



# Consideration May Be Given to Lowering the Threshold for the Addition of Remplissage in Patients With Subcritical Glenoid Bone Loss Undergoing Arthroscopic Bankart Repair

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**Purpose:** Treatment for patients with anterior glenohumeral instability with subcritical bone loss is evolving. The purpose of this study was to compare 2-year outcomes of arthroscopic Bankart repair with and without Hill–Sachs remplissage in patients with <15% glenoid bone loss. **Methods:** A multicenter retrospective study was performed on a consecutive series of patients who underwent primary isolated arthroscopic Bankart repair (IBR) or arthroscopic Bankart repair with remplissage (REMP) by 4 shoulder specialists between 2013 and 2019. Range of motion (ROM) and patient-reported outcomes (PROs) were collected at baseline and 2 years postoperative: Western Ontario Shoulder Instability Index, Single Assessment Numeric Evaluation, and visual analog scale for pain. Recurrence, return to sport, satisfaction, complications, and revisions also were reviewed. **Results:** A total of 123 patients were available, including 75 IBR and 48 REMP. Baseline demographics, activity, ROM, and PROs were similar. Mean glenoid bone loss (2.5% vs 6.1%:  $P < .001$ ) was greater in REMP, although the number of on-track lesions was similar (98.7% vs 93.8%:  $P = .298$ ). WOSI scores were improved for REMP (196.5 vs 42.7:  $P = .004$ ), but otherwise no difference in postoperative PROs or ROM. Differences between cohorts did not reach significance in return to sport (73% vs 83%:  $P = .203$ ), recurrence (9.3% vs 2.1%:  $P = .148$ ), or revisions (6.8% vs 2.1%:  $P = .403$ ). For on-track lesions there were 6 recurrences in IBR (6 of 74; 8.1%) and 1 recurrence in REMP (1 of 45; 2.2%). **Conclusions:** Despite slightly worse pathology, patients with subcritical bone loss who undergo REMP experience similar short-term postoperative function to isolated IBR. Recurrence, revision, and return to sport favored REMP but this study was underpowered to show statistical significance. Recurrence was common following IBR, despite subcritical glenoid bone loss and primarily on-track lesions, suggesting that REMP can be considered in on-track lesions. **Level of Evidence:** III, retrospective comparative study.

The shoulder's incredible mobility has led it to be the most dislocated joint of the human body.<sup>1,2</sup> Anterior glenohumeral instability is the most common

(90%) and experienced by 1.7% of the general population, but most commonly in men, contact athletes, and military personnel.<sup>1,2</sup> Traumatic anterior instability

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leads to injury of both the capsulolabral complex and bone (glenoid and humeral head), which increases as the severity and number of dislocations increase<sup>1,3-5</sup> Failure to address this altered anatomy leads to increased risk of further dislocation, bony destruction, and patient morbidity over time.<sup>5-7</sup>

The severity of glenoid bone loss (GBL) and Hill–Sachs lesion have been used to provide guidance on the ideal surgical treatment.<sup>3,5,8-10</sup> Once defined as 25%, the definition of critical GBL requiring bony reconstruction of the glenoid has been reported as low as 15%.<sup>11</sup> Following the recognition of GBL as a risk factor for recurrence, the concept of the glenoid track was proposed to provide guidance on the use of remplissage.<sup>3,8,12</sup> The addition of the Hill–Sachs remplissage was described and later modified to its most widely used form in 2009.<sup>12,13</sup> It has proven to be effective in reducing dislocations while maintaining satisfactory patient outcomes for patients with off-track lesions with subcritical bone loss in nonrandomized and randomized settings.<sup>14-19</sup> Initially, concern for decreased external rotation (ER) and possible posterior shoulder pain was suggested, but more recent studies have questioned the change in range of motion (ROM) and have also affirmed similar patient-reported outcomes (PROs) with low recurrence at short-term follow-up for those undergoing remplissage.<sup>18-22</sup> Recurrence rates for isolated Bankart repair are unacceptably high at roughly 10%, even in ideal conditions with no bone loss.<sup>23</sup> Given the apparent safety and outcomes of remplissage (including recurrence <5%)<sup>19</sup> in patients with bone loss and off-track lesions, the question arises if the threshold for its use should be lowered and applied for patients with on-track lesions.

