Technical Note

Inlay Dynamic Anterior Stabilization With the Long Head of the Biceps Tendon and Remplissage Procedure for Patients With Subcritical Glenoid Bone Loss and On-Track Hill-Sachs Lesion

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Abstract: Augmented Bankart with dynamic anterior stabilization (DAS) using the long head of the biceps tendon (LHBT) aims to address anteroinferior glenohumeral instability but does not specifically target Hill-Sachs lesions. The remplissage technique, "filling" the Hill-Sachs lesion, is popular for off-track lesions. The proposed combined approach seeks to stabilize the humeral head without sacrificing the coracoid, making it suitable for high-risk patients prone to recurrent shoulder instability, such as patients with subcritical glenoid bone loss. The operative technique includes patient preparation, creation of arthroscopic portals, confirmation of glenoid bone loss and other injuries, LHBT preparation and tenodesis to the anterior glenoid, and completion of the remplissage procedure. Postoperative protocols involve wearing a sling, self-mobilization, and gradual return to sports. The method aims to improve stability and outcomes in patients with complex shoulder instability issues. The DAS and remplissage is a rational choice for high-demand patients with subcritical glenoid bone loss and on-track Hill-Sachs lesions because it may provide better stability than isolated Bankart repair or Bankart plus remplissage procedures.

Yamamoto et al. developed the glenoid track theory,[1] taking the size of both glenoid bone and Hill-Sachs lesions into consideration in anterior shoulder instability. Since this development, the bipolar lesion has gained popularity, and criteria have been established for surgical treatment. Glenoid bone loss measurement is not always precise, and therefore the accuracy of the glenoid track theory, which combines 2 measurements, may also be affected. Therefore, a more comprehensive evaluation of the glenoid and humeral head morphology is necessary for accurate assessment the severity of bipolar lesions and to determine the most appropriate surgical treatment for anterior shoulder instability.

Collin and Lädermann proposed an augmented Bankart procedure termed, dynamic anterior stabilization (DAS), using the long head of the biceps tendon (LHBT) to reinforce the anterior part of the capsule for anteroinferior glenohumeral instability.[2] However, DAS does not specifically address the Hill-Sachs lesion, and the indication of this technique regarding glenoid tract theory remains unclear.[3-5] Remplissage is usually performed on off-track lesions by tightening the infraspinatus and teres minor tendon and the posterior capsule at the level of the defect.[6,7] Association of augmented Bankart and remplissage has rarely been described. In this article, we present a surgical technique combining arthroscopic inlay DAS with LHBT and remplissage procedure. This technique aims to stabilize the humeral head without

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Received July 6, 2024; accepted August 6, 2024.

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2212-6287/241085
https://doi.org/10.1016/j.eats.2024.103256

Table 1. Indications and Contraindications of Arthroscopic Inlay Dynamic Anterior Stabilization and Remplissage for Patients With Subcritical Glenoid Bone Loss and On-Track Hill-Sachs Lesions

Indications
Anteroinferior glenohumeral instability
Anterior glenoid bone loss between 13.5% to 20%
On-track Hill-Sachs lesion
A positive apprehension test at 90° degrees of abduction and external rotation
Contraindications
Anterior glenoid bone loss greater than 20%
Lost or spontaneous rupture of long head of the biceps tendon (LHBT)
Previous LHBT tenotomy or tenodesis
Associated subscapularis lesion
Glenohumeral osteoarthritis
Shoulder stiffness

sacrificing the coracoid and provides a stronger construct than the arthroscopic Bankart plus remplissage procedure in the high-risk group for recurrent shoulder instability, such as patients with subcritical glenoid bone loss and on-track Hill-Sachs lesions.

Surgical Technique

Surgical Indications

The indications and contraindications of arthroscopic inlay DAS and remplissage for patients with subcritical glenoid bone loss and on-track Hill-Sachs lesions are listed in Table 1.

Patient preparation and arthroscopic portals

All patients have general anesthesia with interscalene nerve block and are placed in the beach-chair position with a traction device. The device should be adjustable during the surgery because different shoulder and elbow positions are required for this procedure. Typically, 4 arthroscopic portals are necessary: posterior, posterolateral, anterior, and anterolateral portals (Fig 1). The anterior portal should be positioned low enough to provide a suitable angle for placing the drilling device at the 4:30-o'clock position of the right glenoid (7:30-o'clock for the left shoulder).

