sports, defined as football, rugby, wrestling, or boxing/MMA, were responsible for 47% of injuries (Table 1). The average number of dislocations before surgery was 2.6 ± 3.4 , with a mean of 4.6 ± 2.1 anchors placed at the time of arthroscopy (Table 1). One patient underwent a Remplissage procedure at the time of initial surgery; this patient was in the non-failure group. Patients in this cohort had a mean follow-up of 5.1 ± 2.8 years, and the mean PASS score was 88 ± 14 (Table 1).

A majority of patients, 78%, had anterior shoulder instability, 17% had posterior instability, and 5% had multidirectional instability (MDI; Table 2). A total of 35 patients (34.7%) experienced a failure, defined as at least one episode of recurrent instability, and 10 patients (10%) underwent a revision procedure (Fig. 1). Thirteen of these were traumatic recurrences, 12 were atraumatic, and 10 were of unknown mechanism or were not otherwise documented in the medical record. Those with recurrent instability were found to be younger, had a longer clinical follow-up duration, and had a lower final PASS score (Table 3). While the direction of instability was not associated with recurrence rate, the MDI cohort had an 80% failure rate, with 4 out of 5 patients with MDI experiencing recurrent instability (Table 2). Other factors such as sex, the number of dislocations before surgical intervention, and participation in contact sports were not found to be significantly associated with recurrent instability (Table 3).

Regarding the imaging subanalysis that was per-

TABLE 1. Demographic Information and Perioperative Data of Included Patients (n = 101)

Patient information	
Age at surgery (y, mean \pm SD)	14.8 \pm 1.4
Sex (M/F)	75/26
Laterality (L/R)	42/59
Contact sport played (football, wrestling, rugby, boxing/MMA) (N/Y)	54/47
No. dislocations preoperative (mean \pm SD)	2.6 \pm 3.4
No. anchors placed operatively (mean \pm SD)	4.6 \pm 2.1
PASS score (0-100, mean \pm SD)	88 \pm 14
Time from surgery to PASS score (y, mean \pm SD)	5.1 \pm 2.78

TABLE 2. Instability Direction of Included Patients (n = 101) and Associated Failure Rates

Instability direction	Frequency (% of cohort)	No. failures (% of instability direction)	Failure rate (% of total cohort, n = 101)	% of total failures (n = 35)
Anterior	79 (78.2)	26 (32.9)	25.7	74.3
Posterior	17 (16.8)	5 (29.4)	5.0	14.3
Multidirectional (MDI)	5 (5)	4 (80)	4.0	11.4

Failure is defined as recurrent instability.

formed, glenoid bone loss, Hill-Sachs lesion width, and on/off track status were evaluated for a subset of patients with anterior instability whose imaging was available at the time of review (n = 64). Nine patients (14%) were found to have glenoid bone loss, which averaged 16% for these patients. Approximately half of patients (n = 30, 47%) were noted to have Hill-Sachs lesions, which averaged 14 mm in the axial plane (Table 4). One patient (1.6%) was classified as having an off-track lesion. No HAGL lesions were identified. All patients with Hill-Sachs lesions were also found to have glenoid bone loss (n = 30, 47%). Presence of glenoid bone loss was not significantly associated with failure, though it was significantly associated with undergoing repeat surgery. The presence of Hill-Sachs lesion was significantly associated with failure and repeat surgery (Table 5).

DISCUSSION

This study demonstrates that a majority of skeletally immature children and adolescents undergoing arthroscopic shoulder stabilization can achieve favorable results, as determined from PASS scores; however, approximately one-third of patients in this cohort experienced at least one episode of recurrent instability. Further, these results illustrate that among skeletally immature patients, those who are younger and with MDI are more likely to experience recurrent instability fol-

lowing surgical intervention (Table 3). The overall recurrence rate for the cohort investigated was 34.7%, which is higher than recurrence rates reported in the literature (14% to 25%) for older adolescent patients.^{25,26} In this cohort, younger age at surgery was associated with a higher failure, suggesting that skeletal immaturity may be linked to an increased failure rate, compared with their skeletally mature counterparts. Clinical follow-up was also found to be statistically longer in patients who experienced recurrent instability (Table 3). This effect is most likely due to extra visits that were scheduled for longitudinal observation and treatment following the recurrent episode. This likely parallels the finding that those who experienced recurrent instability also had statistically lower PASS scores (Table 3). A lower PASS score follows as the natural consequence of recurrent instability in that the scoring of PASS will be lower if a respondent has indicated an event of instability.²⁴ Revision surgery was recommended on a case-by-case basis with consideration of patient goals and preferences. Patients were offered physical therapy and lifestyle or activity modification if they did not wish to proceed with additional surgery. In addition, given that both institutions are tertiary pediatric centers, patients may leave for college, relocate, or transition to adult providers, which can contribute to loss to follow-up.