The purpose of this study was to compare 2-year outcomes of arthroscopic Bankart repair with and without Hill–Sachs remplissage in patients with <15% GLB. The hypothesis was that there would be similar functional outcomes and recurrence between groups.

## Methods

A multicenter retrospective review was performed of prospectively collected data at 4 institutions between December 2013 and August 2019. Inclusion criteria included primary arthroscopic surgery for anterior glenohumeral instability managed with either isolated arthroscopic Bankart repair (IBR) or arthroscopic Bankart repair with remplissage (REMP) with <15% GBL and a minimum 2-year postoperative follow-up. Exclusions included revision surgery and those lacking standard baseline data. Institutional review board approval was obtained before commencing the study.

## Surgical Technique

Treatment choice was based on surgeon preference at the 4 institutions. The 3 treating surgeons operated in

3 different continents but had completed the same arthroscopic shoulder fellowship representing a similarity in surgical technique. Each surgery was performed in lateral position and began with diagnostic arthroscopy. To affirm preoperative measurements, intraoperative assessment was performed with a calibrated probe for confirmation in 95.4% of patients as previously described.<sup>3</sup> Intraoperative measurements did not change the glenoid track status in any patients. Final decision to perform IBR versus REMP was left to the discretion of the surgeon. There was no agreed-upon criteria for each procedure to be performed, but indications were based on individual assessment of imaging, intraoperative assessment, and patient factors including but not limited to age, laxity, soft-tissue quality, and level of activity.

Arthroscopic Bankart capsulolabral repair was performed with suture anchors and standard technique. IBR used  $3.0 \pm 0.5$  anterior anchors and REMP used  $3.2 \pm 0.4$  ( $P = .086$ ). If performed, 2 additional anchors were used for the remplissage of the posterior capsule and rotator cuff tendon into the Hill–Sachs defects. During remplissage, care was taken to pass sutures through tendon and capsules only to avoid muscular damage to the posterior rotator cuff.<sup>24</sup> A mixture of knotted, knotless, and hybrid techniques were applied based on surgeon preference. Postoperatively, the shoulder was placed into a sling for 6 weeks. The sling was discontinued, and ROM/strengthening activities were initiated. Sports, contact or noncontact, were commenced at 6 months' postoperative.

## Clinical Assessment

Baseline demographics recorded included gender, age, hand dominance, arm involved, and level of activity. Preoperative ROM assessment by the treating surgeon (P.N., A.L., J.B., P.J.D.) included ER at the side, forward flexion, and internal rotation to the nearest spinal level. Patient-reported outcome (PRO) measures included visual analog scale (VAS) for pain, Western Ontario Shoulder Instability Index (WOSI), and Single Assessment Numeric Evaluation (SANE). ROM and PROs were then reassessed at 2-year follow-up. Final follow-up information also included return to sport, satisfaction, recurrent instability, complication, and revision rates.

## Bone Loss Assessment

Bone loss assessment included GBL, the Hill–Sachs interval (lesion width) and depth, and subsequent calculation of on-track or off-track lesions.<sup>25</sup> Assessment was performed by the treating surgeon based on preoperative magnetic resonance imaging (91.6%) or computed tomography (8.4%) as previously described.<sup>10</sup> Glenoid track calculation was performed using previously described formula ( $0.83D-d$ ).<sup>8</sup>