Surgical Technique

Confirmation of the Glenoid Bone Loss, Hill-Sachs Lesion, and Other Soft Tissue Injuries. A thorough intra-articular diagnostic arthroscopy examination is performed through a standard posterior portal. An anterolateral portal is then created using an outside-in technique. Rotator interval and subcoracoid space are widely opened, facilitating further LHBT passage (Fig 2A). The subscapularis split can be performed at this point, with a split made in the middle of the subscapularis muscular part (Fig 2B).[8] The extent of anterior glenoid bone loss (Fig 2C), the reparability of the remnant labrum and inferior glenohumeral ligament integrity (Fig 2D), the presence of a Hill-Sachs lesion (Fig 2E), and the presence of a SLAP tear (Fig 2F) can be further assessed.

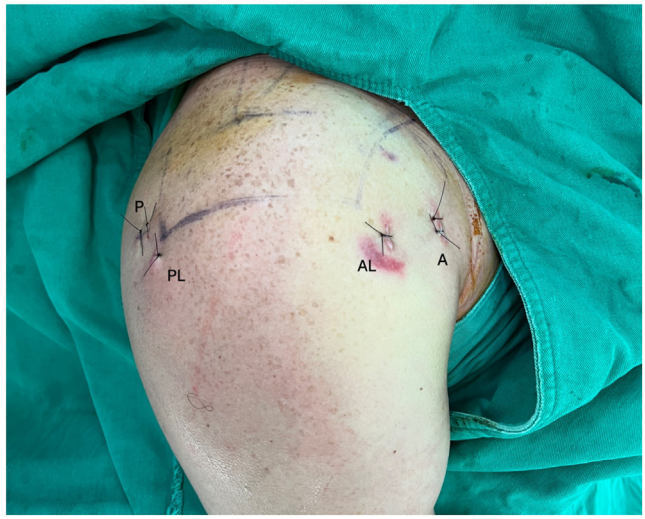

Fig 1. Right shoulder, viewed from lateral side. Patients are placed in the beach-chair position. Four arthroscopic portals are necessary: posterior, posterolateral, anterior, and anterolateral. The anterior portal should be positioned low enough and just lateral to the conjoint tendon to provide a suitable angle for placing the drilling device at the 4:30 position of the right glenoid (7:30 for the left shoulder). A, anterior portal; AL, anterolateral portal; P, posterior portal; PL, posterolateral portal.

Remplissage Procedure. The arthroscope is then shuttled to the subacromial space to clear the bursa. Next, the scope is introduced into the glenohumeral joint through the rotator interval from the anterolateral portal, confirming the position of the Hill-Sachs lesion. A double or triple-loaded suture-based anchor is inserted through the posterolateral portal, aiming at the deepest part of the Hill-Sachs lesion (Fig 3A). After passing the sutures through the infraspinatus musculotendinous junction (Fig 3B), the sutures are left without tying (Fig 3C) to provide more space in the glenohumeral joint for performing the DAS procedure.

Anterior Glenoid Preparation. Viewing from the anterolateral portal, a low anterior portal is created. Care is taken to ensure the drilling jig lies at the edge of the anterior glenoid. A 6-mm drill is then used to prepare a hole at the edge of the anterior glenoid at 4:30 for the right shoulder (7:30 for the left shoulder) (Fig 4A). The hole will be 4 to 6 mm wide and 20 mm deep (Fig 4 B and C), depending on the preference of the surgeon and the size of the long head of the biceps. The remnant labrum can be repaired in a manner similar to a conventional Bankart repair (Fig 4D). A suture is passed around the labrum and pulled through the posterior portal for further usage.

