What Are the Effects of Remplissage on 6-Month Strength and Range of Motion After Arthroscopic Bankart Repair?

A Multicenter Cohort Study

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Background: Patients who have undergone shoulder instability surgery are often allowed to return to sports, work, and high-level activity based largely on a time-based criterion of 6 months postoperatively. However, some believe that advancing activity after surgery should be dependent on the return of strength and range of motion (ROM).

Hypothesis: There will be a significant loss of strength or ROM at 6 months after arthroscopic Bankart repair with remplissage compared with Bankart repair alone.

Study Design: Cohort study; Level of evidence, 2.

Methods: A total of 38 patients in a prospective multicenter study underwent arthroscopic Bankart repair with remplissage (33 males, 5 females; mean age, 27.0 $\pm$ 10.2 years; 82% with $\geq$2 dislocation events in the past year). Strength and ROM were assessed preoperatively and at 6 months after surgery. Results were compared with 104 matched patients who had undergone Bankart repair without remplissage, although all had radiographic evidence of a Hill-Sachs defect.

Results: At 6 months, there were no patients in the remplissage group with anterior apprehension on physical examination. However, 26% had a $\geq 20^\circ$ external rotation (ER) deficit with the elbow at the side, 42% had a $\geq 20^\circ$ ER deficit with the elbow at 90° of abduction, and 5% had persistent weakness. Compared with matched patients who underwent only arthroscopic Bankart repair, the remplissage group had greater humeral bone loss and had a greater likelihood of a $\geq 20^\circ$ ER deficit with the elbow at 90° of abduction ($P = .004$). Risk factors for a $\geq 20^\circ$ ER deficit with the elbow at 90° of abduction were preoperative stiffness in the same plane ($P = .02$), while risk factors for a $\geq 20^\circ$ ER deficit with the elbow at the side were increased number of inferior quadrant glenoid anchors ($P = .003$), increased patient age ($P = .02$), and preoperative side-to-side deficits in ER ($P = .04$). The only risk factor for postoperative ER weakness was preoperative ER weakness ($P = .04$), with no association with remplissage ($P = .26$).

Conclusion: Arthroscopic Bankart repair with remplissage did not result in significant strength deficits but increased the risk of ER stiffness in abduction compared with Bankart repair without remplissage at short-term follow-up.

Keywords: Bankart repair; remplissage; ROM; strength; shoulder arthroscopic surgery

Anterior shoulder instability is a common problem in the United States, with rates as high as 15% in some specific populations.[19,21,26,42] Not only is this a common problem in young athletes[41,47] and the physically active population,[11,42] but it also affects the general public.[11,30,32,38,56] Many of these patients require shoulder stabilization surgery in some form.[17,31,49] For those with an off-track and engaging Hill-Sachs lesion,[8,10,24,36,44,54] remplissage can be utilized in conjunction with arthroscopic Bankart repair to reduce the rates of recurrence.[27,45,51,52,57] The addition of this procedure is thought to reduce the risk of recurrent instability by filling the Hill-Sachs lesion with the infraspinatus tendon, not allowing further engagement of the Hill-Sachs lesion with the anterior inferior glenoid.[8,33] However, there is concern that this procedure can limit range of motion (ROM) and/or strength, particularly in external rotation (ER), as the posterior structures are being tethered into the Hill-Sachs lesion.[3-5,9,16,18,20,39,43]

Patients who have undergone shoulder instability surgery are often allowed to return to sports, work, and

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high-level activity based largely on a time-based criterion of 6 months postoperatively.[1,13,25,28] However, some believe that advancing activity after surgery should be dependent on the return of strength and ROM.[14,34,37] Currently, the literature is inconclusive regarding any early limitations in strength or ROM after Bankart repair with remplissage at 6 months postoperatively. The primary aim of this study was to determine whether any additional loss of strength or ROM is present at 6 months after remplissage versus arthroscopic Bankart repair without remplissage. Secondarily, we aimed to identify independent risk factors for persistent stiffness or weakness at 6 months after arthroscopic Bankart repair with or without remplissage. We hypothesized that the addition of remplissage would result in decreased ROM with no change in strength at 6 months relative to matched arthroscopic Bankart repair controls.

METHODS

Study Design

Our research collaborative comprises 26 sports medicine or shoulder fellowship-trained surgeons from 10 academic and private groups throughout the United States, as previously described.[6,7,29] This prospective cohort study enrolled patients undergoing surgical treatment for shoulder instability. Baseline demographic data, patient-reported metrics, physician examination data, and surgical data were collected. After undergoing Bankart repair with remplissage, patients followed standardized anterior shoulder stabilization postoperative care, sling usage, and rehabilitation protocols at all sites,[40] and outcomes were measured at the 6-month follow-up visit. Participants provided written, informed consent using institutional review board–approved consent forms and procedures.