**Table 1.** Characteristics of the Study Population

Parameter	All Patients	Procedure		P
		Bankart	Bankart + Remplissage	
Total*	123 (100)	75 (61.0)	48 (39.0)	
Age, y <sup>†</sup>	26.1 ± 8.8	25.3 ± 8.9	27.4 ± 8.7	.195
Sex <sup>‡</sup>				
Female	24 (19.5)	16 (21.3)	8 (16.7)	.524
Male	99 (80.5)	59 (78.7)	40 (83.3)	
Participation in overhead or contact sports <sup>†</sup>	83 (67.5)	51 (68.0)	32 (66.7)	.878
Glenoid bone loss, (%) <sup>†</sup>	3.9 ± 4.8	2.5 ± 4.1	6.1 ± 4.9	<b>&lt;.001</b>
Hill–Sachs size, mm <sup>†</sup>				
Width on axial cut	8.2 ± 7.4	2.7 ± 4.5	14.5 ± 3.7	<b>&lt;.001</b>
Depth on axial cut	4.4 ± 4.6	1.5 ± 2.5	8.6 ± 3.6	<b>&lt;.001</b>
On-track Hill–Sachs lesion*	119 (96.7)	74 (98.7)	45 (93.8)	.298
Number of labral anchors <sup>†</sup>	3.1 ± 0.5	3.0 ± 0.5	3.2 ± 0.4	.086
Preoperative range of motion <sup>†</sup>				
Forward flexion, °	167 ± 19	167 ± 21	168 ± 15	.654
External rotation at the side, °	65 ± 17	64 ± 18	66 ± 16	.628
Internal rotation (spinal level)	T8 ± 2	T8 ± 3	T8 ± 2	.376
Preoperative patient-reported outcomes <sup>†</sup>				
SANE	65.7 ± 19.1	65.3 ± 20.9	66.3 ± 16.3	.772
VAS Pain	2.3 ± 2.1	2.4 ± 2.2	2.3 ± 2.0	.772
WOSI	1,115.7 ± 349.1	1,129.1 ± 351.8	1,094.7 ± 347.6	.599

SANE, Single Assessment Numeric Evaluation; VAS, visual analog scale; WOSI, Western Ontario Shoulder Instability Index.

Bold values indicate statistically significant.

\*The values are given as the number of patients, with the percentage in parentheses.

<sup>†</sup>The values are given as the mean and the standard deviation.

## Statistical Analysis

To compare baseline characteristics and outcomes between the REMP and IBR cohorts, Pearson  $\chi^2$  tests were used for categorical variables and independent samples tests were used for continuous variables. Paired *t* tests were performed to compare absolute preoperative and postoperative ROM and PRO scores within groups, as well as relative improvement over time.

The minimal clinically important difference (MCID) was determined using a distribution-based method of one-half the standard deviation of the difference between preoperative and postoperative outcome scores. It was decided to calculate population-specific MCID scores because there were no prior established MCID scores for these outcomes scores. Continuous variables were presented in terms of the mean and standard deviation, and categorical variables were reported with frequencies and percentages. Statistical tests were 2-sided, with  $P < .05$  denoting statistical significance.

## Results

### Demographics

A total of 123 patients met the study criteria and were available for follow-up at an average of 2.5 years postoperative (range 2–3.8 years). The cohort included 75 IBRs and 48 REMPs. Revision patients and those without 2-year data were excluded from study. Return to sport and patient satisfaction were available on 121 patients including 74 IBRs and 47 REMPs. Baseline demographics showed similarity in age, gender, athletic

participation, and preoperative function (Table 1). Mean preoperative GBL (2.5% vs 6.1%;  $P < .001$ ), Hill–Sachs width (2.7 mm vs 14.5 mm;  $P < .001$ ), and Hill–Sachs depth (1.5 mm vs 8.6 mm;  $P < .001$ ) were greater in the REMP cohort. The Hill–Sachs lesions were on-track in 98.7% (74 of 75) of IBRs and 93.8% (45 of 48) of REMPs ( $P = .298$ ).