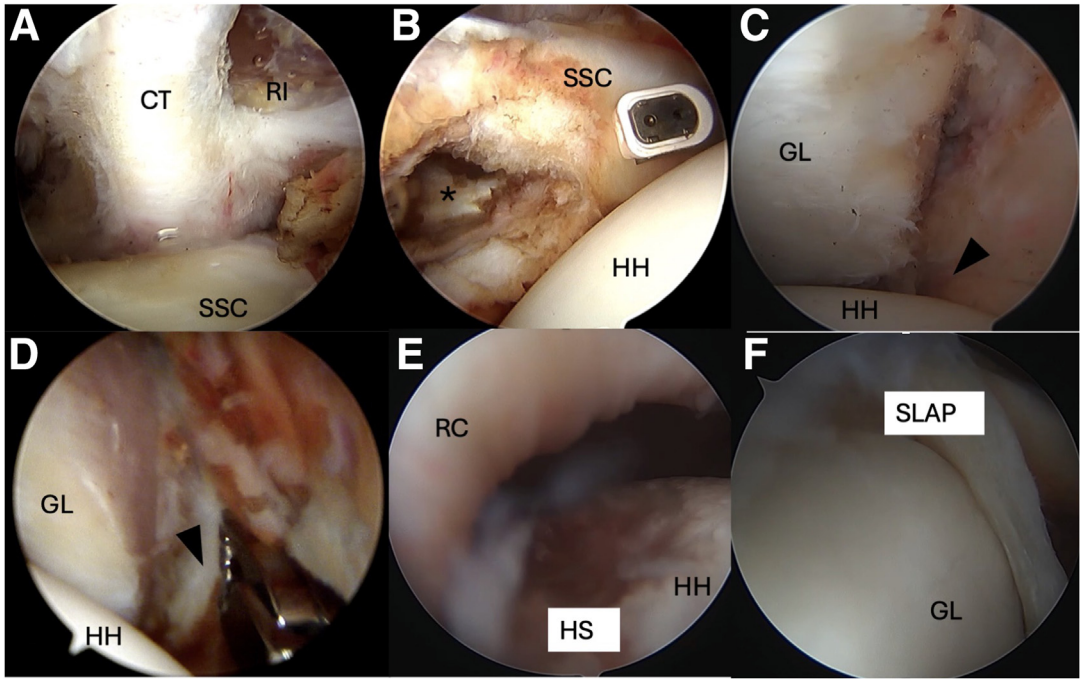

Fig 2. Views from different portals of the right shoulder. (A) View from the posterior portal: the RI and subcoracoid space are opened widely, facilitating further LHBT passage. (B) View from the posterior portal: the subscapularis split (asterisk) is made in the middle of the subscapularis muscular part. View from the anterolateral portal down into the glenohumeral joint: (C) the extent of anterior glenoid bone loss and (D) the reparability of the remnant anteroinferior labrum (arrowhead) and inferior glenohumeral ligament integrity are measured. (E) View from the anterolateral portal: the scope is placed underneath the supraspinatus tendon, and the presence of a Hill-Sachs lesion is confirmed. (F) From the posterior portal, the presence of a SLAP tear can be assessed. CT, conjoint tendon; GL, glenoid; HH, humeral head; HS, Hill-Sachs; LHBT, long head of the biceps; RC, rotator cuff; RI, rotator internal; SSC, subscapularis.

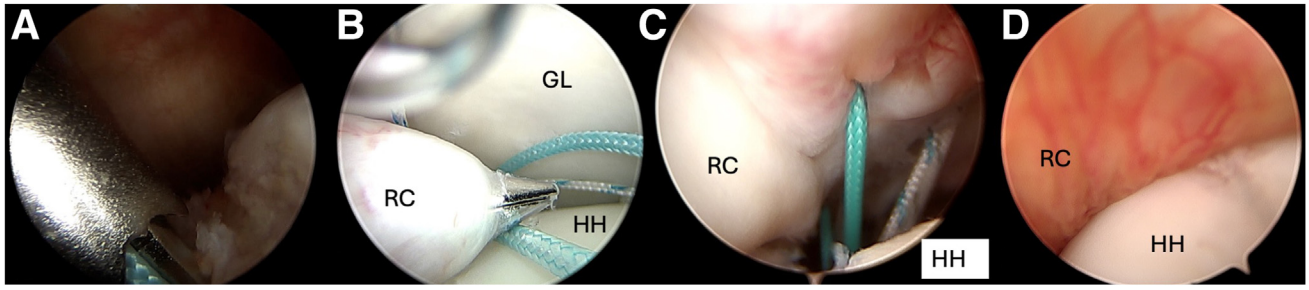

Fig 3. Right shoulder, viewed from the anterolateral portal with the scope placed underneath the supraspinatus tendon. (A) A double- or triple-loaded suture-based anchor is inserted through the posterolateral portal, aiming at the deepest part of the Hill-Sachs lesion. (B) Passing the sutures through the infraspinatus musculotendinous junction with a suture manipulator. (C) The sutures are left in situ without tying. (D) After tying the knots, the remplissage procedure is completed. HH, humeral head; GL, glenoid; RC, rotator cuff.