Of the 101 patients in this study, 79 patients had

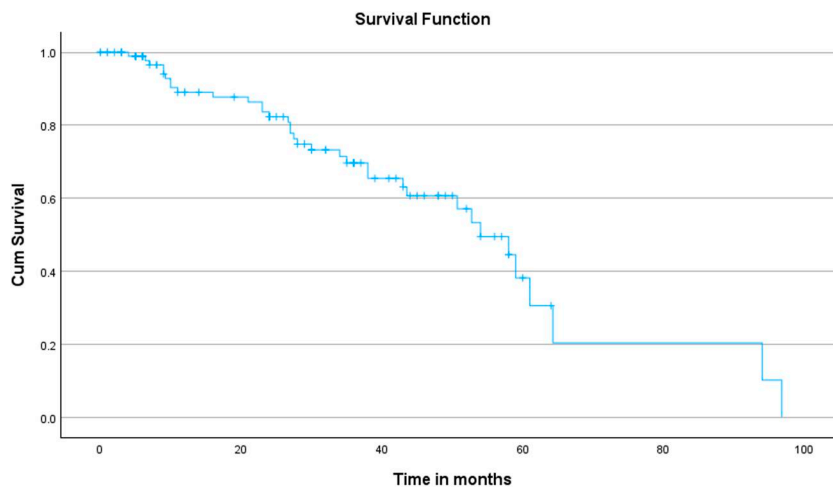


FIGURE 1. Kaplan-Meier survival analysis for skeletally immature patients with shoulder instability from the time of surgery to failure (recurrent instability) or final clinical follow-up for those without failure.

TABLE 4. Descriptive Statistics for Imaging Findings

Percent glenoid bone loss (mean \pm SD), n = 9	16.3 \pm 3.0
Anterior Hill-Sachs width in axial plane (mm), mean \pm SD, n = 30	14.2 \pm 3.6
Presence of glenoid bone loss (Y/N), n = 64; n (%)	9/54 (14/84)
Presence of Hill-Sachs lesion (Y/N), n = 64; n (%)	30/33 (47/52)
On or off-track (on/off), n = 64; n (%)	62/1 (97/2)

anterior instability (78%) and 26 patients experienced recurrent instability (Table 2). Further, the failure rate among patients with anterior instability was 32.9% (Table 2). The vast majority of the patients in this study with anterior instability mirrors the trend reported in the literature that suggests a high prevalence of anterior instability among the general population.⁹ Shanmugaraj et al⁷ reported a 24% recurrence rate in a cohort of 525 adolescent patients (mean age 16.6 + 2.5 y) who underwent arthroscopic repair for anterior shoulder instability. This is similar to the results of the present study. In adults, the range of reported recurrence rate is wide (6.3% to 22%), depending on whether patients are classified as experiencing a first-time instability event or as athletes.^{27–29} Higher rates of recurrence in anterior instability in this skeletally immature cohort suggest that the effect of skeletal immaturity may drive recurrent instability more than instability direction or age alone.

Posterior instability is less common when compared with anterior instability and accounts for 2% to 5% of all shoulder instability in adult populations.^{30–32} In this cohort, 17 of 101 (17%) of skeletally immature patients experienced posterior instability, yet they performed similarly to the anterior instability cohort with a recurrence rate of 29.4% (Table 2). This is notably higher than recurrence rates in adults (8.1%, range: 0% to 25%) reported by a systematic review from DeLong and colleagues, as well as other reported recurrence rates (8.5% to 13%) in older adolescents.^{33–36} Again, it can be

TABLE 3. Effect of Selected Variables on Failure Rate

	Failure (N/ Y)		Mean \pm SD	P
	N	Y		
PASS score (0-100)	N	Y	92 \pm 10	<0.001
Time from surgery to PASS (mo)	N	Y	58.2 \pm 33.6	0.153
	N	Y	68.1 \pm 31.9	—
Clinical follow-up duration (mo)	N	Y	26.8 \pm 19.2	0.01
	N	Y	38.1 \pm 22.5	—
Age at surgery (y)	N	Y	15.1 \pm 1.2	0.005
	N	Y	14.3 \pm 1.6	—
No. dislocations preoperative	N	Y	2.4 \pm 3.2	0.436
	N	Y	2.9 \pm 3.8	—
No. anchors placed operatively	N	Y	4.3 \pm 2.0	0.053
	N	Y	5.1 \pm 2.2	—
No. anterior anchors	N	Y	3.2 \pm 2.0	0.726
	N	Y	3.4 \pm 1.9	—
No. posterior anchors	N	Y	1.1 \pm 1.3	0.099
	N	Y	1.5 \pm 1.3	—