Participants and Matching Procedure

Patients were enrolled at any of the 10 participating institutions. Patients were eligible if they were aged ≥12 years undergoing remplissage in addition to arthroscopic Bankart repair for a diagnosis of anterior shoulder instability between November 5, 2012, and August 30, 2018. Exclusion criteria included patients with concomitant rotator cuff repair, open stabilization, bony procedures, posterior or multidirectional instability, and workers' compensation claims. Indications and techniques for remplissage were left to the discretion of the operating surgeon.

A total of 527 anterior arthroscopic Bankart repair procedures for primary shoulder instability were included in the database, 38 of which also were accompanied by remplissage for a Hill-Sachs defect. From the remaining 489 anterior Bankart repair procedures without remplissage, a matched cohort was obtained among those patients with some degree of documented humeral bone loss in which remplissage still could have been considered a surgical option. Thus, 226 were excluded because of a lack of any Hill-Sachs defect, and 159 were excluded because of a lack of a corresponding match to a patient with remplissage with regard to age, sex, injury during sporting versus nonsporting activity, and number of dislocations in the past year. The remaining 104 Bankart repair procedures without remplissage all had at least a minimal Hill-Sachs defect and were matched to the 38 Bankart repair procedures with remplissage by sex, age within 5 years, injury during sporting versus nonsporting activity, and number of dislocations in the past year. As remplissage is preferentially employed in the setting of large Hill-Sachs defects, the remplissage and nonremplissage groups could not be matched according to humeral defect size.

Data Collection

A detailed physical examination on each patient was performed and documented by the operating surgeon. At the baseline preoperative and 6-month follow-up visits, participants were evaluated for ROM in forward elevation, abduction, ER at the side, ER at 90° of abduction, and internal rotation at 90°. Strength was assessed using a standard 5-point muscle testing scale with forward elevation, abduction, ER with the elbow at the side, the liftoff test, and the belly-press test. All measurements were performed on the surgical and contralateral extremities, and no specific device was used to measure strength or ROM. Contralateral extremity measures were used to assess whether any preoperative deficit was present. Postoperative measurements and return to baseline were established based on measuring the same extremity. The same surgeon performed a physical examination for both preoperative and postoperative assessments. Preoperative Western Ontario Shoulder Instability Index (WOSI),[48] Single Assessment Numeric Evaluation (SANE), Beighton, and American Shoulder and Elbow Surgeons (ASES)[35,53] scores were recorded for each patient. Bankart repair with and without remplissage was performed according to each surgeon's preferred technique. Postoperatively, patients participated in a standardized protocol that was used at all 10 participating

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institutions.[40] Operative forms were filled out immediately after each surgery and documented the type of surgery (revision vs primary), exact surgery performed, and number and location of anchors used in the glenoid. Hill-Sachs lesions were recorded, specifically the estimated width of the defect as a percentage of the humeral head and if the lesion engaged. Any capsular abnormality and treatment to address it were noted. Articular cartilage abnormalities on both the humerus and glenoid were recorded as well as the size and percentage of bone loss for any bony Bankart or glenoid bone deficiency.

Definition of Outcome

Changes between the baseline and 6-month follow-up visits were determined. As described in previous MOON research, satisfactory return-to-play criteria were defined as having ROM within 20° of the baseline surgical extremity value in all planes and a strength measurement equal to or greater than the baseline value.[7] A failure to meet return-to-play criteria by the patient's 6-month visit was defined as a ≥20° loss of ROM compared with baseline in any plane or strength grade less than the baseline value or both. Of note, this study does not directly comment on whether these patients had successfully returned to sport at the 6-month postoperative point but rather comments only on whether they have successfully returned to baseline ROM and strength.

Statistical Analysis

All analyses were performed using a standard statistical package (STATA 15.1; StataCorp). Descriptive statistics were first generated for the entire sample. Bivariate comparisons between remplissage and nonremplissage Bankart repair procedures were performed with and without matching using the appropriate unpaired and paired statistical tests, respectively. To determine the independent effect of remplissage on postoperative stiffness, weakness, or instability at 6 months, a series of conditional logistic regression models was created with grouping by matched group. Remplissage status was included by default, and the remaining variables were considered in a backward selection manner with an exit criterion of alpha >0.05. As all patients in the remplissage group were matched to those in the nonremplissage group by sex, injury during sporting versus nonsporting activity, and number of dislocations in the past year, these variables were not considered in the regression analyses. The remaining variables considered for inclusion were age (as matching by age was within 5 years, not exact age); humeral defect size; baseline ASES, WOSI, SANE, and Beighton scores; preoperative ER ROM; preoperative ER strength; and number and location of glenoid anchors.