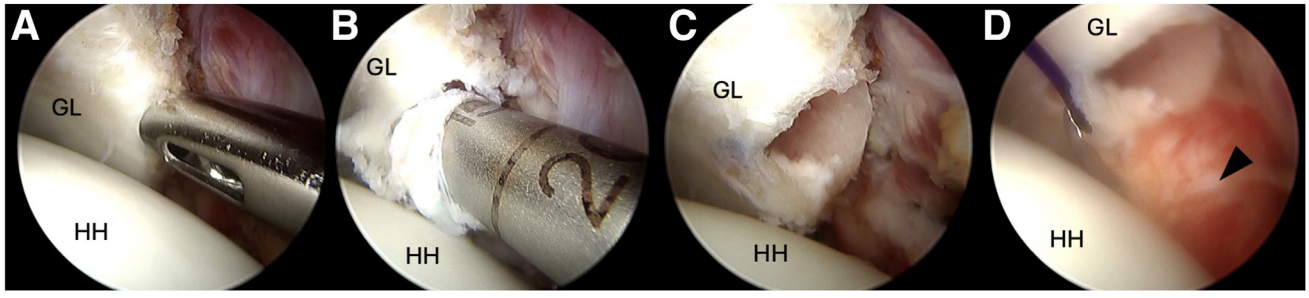

Figure 4. Viewing from the anterolateral portal of the right shoulder and down into the glenohumeral joint. (A) A 6 mm drill is then used to prepare a hole at the edge of the anterior glenoid at 4:30 for the right shoulder (7:30 for the left shoulder). (B, C). The hole will be 4 to 6mm wide and 20 mm deep. (D) The remnant labrum (arrowhead) can be repaired in a manner like a conventional Bankart repair. GL, glenoid; HH, humeral head.

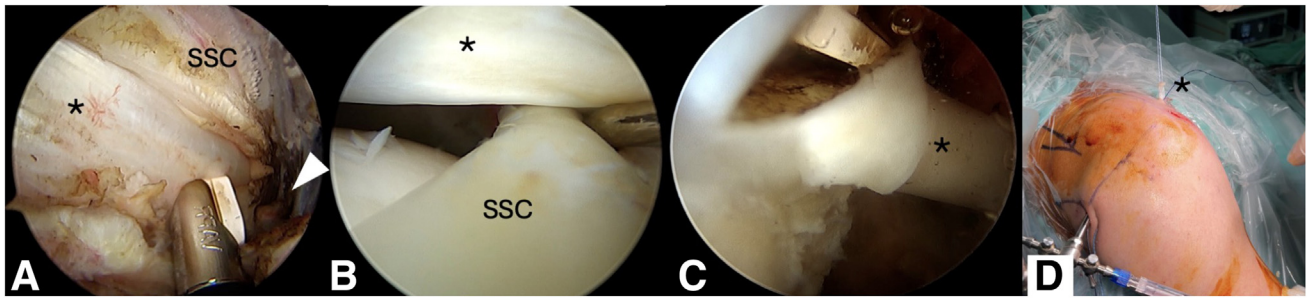

Figure 5. Viewing from the anterolateral portal of the right shoulder in the subacromial space. (A) The transverse humeral ligament (arrowhead) is released to facilitate LHBT (asterisk) mobility. (B) The LHBT can be easily moved medial to the bicipital groove after the release of the transverse humeral ligament. (C) Viewing from the posterior portal of the right shoulder. The LHBT tenotomy is released at the most proximal part of the supraglenoid tubercle. (D) The LHBT is exteriorized through the anterior portal and secured using a SpeedWhip technique with No. 2 Ultrabraid suture. SSC, subscapularis.