### Patient-Reported Outcomes

Minimum 2-year postoperative PROs were similarly improved in both cohorts. Postoperative SANE, VAS, and WOSI scores were all greater for the patients who received REMP, although the magnitude of improvement was only statistically greater for the WOSI score (196.5 vs 42.7;  $P < .001$ ) (Table 2). MCID was not achieved for the PROs (Table 3). With regards to ROM, both groups demonstrated similar loss of ER and improvement of forward flexion and internal rotation at final follow-up (Table 4).

### Return to Sport, Satisfaction, Recurrence, and Revisions

Return to sport (73% vs 83%;  $P = .203$ ), satisfaction (91.9% vs 95.7%;  $P = .482$ ), recurrence (9.3% vs 2.1%;  $P = .148$ ), and revisions (6.8% vs 2.2%;  $P = .403$ ) all favored for the REMP cohort, but these differences did not reach statistical significance (Table 5). Of note, only 1 of the 8 (12.5%) total dislocations was found to be off-track preoperatively. Six of seven (85.7%) IBR recurrences were on-track, and the single REMP recurrence was on-track. The single IBR

**Table 2.** Minimum 2-Year Postoperative Patient-Reported Outcomes (Average Follow-up: 2.5 Years, Range: 2-3.8 Years)

Outcome*	Bankart			Bankart + Remplissage		
	Preoperative	Postoperative	$\Delta$	Preoperative	Postoperative	$\Delta$
SANE	65.3 $\pm$ 20.9	94.6 $\pm$ 14.6	29.6 $\pm$ 26.9	66.3 $\pm$ 16.3	98.1 $\pm$ 4.0	32.2 $\pm$ 17.3
<i>P</i> -value within group	—	—	<b>&lt;.001</b>	—	—	<b>&lt;.001</b>
<i>P</i> -value between groups	.772	.057	.516	—	—	—
VAS Pain	2.4 $\pm$ 2.2	0.5 $\pm$ 1.2	1.9 $\pm$ 2.4	2.3 $\pm$ 2.0	0.4 $\pm$ 0.7	1.9 $\pm$ 2.0
<i>P</i> -value within group	—	—	<b>&lt;.001</b>	—	—	<b>&lt;.001</b>
<i>P</i> -value between groups	0.772	0.487	.901	—	—	—
WOSI	1,129.1 $\pm$ 351.8	196.5 $\pm$ 432.9	936.6 $\pm$ 557.6	1,094.7 $\pm$ 347.6	42.7 $\pm$ 67.4	1,063.9 $\pm$ 342.2
<i>P</i> -value within group	—	—	<b>&lt;.001</b>	—	—	<b>&lt;.001</b>
<i>P</i> -value between groups	.599	<b>.004</b>	.167	—	—	—

SANE, Single Assessment Numeric Evaluation; VAS, visual analog scale; WOSI, Western Ontario Shoulder Instability Index.

Bold values indicate statistically significant.

\*The values are given as the mean and the standard deviation.

off-track lesion recurred, and 0 of 3 REMP off-track lesions recurred. IBR revisions included 3 Latarjets and 2 revision Bankart repair with remplissage. Two IBR recurrence patients deferred further surgery. The single REMP recurrence was revised to Latarjet. There were no major surgical complications between the groups. The IBR group had 4 (5.3%) minor complications that included 2 patients with biceps pain and 2 patients with pain inhibiting sleep.

## Discussion

The primary findings of the current study affirmed our hypothesis in that 2-year postoperative ROM and PROs are similar following either IBR or REMP for patients with GBL <15%. Recurrence and revision rates were greater following IBR, but the differences did not reach statistical significance. These results add to the growing body of evidence that the remplissage procedure is safe and effective, without necessarily causing a decrease in ER. Indications to perform REMP versus IBR should be further distinguished with larger and prospective trials.