Sample Size Estimation

The rates of meeting ROM and strength return-to-play criteria for remplissage have not been previously described; it is our clinical opinion that the accurate estimation of meeting ROM and strength criteria within a 20% margin of error for remplissage and detection of a ≥25% difference in rates of postoperative stiffness or weakness for remplissage versus Bankart repair without remplissage is acceptable. The study sample (n = 38 with remplissage; n = 104 without remplissage) is adequately powered to estimate the prevalence of these outcomes after remplissage with a 15% margin of error and a 23% difference in rates of stiffness or weakness after Bankart repair with versus without remplissage at 80% power and an alpha of 0.05.

RESULTS

Among the 38 patients who underwent anterior Bankart repair with remplissage, the mean age was 27.0 ± 10.2 years, and 87% were male (Table 1). The initial instability episode occurred during sporting activity in 66% of cases. All patients in the remplissage group had a Hill-Sachs defect visible at the time of arthroscopic surgery, with a defect size of 0% to 10% of the humeral head in 18% of patients, 11% to 20% in 58% of patients, and 21% to 30% in 24% of patients. No patient in this series had >30% humeral bone loss. On average, 1.4 ± 0.5 anchors were used for remplissage. Among matched groups, in the bivariate analysis, there was a greater degree of humeral bone loss (0%-10%, 18%; 11%-20%, 58%; 21%-30%, 24%; $P < .001$) and a higher likelihood of a ≥20° ER deficit with the elbow at 90° of abduction at 6-month follow-up for Bankart repair with remplissage compared with Bankart repair without remplissage ($P = .004$); otherwise, there were no significant differences in any other preoperative, intraoperative, or postoperative variables between the Bankart repair with versus without remplissage groups. This includes the number of anchors used in the Bankart repair with remplissage (total, 4.5; superior quadrant, 0.7 ± 0.9; inferior quadrant, 1.2 ± 0.9; anterior quadrant, 2.2 ± 0.8; posterior quadrant, 0.4 ± 0.8) and without remplissage groups (total, 4.8; superior quadrant, 0.8 ± 1.0; inferior quadrant, 1.5 ± 0.9; anterior quadrant, 2.1 ± 0.7; posterior quadrant, 0.4 ± 0.7; $P >$ .05 for all).

Complications, ROM, and Strength

At 6 months postoperatively, no patients with remplissage had anterior apprehension on physical examination. However, 26% of patients in the remplissage group had a ≥20° ER deficit with the elbow at the side, and 42% had a ≥20° ER deficit with the elbow at 90° of abduction. A total of 5% had persistent weakness with ER.

Independent Predictors of Persistent Side-to-Side ER Deficits

Among matched groups, remplissage did not increase the likelihood of failing to achieve ER with the elbow at the side within 20° of the contralateral arm ($P = .89$) (Table 2). Patients with remplissage preoperatively had 65° ± 20° ER with the elbow at the side, with 16% having a ≥20° deficit, and postoperatively had 59° ± 16° ER, with 26% having a ≥20° deficit, while those patients without remplissage preoperatively had 63° ± 20° ER, with 13% having a

TABLE 1
Descriptive Statistics and Bivariate Analyses[a]

	With Remplissage (n = 38)	Without Remplissage (n = 104)	Unpaired P Value[b]	Paired P Value[c]
Age, y	27.0 ± 10.2	22.4 ± 7.9	.005	.20
Sex, %			.06	.20
Male	87	96		
Female	13	4		
Injury during sporting activity, %	66	88	.005	.13
No. of times dislocated in past year, %			.97	.84
0	3	4		
1	16	13		
2-5	53	52		
>5	29	31		
Hill-Sachs defect noted on arthroscopic surgery, %	100	100	≥.99	≥.99
Humeral bone loss from Hill-Sachs defect, %			<.001	**<.001**
0%-10%	18	72		
11%-20%	58	28		
21%-30%	24	0		
>30%	0	0		
Preoperative ASES score	69.3 ± 19.7	70.2 ± 19.1	.81	.54
Preoperative WOSI score	43.2 ± 19.3	43.6 ± 19.4	.92	.82
Preoperative SANE score	46.7 ± 28.0	44.2 ± 23.6	.61	.27
Preoperative motion				
ER with elbow at side, deg	65 ± 20	63 ± 20	.70	.85
Side-to-side deficit, deg	–6 ± 11	–4 ± 12	.47	.76
≥20° deficit, %	16	13	.61	.79
ER with elbow at 90° of abduction, deg	86 ± 17	83 ± 20	.39	.10
Side-to-side deficit, deg	–9 ± 16	–10 ± 20	.72	.27
≥20° deficit, %	21	24	.71	.30
Preoperative ER weakness (strength grade <5/5), %	3	4	.83	.37
No. of anchors				
Superior quadrant	0.7 ± 0.9	0.8 ± 1.0	.81	.88
Inferior quadrant	1.2 ± 0.9	1.5 ± 0.9	.12	.49
Anterior quadrant	2.2 ± 0.8	2.1 ± 0.7	.93	.42
Posterior quadrant	0.4 ± 0.8	0.4 ± 0.7	.80	.90
Remplissage anchors	1.4 ± 0.5	N/A	N/A	N/A
Motion at 6 mo				
ER with elbow at side, deg	59 ± 16	62 ± 18	.40	.29
Side-to-side deficit, deg	–10 ± 14	–8 ± 11	.49	.70
≥20° deficit, %	26	19	.37	.69
ER with elbow at 90° of abduction, deg	82 ± 16	85 ± 13	.15	.44
Side-to-side deficit, deg	–13 ± 15	–8 ± 12	.03	.11
≥20° deficit, %	42	16	.002	**.004**
ER weakness at 6 mo (strength grade <5/5), %	5	2	.29	.47
Anterior apprehension at 6 mo, %	0	3	.56	.10