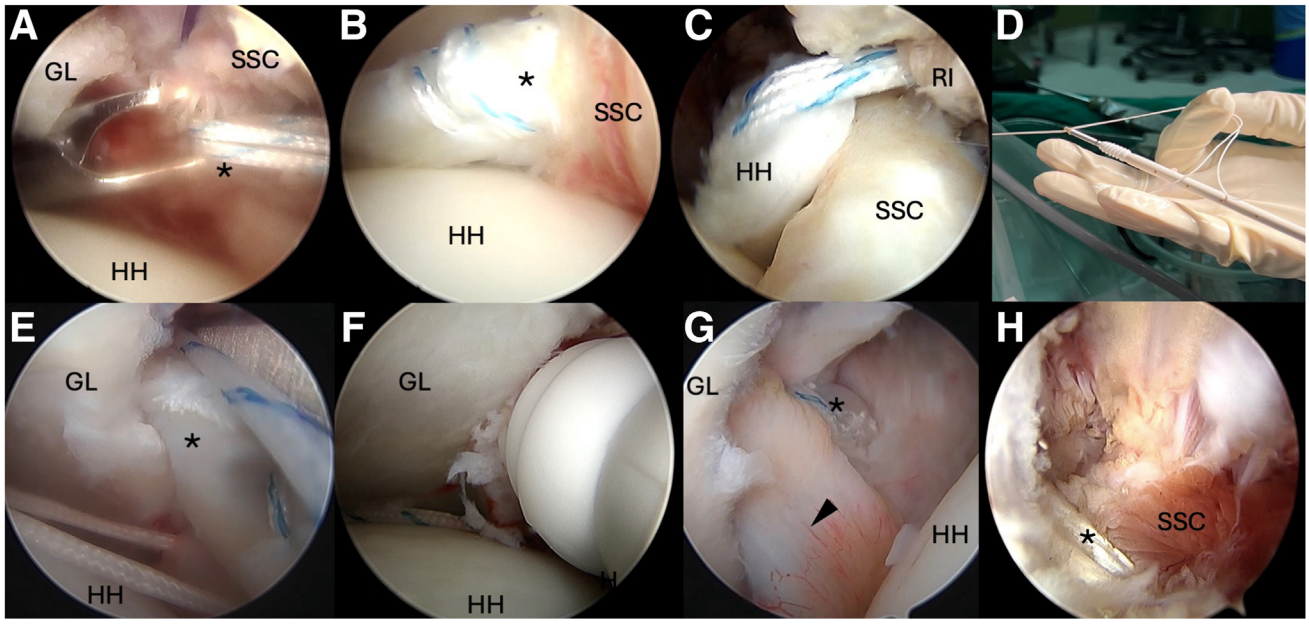

Figure 6. Viewing from the anterolateral portal of the right shoulder down into the glenohumeral joint. (A) The sutured LHBT (asterisk) can then be retrieved from the anterior part of the subscapularis through the muscle split initially made. (B) To the posterior part of the glenohumeral joint. (C) The suture of the LHBT can be retrieved anteriorly again from the rotator interval (RI) through the anterior portal, ensuring that it passes through the subscapularis split. (D) The two suture limbs fixing the LHBT are then shuttled through the eyelet of the Bio-Tenodesis Screw. (E, F) The LHBT, passing through the subscapularis split, is fixed into the glenoid hole with the Bio-Tenodesis Screw entering through the rotator interval. (G) The additional suture passed through the labrum (arrowhead) can be used to fix it onto the glenoid through the Fiberwire inside the Bio-Tenodesis Screw to complete a Bankart repair. (H) Viewing from the anterolateral portal of the right shoulder and aiming at the subcoracoid space. The fixed LHBT provides a sling and hammock effect, lowering the subscapularis. GL, glenoid; HH, humeral head; SSC, subscapularis; RI, rotator interval.

LHBT Preparation. Before the LHBT tenotomy, the transverse humeral ligament is released to facilitate LHBT mobility (Fig 5A). After the confirmation that the LHBT can be easily moved medial to the bicipital groove (Fig 5B), an LHBT tenotomy is released at the most proximal part of the supraglenoid tubercle (Fig 5C), providing the longest possible distance of the LHBT for further fixation. The LHBT is then exteriorized through the anterior portal (Fig 5D) and secured using a SpeedWhip technique with No. 2 Ultrabraid suture (Smith & Nephew, Andover, MA), 20 mm from the proximal tendon. If the cut end of the LHBT is too large, some trimming can be done to fit the glenoid hole just created without compromising the sutures on the LHBT.