Overall, functional outcomes appear to be similar between IBR or REMP. Previous studies have demonstrated similar postoperative forward flexion and internal rotation have following IBR or REMP.<sup>15,16,20,26</sup> Our findings were similar, with no differences between groups. Loss of ER has been raised as a concern with remplissage procedure, especially in biomechanical testing.<sup>18,21,22,27</sup> Mixed results have been noted when the 2 procedures are compared clinically.<sup>16,21,28</sup> MacDonald et al.<sup>19</sup> evaluating noted that patients receiving REMP had 10° loss at 1 year that resolved by the 2-year follow-up. Similarly, while our REMP group lost 4°, there was no difference between the IBR and REMP groups at 2 years postoperative. Finally, PROs have been consistently similar between IBR and REMP cohorts as well.<sup>16,19,20</sup> This is reaffirmed in our study with regards to VAS and SANE scores, although the WOSI scores were slightly improved in the

REMP group (196.5 vs 42.7;  $P < .001$ ). Our study reiterates previous studies showing satisfaction rates to be consistently high and surgical complications to be consistently low in the literature for both procedures.<sup>2,9,14,24,29</sup> Although not reported as major, we did note minor complications of biceps pain ( $n = 2$ ) and pain inhibiting sleep ( $n = 2$ ) in the IBR cohort. It is likely that these were due to chance and/or surgeon reporting rather than the addition of remplissage having a protective effect against these complaints.

The glenoid track concept has emerged as a common tool for guiding treatment in patients with bipolar bone loss.<sup>3,8,10</sup> Hartzler et al.<sup>30</sup> biomechanically concluded that whereas on-track lesions could be treated with IBR, off-track lesions required remplissage to avoid dislocation. In a retrospective study of 57 patients, Shaha et al.<sup>25</sup> clinically validated that the track concept was more predictive than GBL alone. They noted that the glenoid track had a 75% positive predictive value for predicting postoperative stability compared with 44% based on 20% GBL alone. Findings such as this imply that the concept is effective for ruling patients in for additional stabilization procedures such as remplissage.

Much of the literature involving the glenoid track and remplissage has revolved around patients with bipolar bone loss. However, in our study evaluating only patients with <15% bone loss, and consequently predominantly on-track, we observed recurrence rates

**Table 3.** MCID and PASS Analysis

Outcome Measure	MCID	MCID, % Achieved		<i>P</i>
		Bankart	Bankart + Remplissage	
SANE	11.8	71.2	83.0	.142
VAS Pain	1.1	47.9	53.2	.575
WOSI	244.1	91.8	100	.081

MCID, minimal clinically important difference; SANE, Single Assessment Numeric Evaluation; PASS, patient acceptable symptomatic state; VAS, visual analog scale; WOSI, Western Ontario Shoulder Instability Index.



**Table 4.** Minimum 2-Year Postoperative Range of Motion (Average Follow-up: 2.5 Years, Range: 2-3.8 Years)

Range of Motion*	Bankart			Bankart + Remplissage		
	Preoperative	Postoperative	Δ	Preoperative	Postoperative	Δ
Forward flexion, °	167 ± 21	175 ± 22	8 ± 29	168 ± 15	179 ± 3	10 ± 16
<i>P</i> -value within group	—	—	<b>.016</b>	—	—	<b>&lt;.001</b>
<i>P</i> -value between groups	.654	.152	.655	—	—	—
External rotation at the side, °	64 ± 18	61 ± 15	-3 ± 15	66 ± 16	62 ± 12	-4 ± 14
<i>P</i> -value within group	—	—	.157	—	—	<b>.035</b>
<i>P</i> -value between groups	.628	.845	.483	—	—	—
Internal rotation (spinal level)	T8 ± 3	T8 ± 2	± 3	T8 ± 2	T7 ± 1	1 ± 2
<i>P</i> -value within group	—	—	.588	—	—	<b>.082</b>
<i>P</i> -value between groups	.376	<b>.008</b>	.494	—	—	—