[a]Data are shown as mean ± SD unless otherwise indicated. Boldface P values indicate statistical significance. ASES, American Shoulder and Elbow Surgeons; ER, external rotation; N/A, not applicable; SANE, Single Assessment Numeric Evaluation; WOSI, Western Ontario Shoulder Instability Index.
[b]Unmatched comparison.
[c]Matched by age, sex, injury during sporting activity, and number of dislocations.

≥20° deficit, and postoperatively had 62° ± 18° ER, with 19% having a ≥20° deficit.

Independent predictors of failing to meet these ROM criteria were increased number of inferior quadrant glenoid anchors (per additional anchor; conditional odds ratio [cOR], 2.36 [95% CI, 1.33-4.19]; P = .003), increased patient age (per 5 years; cOR, 3.35 [95% CI, 1.18-9.57]; P = .02), and preoperative side-to-side deficits in ER with the elbow at the side (per 10° increased deficit; cOR, 1.64 [95% CI, 1.03-2.63]; P = .04) (Table 2).

Among matched groups, remplissage did independently increase the likelihood of failure to achieve ER within 20° of the contralateral arm with the elbow at 90° of abduction (cOR, 4.69 [95% CI, 1.41-15.60]; P = .01) (Table 3). Patients with remplissage preoperatively had 86° ± 17° ER, with 21% having a ≥20° deficit, and postoperatively had 82° ± 16° ER, with 42% having a ≥20° deficit, while those patients without remplissage preoperatively had 83° ± 20° ER, with 24% having a ≥20° deficit, and postoperatively had 85° ± 13° ER, with 16% having a ≥20° deficit.

TABLE 2
Independent Predictors of Range of Motion Deficit ≥20° in ER With Elbow at Side[a]

	Conditional Odds Ratio (95% CI)	P Value
No. of anchors in inferior quadrant	2.36 (1.33-4.19)	.003
Age per 5y increase	3.35 (1.18-9.57)	.02
Side-to-side ER deficit at baseline per 10° increase in deficit	1.64 (1.03-2.63)	.04
Remplissage	0.91 (0.23-3.52)	.89

[a]Sex, injury during sporting versus nonsporting activity, and number of dislocations in the past year were not considered, as these were used as matching criteria for the remplissage versus nonremplissage groups. Additional variables considered for inclusion were humeral defect size; preoperative ER strength; and baseline American Shoulder and Elbow Surgeons, Western Ontario Shoulder Instability Index, Single Assessment Numeric Evaluation, and Beighton scores. These variables were all nonsignificant and not included in the final multivariate model. ER, external rotation.

TABLE 3
Independent Predictors of Range of Motion Deficit ≥20° in ER With Elbow at 90° of Abduction[a]

	Conditional Odds Ratio (95% CI)	P Value
Remplissage	4.69 (1.41-15.60)	.01
≥20° ER deficit with elbow at 90° of abduction at baseline	4.21 (1.27-14.00)	.02
Beighton score per point increase	0.59 (0.36-0.97)	.04

[a]Sex, injury during sporting versus nonsporting activity, and number of dislocations in the past year were not considered, as these were used as matching criteria for the remplissage versus nonremplissage groups. Additional variables considered for inclusion were age (as matching by age was within 5 years, not the exact age); humeral defect size; baseline American Shoulder and Elbow Surgeons, Western Ontario Shoulder Instability Index, and Single Assessment Numeric Evaluation scores; preoperative ER strength, and number and location of glenoid anchors. These variables were all nonsignificant and therefore not included in the final multivariate model. ER, external rotation.

Additional independent predictors of failing to meet ROM criteria with the elbow at 90° of abduction were a baseline ER deficit of ≥20° in this position (cOR, 4.21 [95% CI, 1.27-14.00]; $P = .02$), while an increased Beighton score was protective (per point increase; cOR, 0.59 [95% CI, 0.36-0.97]; $P = .04$) (Table 3).