Significant *P*-values are bolded. Significance set at *P* < 0.05 (n = 101).

postulated that the higher rates of instability in this cohort may be attributed to risk factors related to skeletal immaturity. It is possible that there are unique factors to be considered regarding the management of posterior instability in skeletally immature patients. However, this study was not adequately powered to assess such effect, as the aim of this study involved primarily assessing outcome and recurrence rates for skeletally immature patients who had all undergone arthroscopic stabilization.

While only 5 patients in our cohort had MDI, 4 experienced recurrent instability (Table 2). It is difficult to identify distinct factors leading to recurrent instability in MDI patients, as conditions such as Ehlers-Danlos syndrome and other collagen disorders often co-occur and may warrant a change in approach to treatment when these disorders are identified. While physical therapy and rehabilitation are considered the first-line treatment for MDI and may preliminarily satisfy patient goals, patients who have not benefited from conservative management often choose to undergo open inferior capsular shift or arthroscopic stabilization.^{4,37,38} Reported rates of failures in MDI patients undergoing arthroscopic stabilization range from 3% to 15% in adult populations.^{39–41} Mitchell et al⁴² studied the results of arthroscopic stabilization in pediatric patients with MDI (mean age of 15.8) and reported a recurrence rate of 26%. In contrast, this current study had a failure rate for skeletally immature patients with MDI much higher at 80%. MDI is a clinically difficult syndrome to manage and often exists alongside potentially confounding disorders for which this analysis did not account for. Yet, based on the recurrence rate for patients in this cohort with MDI alone, one may question the benefit of undergoing arthroscopic repair while skeletally immature. Larger future studies assessing MDI in skeletally immature patients are warranted to further investigate this population.

Further imaging analysis for a subset of this cohort revealed a strong association between patients with glenoid bone loss and Hill-Sachs lesions. Glenoid bone loss is an established risk factor for and is more likely in patients with recurrent instability.^{43,44} This was again demonstrated through this study, though significantly associated only with the need for repeat surgery. The size of Hill-Sachs lesion has been associated with recurrent instability, though this parameter was not evaluated in this study.⁴³ Regardless, imaging analysis was unable to be performed for all patients in this cohort; thus, future analysis with larger cohorts may be useful in fully elucidating this effect.

Limitations of this study include that it is a review of a heterogeneous patient cohort, encompassing various instability patterns, which may impact the generalizability of these findings. Its retrospective nature also limits its power by restricting our documentation of failure solely due to our follow-up window. The chosen patient-reported outcome measure for this study was PASS, and other commonly used measures such as DASH/QuickDASH or SANE were not utilized, which may be perceived as a limitation.²⁴ The criteria for failure and recurrent instability may also be a source of error, as patients subjectively reported their own

TABLE 5. Association Between Imaging Findings and Recurrent Instability or Repeat Surgery (n=63)

	Failure or recurrent instability; n (%)	No failure or recurrent instability; n (%)	P	Repeat surgery; n (%)	No repeat surgery; n (%)	P
Glenoid bone loss	6 (67)	3 (33)	0.14	4 (44)	5 (56)	0.011
No glenoid bone loss	19 (35)	35 (65)	—	4 (7)	50 (93)	—
Hill-Sachs lesion	16 (53)	14 (47)	0.043	8 (27)	22 (73)	0.002
No Hill-Sachs lesion	9 (27)	24 (73)	—	0	33 (100)	—

subluxation and instability events. The quality of labral pathology was not assessed on preoperative imaging, as no validated classification system currently exists for skeletally immature patients. The small sample sizes in the posterior instability and MDI subgroups limit the statistical power and the ability to draw more definitive conclusions about these instability groups. These factors should be considered when interpreting the study results and their broader applicability.

CONCLUSIONS

This study demonstrates that while a majority of skeletally immature children and adolescents undergoing arthroscopic shoulder stabilization can achieve favorable outcomes, upwards of one-third of patients may go on to experience at least one episode of recurrent instability. Those who experienced recurrent instability were significantly younger at the time of surgery, had a longer length of clinical follow-up, and had lower final PASS. Further, skeletally immature patients with MDI and posterior instability may have higher rates of recurrent instability compared with their skeletally mature counterparts. With these considerations, careful patient selection and thoughtful discussion of goals of treatment appear essential among skeletally immature patients facing this risk for recurrent instability.

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