SANE, Single Assessment Numeric Evaluation; VAS, visual analog scale; WOSI, Western Ontario Shoulder Instability Index.  
 \*The values are given as the mean and the standard deviation.

of 9.3% and 2.1% for IBR and REMP, respectively ( $P = .148$ ). The IBR rate is similar to Nakagawa et al.<sup>7</sup> (7%) and Thomazeau et al.<sup>23</sup> (10%) following IBR in patients without GBL. Nakagawa et al.<sup>7</sup> additionally noted a 27% rate of recurrence in patients with 1% to 10% GBL. The addition of the remplissage procedure has consistently yielded improved recurrence rates, which our results confirm.<sup>18,19,20,31</sup> A systemic review by Hurley et al.<sup>17</sup> noted a recurrence rate of 16.8% and 3.2% for IBR and REMP, respectively ( $P < .05$ ). A recent randomized controlled trial by MacDonald et al.<sup>19</sup> evaluating 108 engaging lesions (54/cohort) found recurrence rates favoring REMP patients as well (18% vs 4%:  $P = .027$ ). Ultimately, REMP showed similar results in patients with slightly worse pathology based on bone loss (Table 1). Our overall results do trend to favoring remplissage, but the study is underpowered to detect a statistically significant difference. Based on the dislocation rates in the current study, 324 patients (162 patients per cohort) would be required to reach a power of 80%. With our current study of 123 patients involving 4 busy international surgeons over 6 years we only able to reach a power of 33%.

While the glenoid track represented an advancement by providing a paradigm for evaluating bipolar bone loss, its analysis is limited to the bone alone. As noted

previously, the glenoid track is a valuable concept that is beneficial in ruling patients in for additional stabilization. However, we propose that it is not effective in ruling patients OUT for remplissage. Six of the 7 IBR recurrences and the single REMP recurrence were in patients with on-track lesions. Unfortunately, Bottani et al.<sup>32</sup> showed that we can expect further increased recurrences following IBR in particular with longer follow-up. The glenoid track concept simply does not account for extent of capsular injury or patient factors such as age, sport, and hyperlaxity. In addition to labral injury and potential bony injury, the initial shoulder dislocation results in permanent changes to the capsule that can worsen over time.<sup>1</sup> Boileau et al.<sup>33</sup> demonstrated that a minimum of 3 anchors are needed with IBR to adequately reduce recurrences in patients with subcritical bone loss, even if the extent of injury did not appear to warrant it. They emphasized the need to tighten the anterior capsule even if severe injury was not obvious. However, despite a similar population and use of a mean of 3 anchors for Bankart repair in the current study, we continued to observe recurrence with IBR. These findings suggest that the anterior capsulolabral injury can often not be overcome with an anterior soft-tissue procedure alone. A cadaveric study by Hartzler et al.<sup>30</sup> demonstrated that the primary mechanisms by which remplissage reduces recurrence is by increasing joint stiffness and providing a posterior restraint. While effective, remplissage is relatively new, and further long-term studies are expected to ascertain the long-term effects on the glenohumeral joint. Nonetheless, with its safety and excellent results in patients with off-track lesions thus far, it appears reasonable to lower the threshold for its use in select on-track patients as well.

**Limitations**

This multicenter investigation was not without limitation. First, the study design was retrospective and treatment choice was based on surgeon preference without any agreed-upon algorithms to perform one

**Table 5.** Postoperative Outcomes

Parameter	Procedure		<i>P</i>
	Bankart	Bankart + Remplissage	
Return to same level of sport*	54 (73.0)	39 (83.0)	.203
Patient satisfaction*	68 (91.9)	45 (95.7)	.482
Recurrent dislocation	7 (9.3)	1 (2.1)	.148
Surgical complication	0	0	N/A
Revision surgery	5 (6.8)	1 (2.2)	0.403

NOTE. The values are given as the number of patients, with the percentage in parentheses.