Independent Predictors of Persistent ER Weakness

Among matched groups, remplissage did not increase the likelihood of having persistent ER weakness at 6 months postoperatively ($P = .26$) (Table 4). The only significant independent predictor of weakness at 6 months was preoperative ER weakness (cOR, 13.20 [95% CI, 1.10-1.72]; $P = .04$) (Table 4).

TABLE 4
Independent Predictors of ER Weakness at 6 Months

	Conditional Odds Ratio (95% CI)	P Value
Preoperative ER weakness	13.20 (1.10-1.72)	.04
Remplissage	3.28 (0.41-26.30)	.26

[a]Sex, injury during sporting versus nonsporting activity, and number of dislocations in the past year were not considered, as these were used as matching criteria for the remplissage versus nonremplissage groups. Additional variables considered for inclusion were age (as matching by age was within 5 years, not the exact age); humeral defect size; baseline American Shoulder and Elbow Surgeons, Western Ontario Shoulder Instability Index, Single Assessment Numeric Evaluation, and Beighton scores; preoperative ER range of motion; and number and location of glenoid anchors. These variables were all nonsignificant and therefore not included in the final multivariate model. ER, external rotation.

Independent Predictors of Postoperative Anterior Apprehension

Remplissage was not predictive of postoperative anterior apprehension. Because there were no occurrences of anterior apprehension on examination in the remplissage group, odds ratios and CIs could not be estimated for remplissage versus no remplissage.

DISCUSSION

Engaging Hill-Sachs lesions continue to be of concern in patients with anterior shoulder instability. The literature suggests that remplissage is best utilized in the patient with little to no glenoid bone loss and a sizable Hill-Sachs defect that is "off-track" or engaging.[8,22,36,44,54] The use of arthroscopic remplissage to address this abnormality has demonstrated good clinical outcomes at various stages of follow-up.[4,5,9,18,20,39,57] Prior literature has suggested that at beyond 2 years, there is a recurrent instability rate of 5.6% to 11.8%.[5,9,20,39] Initial in vivo and clinical outcome studies expressed a concern over the loss of ROM, particularly in ER,[4,18] but most recent outcomes suggest that there is no significant clinical loss of ROM at 2-, 5-, and 8-year follow-up.[5,9,20,33,39] However, our data did demonstrate that at only 6 months postoperatively, 26% of patients who underwent remplissage had a ≥20° ER deficit with the elbow at the side, and 42% had a ≥20° ER deficit in abduction. While the return of ROM likely occurs over a wide time frame, our data suggest that a large percentage of patients still possess a significant ROM discrepancy at 6 months. Further follow-up is needed to determine whether this diminishes over time.

The 6-month postoperative mark is commonly used as a metric for return to work, sport, and play but without strong supporting literature.[1,13,25,28] There is concern that returning to sport before obtaining full strength and ROM may increase the likelihood for recurrent or additional injuries; thus, recent rationale suggests that patients should have full strength and return of ROM before potentially competing in sport and rely less on a chronological time point to determine return to play.[14,34,37] A recent prior study utilizing magnetic resonance imaging after arthroscopic remplissage demonstrated tissue/tendon incorporation into the humerus at 8 months postoperatively, but no images were obtained earlier than this, so the exact time of healing remains unclear.[43] Prior literature also suggests a return-to-sport rate of 71% to 95.5%, with a mean time to return of 7 months.[5,20] As many as 81% of these athletes were able to return to the same level/intensity of competition.[20] Knowing this, return-to-play criteria after remplissage need to be critically evaluated. However, the ability to perform sport-specific tasks with loss of 20° ER will vary greatly. For many athletes and positions, this would not be a problem, but for the overhead thrower, it could delay return to sport and be potentially career ending.[20]

Because recent clinical outcome literature after remplissage has not demonstrated a significant difference in ROM at greater than 2 years,[5,9,33,39] this is the first study, to our knowledge, to examine risk factors for the loss of ROM, particularly ER. Risk factors for a $\geq$20° ER deficit with the elbow at the side or in abduction were increased number of inferior quadrant glenoid anchors, older patient age, and preoperative side-to-side deficits in ER or baseline ER deficit of $\geq$20°, respectively. Perhaps not surprisingly, an increased Beighton score was found to be protective against motion loss. With regard to suture anchor position, an increased number of inferior quadrant anchors led to increased stiffness in ER. This is likely the result of tightening the anterior inferior shoulder capsule.[2,22] Furthermore, it seems logical that those with a true preoperative ER deficit would have a more difficult time achieving full ROM postoperatively, although to the best of our knowledge, this has not previously been reported. The Latarjet procedure is often an option in these patients as well, as it serves to extend the glenoid track and keep the Hill-Sachs lesion from engaging, but comes with its own inherent risks and a complication rate higher than remplissage.[12,15,55]

Limitations

This study has several limitations. Our main outcome of return to baseline ROM and strength was recorded without the use of a specific device for objective measurements; however, there is known fair to good reliability between visual estimations and the use of a goniometer.[23,46,50] In addition, manual muscle testing is unlikely to detect more subtle strength deficits. Also, the definition of symmetric ROM being within 20° is based on group surgeon consensus[7] and may not be a useful criterion for return to sport. Furthermore, the study identified whether patients failed to meet designated return-to-play criteria, but it did not assess actual rates of return to recreational, collegiate, or professional sport. Data on the actual date of release to sporting activity were not collected. In addition, while an effort was made to closely match participants with a control group, they could not be matched according to the exact abnormality, as remplissage is selectively performed in patients with larger humeral head defects. Given this imperfect match, the argument could be made that patients undergoing Bankart repair without humeral bone loss still should have been included in the matched cohort analysis. However, we believe that it was more appropriate to compare only those with humeral bone loss undergoing Bankart repair with and without remplissage. Also, exact surgical indications and techniques may vary slightly between surgeons, and no measurements such as glenoid track were recorded. In addition, the number needed to treat was calculated after completion of the study. Finally, the proportion of female patients in the study was low, and although this likely reflects the balance of patients with shoulder instability as it relates to patient sex, the ability to assess sex-based differences was limited. Until longer term follow-up is available, it is unknown how these findings relate to ultimate results in terms of strength, ROM, and return to play as well as the risk for recurrent instability. Despite these potential limitations, this is the largest multicenter, prospective study to evaluate strength, ROM, and return-to-play criteria after remplissage.

CONCLUSION

Arthroscopic Bankart repair with remplissage did not result in significant strength deficits but increased the risk of ER stiffness in abduction compared with Bankart repair without remplissage at short-term follow-up.