N/A, not applicable.

\*Data available on 121 patients.

procedure over the other, which adds the significant potential for selection bias. The surgeons also used heterogenous implants based on preference. Second, it was underpowered to detect differences in recurrence rate. Third, there were likely subtle differences between surgeon clinical assessments, and some data were not complete, including the return to sport and satisfaction surveys, and these patients were unable to be reached. Fourth, the assessment of bone loss varied between computed tomography and magnetic resonance imaging. Fifth, the follow-up was short-term at 2 years postoperative, and recurrence can continue to occur at later time points.<sup>32</sup> Finally, a cost comparison was not practical based on the use of 4 international sites, and therefore we could not assess the value of each procedure.

### Conclusions

Despite slightly worse pathology, patients with subcritical bone loss who undergo REMP experience similar short-term postoperative function to isolated IBR. Recurrence, revision, and return to sport favored REMP, but this study was underpowered to show statistical significance. Recurrence was common following IBR, despite subcritical GBL and primarily on-track lesions, suggesting that REMP can be considered in on-track lesions.

### References

- Dumont G, Russell R, Robertson W. Anterior shoulder instability: a review of pathoanatomy, diagnosis and treatment. *Curr Rev Musculoskelet Med* 2011;4:200-207.
- Galvin J, Ernat JJ, Waterman BR, Stadecker MJ, Parada SA. The epidemiology and natural history of anterior shoulder instability. *Curr Rev Musculoskelet Med* 2017;10:411-424.
- 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;16:677-694.
- Hill HA, Sachs MD. The grooved defect of the humeral head: A frequently unrecognized complication of dislocations of the shoulder joint. *Radiology* 1940;35:690-700.
- Provencher MT, Midtgaard KS, Owens BD, Tokish JM. Diagnosis and management of traumatic anterior shoulder instability. *J Am Acad Orthop Surg* 2021;29:e51-e61.
- Balg F, Boileau P. The instability severity index score: A simple pre-operative score to select patients for arthroscopic or open shoulder stabilisation. *J Bone Joint Surg* 2007;11:1470-1477.
- Nakagawa S, Mae T, Sato S, Okimura S, Kuroda M. Risk factors for the postoperative recurrence of instability after arthroscopic Bankart repair in athletes. *Orthop J Sports Med* 2017;5:2325967117726494.
- Di Giacomo G, Itoi E, Burkhart SS. Evolving concept of bipolar bone loss and the Hill-Sachs lesion: from "engaging/non-engaging" lesion to "on-track/off-track" lesion. *Arthroscopy* 2014;30:90-98.
- Shaha JS, Cook JB, Song DJ, et al. Redefining "critical" bone loss in shoulder instability: Functional outcomes worsen with "subcritical" bone loss. *Am J Sports Med* 2015;43:1719-1725.
- 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;16:649-656.
- Shin SJ, Kim RG, JeonYS. Critical value of anterior glenoid bone loss that leads to recurrent glenohumeral instability after arthroscopic Bankart repair. *Am J Sports Med* 2017;45:2784-2791.
- Wolf EM, Pollack M, Smalley C. Hill-Sachs "remplissage": An arthroscopic solution for the engaging Hill-Sachs lesion. *Arthroscopy* 2007;23:1343-1348.
- Koo S, Burkhart S, Ochoa E. Arthroscopic double-pulley remplissage technique for engaging Hill-Sachs lesions in anterior shoulder instability repairs. *Arthroscopy* 2009;11:1343-1348.
- Buza JA III, Iyengar JJ, Anakwenze OA, Ahmad CS, Levine WN. Arthroscopic Hill-Sachs Remplissage: A systematic review. *J Bone Joint Surg Am* 2014;96:549-555.
- Cho N, Yoo J, Hyung J, Yong G. Anterior shoulder instability with engaging Hill-Sachs defects: A comparison of arthroscopic Bankart repair with and without posterior capsulodesis. *Knee Surg Sports Traumatol Arthrosc* 2016;24:3801-3808.
- Garcia G, Park M, Zhang C, et al. Large Hill-Sachs lesion: A comparative study of patients treated with arthroscopic Bankart repair with or without remplissage. *HSSJ* 2015;11:83-103.
- Hurley E, Toale J, Davey MS, et al. Remplissage for anterior shoulder instability with Hill-Sachs lesions: A systematic review and meta-analysis. *J Shoulder Elbow Surg* 2020;29:2487-2484.
- Lazarides AL, Duchman KR, Ledbetter L, Riboh JC, Garrigues GE. Arthroscopic Remplissage for anterior shoulder instability: A systematic review of clinical and biomechanical studies. *Arthroscopy* 2019;35:617-628.
- MacDonald P, McRae S, Old J, et al. Arthroscopic Bankart repair with and without arthroscopic infraspinatus remplissage in anterior shoulder instability with a Hill-Sachs defect: A randomized controlled trial. *J Shoulder Elbow Surg* 2021;30:1288-1298.
- 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;4:1257-1266.
- Argintar E, Heckmann N, Wang L, Tibone JE, Lee TQ. The biomechanical effect of shoulder Remplissage combined with Bankart repair for the treatment of engaging Hill-Sachs lesions. *Knee Surg Sports Traumatol Arthrosc* 2016;24:585-592.
- 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;94:1003-1012.