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REFERENCES

1. Abdul-Rassoul H, Galvin JW, Curry EJ, Simon J, Li X. Return to sport after surgical treatment for anterior shoulder instability: a systematic review. *Am J Sports Med*. 2019;47(6):1507-1515.
2. Alkaduhimi H, Verweij LPE, Willigenburg NW, van Deurzen DFP, van den Bekerom MPJ. Remplissage with Bankart repair in anterior shoulder instability: a systematic review of the clinical and cadaveric literature. *Arthroscopy*. 2019;35(4):1257-1266.
3. Barlow JD, Grosel T, Higgins J, Everhart JS, Magnussen RA. Surgical treatment outcomes after primary vs recurrent anterior shoulder instability. *J Clin Orthop Trauma*. 2019;10(2):222-230.
4. Boileau P, O'Shea K, Vargas P, Pinedo M, Old J, Zumstein M. Anatomical and functional results after arthroscopic Hill-Sachs remplissage. *J Bone Joint Surg Am*. 2012;94(7):618-626.
5. Brilakis E, Avramidis G, Malahias M-A, et al. Long-term outcome of arthroscopic remplissage in addition to the classic Bankart repair for the management of recurrent anterior shoulder instability with engaging Hill-Sachs lesions. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(1):305-313.
6. Brophy RH, Hettrich CM, Ortiz S, et al. Patients undergoing shoulder stabilization surgery have elevated shoulder activity compared with sex- and age-matched healthy controls. *Sports Health*. 2017;9(1):59-63.
7. Buckwalter JA V, Wolf BR, Glass N, Bollier M, Kuhn JE, Hettrich CM. Early return to baseline range of motion and strength after anterior shoulder instability surgery: a Multicenter Orthopaedic Outcomes Network (MOON) shoulder group cohort study. *J Shoulder Elbow Surg*. 2018;27(7):1235-1242.
8. Burkhart SS, De Beer JF. Traumatic glenohumeral bone defects and their relationship to failure of arthroscopic Bankart repairs: significance of the inverted-pear glenoid and the humeral engaging Hill-Sachs lesion. *Arthroscopy*. 2000;16(7):677-694.
9. Buza JA, Iyengar JJ, Anakwenze OA, Ahmad CS, Levine WN. Arthroscopic Hill-Sachs remplissage. *J Bone Joint Surg Am*. 2014;96(7):549-555.
10. Calandra JJ, Baker CL, Uribe J. The incidence of Hill-Sachs lesions in initial anterior shoulder dislocations. *Arthroscopy*. 1989;5(4):254-257.
11. Cameron KL, Mauntel TC, Owens BD. The epidemiology of glenohumeral joint instability. *Sports Med Arthrosc*. 2017;25(3):144-149.
12. Cho NS, Yoo JH, Rhee YG. Management of an engaging Hill-Sachs lesion: arthroscopic remplissage with Bankart repair versus Latarjet procedure. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(12):3793-3800.
13. Ciccotti MC, Syed U, Hoffman R, Abboud JA, Ciccotti MG, Freedman KB. Return to play criteria following surgical stabilization for traumatic anterior shoulder instability: a systematic review. *Arthroscopy*. 2018;34(3):903-913.
14. Colegate-Stone TJ, van der Watt C, de Beer JF. Evaluation of functional outcomes and complications following modified Latarjet reconstruction in athletes with anterior shoulder instability. *Shoulder Elbow*. 2015;7(3):168-173.
15. Degen RM, Giles JW, Johnson JA, Athwal GS. Remplissage versus Latarjet for engaging Hill-Sachs defects without substantial glenoid bone loss: a biomechanical comparison. *Clin Orthop Relat Res*. 2014;472(8):2363-2371.
16. Deutsch AA, Kroll DG. Decreased range of motion following arthroscopic remplissage. *Orthopedics*. 2008;31(5):1-3.
17. Dugas JR, Crozier MW. Traumatic anterior instability. *Sports Med Arthrosc*. 2018;26(3):95-101.
18. Elkinson I, Giles JW, Faber KJ, et al. The effect of the remplissage procedure on shoulder stability and range of motion: an in vitro biomechanical assessment. *J Bone Joint Surg Am*. 2012;94(11):1003-1012.
19. Galvin JW, Ernat JJ, Waterman BR, Stadecker MJ, Parada SA. The epidemiology and natural history of anterior shoulder instability. *Curr Rev Musculoskelet Med*. 2017;10(4):411-424.
20. Garcia GH, Wu H-H, Liu JN, Huffman GR, Kelly JD. Outcomes of the remplissage procedure and its effects on return to sports: average 5-year follow-up. *Am J Sports Med*. 2016;44(5):1124-1130.
21. Gibbs DB, Lynch TS, Nuber ED, Nuber GW. Common shoulder injuries in American football athletes. *Curr Sports Med Rep*. 2015;14(5):413-419.
22. Hartzler RU, Bui CNH, Jeong WK, et al. Remplissage of an off-track Hill-Sachs lesion is necessary to restore biomechanical glenohumeral joint stability in a bipolar bone loss model. *Arthroscopy*. 2016;32(12):2466-2476.
23. Hayes K, Walton JR, Szomor ZL, Murrell GA. Reliability of five methods for assessing shoulder range of motion. *Aust J Physiother*. 2001;47(4):289-294.
24. Hill HA, Sachs MD. The grooved defect of the humeral head. *Radiology*. 1940;35(6):690-700.
25. Hurley ET, Montgomery C, Jamal MS, et al. Return to sport after surgical treatment for anterior shoulder instability: a systematic review. *Am J Sports Med*. 2019;47(12):3002-3008.
26. Kawasaki T, Ota C, Urayama S, et al. Incidence of and risk factors for traumatic anterior shoulder dislocation: an epidemiologic study in high-school rugby players. *J Shoulder Elbow Surg*. 2014;23(11):1624-1630.
27. Koo SS, Burkhart SS, Ochoa E. Arthroscopic double-pulley remplissage technique for engaging Hill-Sachs lesions in anterior shoulder instability repairs. *Arthroscopy*. 2009;25(11):1343-1348.
28. Kovacic J, Bergfeld J. Return to play issues in upper extremity injuries. *Clin J Sport Med*. 2005;15(6):448-452.
29. Kraeutler MJ, McCarty EC, Belk JW, et al. Descriptive epidemiology of the MOON shoulder instability cohort. *Am J Sports Med*. 2018;46(5):1064-1069.
30. Leroux T, Wasserstein D, Veillette C, et al. Epidemiology of primary anterior shoulder dislocation requiring closed reduction in Ontario, Canada. *Am J Sports Med*. 2014;42(2):442-450.
31. Levy DM, Cole BJ, Bach BR. History of surgical intervention of anterior shoulder instability. *J Shoulder Elbow Surg*. 2016;25(6):e139-e150.
32. Liavaag S, Svenningsen S, Reikerås O, et al. The epidemiology of shoulder dislocations in Oslo. *Scand J Med Sci Sports*. 2011;21(6):e334-e340.
33. Liu JN, Gowd AK, Garcia GH, Cvetanovich GL, Cabarcas BC, Verma NN. Recurrence rate of instability after remplissage for treatment of traumatic anterior shoulder instability: a systematic review in treatment of subcritical glenoid bone loss. *Arthroscopy*. 2018;34(10):2894-2907.
34. McCarty EC, Ritchie P, Gill HS, McFarland EG. Shoulder instability: return to play. *Clin Sports Med*. 2004;23(3):335-351.
35. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness. *J Shoulder Elbow Surg*. 2002;11(6):587-594.
36. Momaya AM, Tokish JM. Applying the glenoid track concept in the management of patients with anterior shoulder instability. *Curr Rev Musculoskelet Med*. 2017;10(4):463-468.
37. Murphy M, Stockden M, Charlesworth J, Withers K, Breidahl W, Chivers P. Madness or legitimate option? 8 week return to play following Latarjet shoulder reconstruction in an Australian footballer. *J Sci Med Sport*. 2017;20:3.
38. Nordqvist A, Petersson CJ. Incidence and causes of shoulder girdle injuries in an urban population. *J Shoulder Elbow Surg*. 1995;4(2):107-112.
39. Nourissat G, Kilinc AS, Werther JR, Doursounian L. A prospective, comparative, radiological, and clinical study of the influence of the "remplissage" procedure on shoulder range of motion after stabilization by arthroscopic Bankart repair. *Am J Sports Med*. 2011;39(10):2147-2152.
40. Ortiz SF. MOON Shoulder Instability Anterior Stabilization Protocol. 2012. http://www.moonshoulder.com/booklets/MOON%20Ant%20Stab%20PT%20Protocol.pdf. Accessed August 19, 2018.