23. Thomazeau H, Langlais T, Hardy A, et al. Long-term, prospective, multicenter study of isolated Bankart repair for a patient selection method based on the instability severity index score. *Am J Sports Med* 2019;47:1057-1061.
24. Laderman A, Arrigoni P, Barth J, et al. Is arthroscopic remplissage a tenodesis or capsulomyodesis? An anatomic study. *Knee Surg Sports Traumatol Arthrosc* 2016;24:573-577.
25. Shaha JS, Cook JB, Rowles DJ, Bottani CR, Shaha SH, Tokish JM. Clinical validation of the glenoid track concept in anterior glenohumeral instability. *J Bone Joint Surg Am* 2016;98:1918-1923.
26. Franceschi F, Papalia R, Rizzello G, et al. Remplissage repair—new frontiers in the prevention of recurrent shoulder instability. *Am J Sports Med* 2012;40:2462-2469.
27. Momaya AM, Tokish JM. Applying the glenoid track concept in the management of patients with anterior shoulder instability. *Curr Rev Musculoskelet Med* 2017;10:463-468.
28. Grimberg J, Diop A, Ghosn RB, Lanari D, Cannone A, Maurel N. Bankart repair versus Bankart repair plus remplissage: An in vitro biomechanical comparative study. *Knee Surg Sports Traumatol Arthrosc* 2016;24:374-380.
29. Ko S-H, Cha J-R, Lee C-C, Hwang I-Y, Choe C-G, Kim M-S. The influence of arthroscopic remplissage for engaging Hill-Sachs lesions combined with Bankart repair on recurrence and shoulder function: Arthroscopic Bankart with vs without remplissage compared with Bankart repair alone. *Clin Orthop Surg* 2016;8:428.
30. Hartzler RU, Bui CN, 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;32:2466-2476.
31. Domos P, Ascione F, Wallace A. Arthroscopic Bankart repair with remplissage for non-engaging Hill–Sachs lesion in professional collision athletes. *Shoulder Elbow* 2019;11:17-25.
32. Bottani CR, Johnson JD, Zhou L, et al. 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. *Am J Sports Med* 2021;49:1999-2005.
33. Boileau P, Villalba M, Héry JY, Balg F, Ahrens P, Neyton L. Risk factors for recurrence of shoulder instability after arthroscopic Bankart repair. *J Bone Joint Surg Am* 2006;88:1755-1763.