41. Owens BD, Agel J, Mountcastle SB, Cameron KL, Nelson BJ. Incidence of glenohumeral instability in collegiate athletics. *Am J Sports Med*. 2009;37(9):1750-1754.
42. Owens BD, Dawson L, Burks R, Cameron KL. Incidence of shoulder dislocation in the United States military: demographic considerations from a high-risk population. *J Bone Joint Surg Am*. 2009;91(4):791-796.
43. Park MJ, Garcia G, Malhotra A, Major N, Tjoumakaris FP, Kelly JD. The evaluation of arthroscopic remplissage by high-resolution magnetic resonance imaging. *Am J Sports Med*. 2012;40(10):2331-2336.
44. Provencher MT, Frank RM, LeClere LE, et al. The Hill-Sachs lesion: diagnosis, classification, and management. *J Am Acad Orthop Surg*. 2012;20(4):242-252.
45. Purchase RJ, Wolf EM, Hobgood ER, Pollock ME, Smalley CC. Hill-Sachs "remplissage": an arthroscopic solution for the engaging Hill-Sachs lesion. *Arthroscopy*. 2008;24(6):723-726.
46. Riddle DL, Rothstein JM, Lamb RL. Goniometric reliability in a clinical setting: shoulder measurements. *Phys Ther*. 1987;67(5):668-673.
47. Robinson TW, Corlette J, Collins CL, Comstock RD. Shoulder injuries among US high school athletes, 2005/2006-2011/2012. *Pediatrics*. 2014;133(2):272-279.
48. Salomonsson B, Ahlström S, Dalén N, Lillkrona U. The Western Ontario Shoulder Instability Index (WOSI): validity, reliability, and responsiveness retested with a Swedish translation. *Acta Orthop*. 2009;80(2):233-238.
49. Trinh TQ, Naimark MB, Bedi A, et al. Clinical outcomes after anterior shoulder stabilization in overhead athletes: an analysis of the MOON Shoulder Instability Consortium. *Am J Sports Med*. 2019;47(6):1404-1410.
50. Williams JG, Callaghan M. Comparison of visual estimation and goniometry in determination of a shoulder joint angle. *Physiotherapy*. 1990;76(10):655-657.
51. Wolf EM, Arianjam A. Hill-Sachs remplissage, an arthroscopic solution for the engaging Hill-Sachs lesion: 2- to 10-year follow-up and incidence of recurrence. *J Shoulder Elbow Surg*. 2014;23(6):814-820.
52. Wolf EM, Pollack ME. Hill-Sachs "remplissage": an arthroscopic solution for the engaging Hill-Sachs lesion (SS-32). *Arthroscopy*. 2004;20:e14-e15.
53. Wylie JD, Beckmann JT, Granger E, Tashjian RZ. Functional outcomes assessment in shoulder surgery. *World J Orthop*. 2014;5(5):623-633.
54. Yamamoto N, Itoi E, Abe H, et al. Contact between the glenoid and the humeral head in abduction, external rotation, and horizontal extension: a new concept of glenoid track. *J Shoulder Elbow Surg*. 2007;16(5):649-656.
55. Yang JS, Mehran N, Mazzocca AD, Pearl ML, Chen VW, Arciero RA. Remplissage versus modified Latarjet for off-track Hill-Sachs lesions with subcritical glenoid bone loss. *Am J Sports Med*. 2018;46(8):1885-1891.
56. Zacchilli MA, Owens BD. Epidemiology of shoulder dislocations presenting to emergency departments in the United States. *J Bone Joint Surg Am*. 2010;92(3):542-549.
57. Zhu Y-M, Lu Y, Zhang J, Shen J-W, Jiang C-Y. Arthroscopic Bankart repair combined with remplissage technique for the treatment of anterior shoulder instability with engaging Hill-Sachs lesion. *Am J Sports Med*. 2011;39(8):1640-1648.