LHBT Tenodesis to Anterior Glenoid. The sutured LHBT can then be retrieved from the anterior part of the subscapularis, through the muscle split that was initially made (Fig 6A), to the posterior part of the

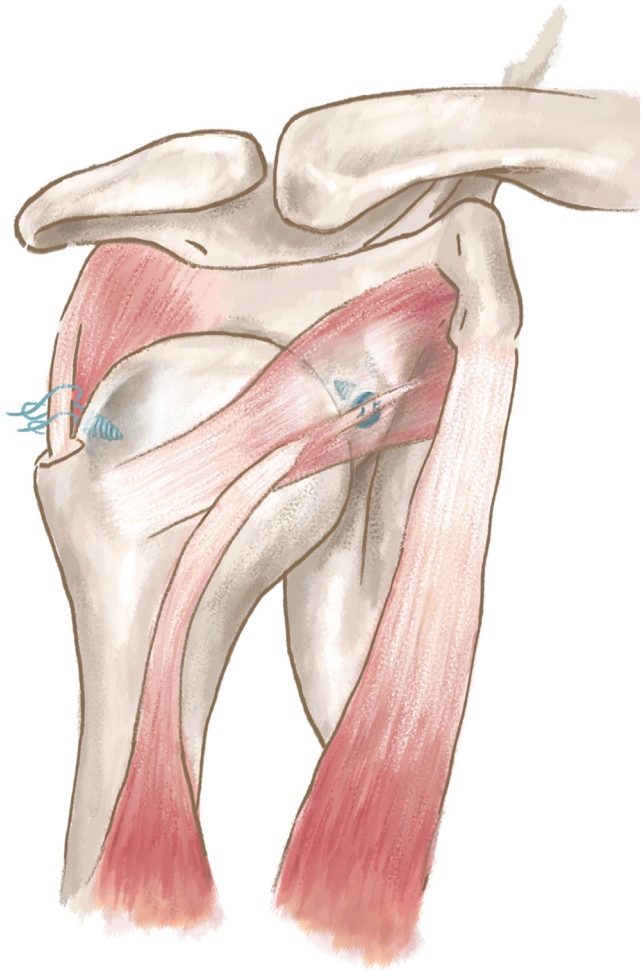

Figure 7. The final construct of the reconstruction.

glenohumeral joint (Fig 6B). The suture of the LHBT can again be retrieved anteriorly from the rotator interval, through the anterior portal, ensuring that it passes through the subscapularis split (Fig 6C). The 2 suture limbs fixing the LHBT are then shuttled through the eyelet of the Bio-Tenodesis Screw (Arthrex, Naples, FL) (Fig 6D). The LHBT, passing through the subscapularis split, is fixed into the glenoid hole we created with the Bio-Tenodesis Screw entering through the rotator interval. Care must be taken to ensure that the sutured 20 mm of the LHBT is inserted into the glenoid hole for better fixation (Fig 6 E and F). The additional suture passed through the labrum can be used to fix it onto the glenoid, through the Fiberwire (Arthrex) inside a 3.9- to 6.25-mm Tenodesis Screw to complete a Bankart repair (Fig 6G). If there is enough labrum superior to the fixed LHBT, another suture can be added at the 3 o'clock position (9 o'clock position in the left shoulder) for augmentation. The fixed LHBT now provides sling and hammock effect,[9] lowering the subscapularis (Fig 6H). After the DAS and Bankart repair are finished, the suture passed through the infraspinatus can be tied to complete the remplissage procedure (Fig 3D). Figure 7 depicts the construct in its entirety.

Postoperative Protocol. Patients are instructed to wear a simple sling for 2 weeks to stabilize the wound. Rehabilitation with self-mobilization in elevation and external rotation is allowed right after the surgery. After suture removal at 2 weeks, normal activity is allowed, and self-mobilization in elevation and external rotation can be continued. Return to low-risk sports is allowed at 6 weeks, and overhead sports are allowed at 3 months after surgery.

The surgical procedure is demonstrated in Video 1. Pearls of the surgical steps are presented in Table 2. The advantages, risks, and limitations of this technique are outlined in Table 3.

Discussion

Regarding anterior shoulder instability, anterior glenoid bone loss is a common factors discussed in the literature.[10,11] Itoi et al. proposed that more than 21% of the glenoid bone length loss will significantly decrease glenohumeral stability.[10] Shaha et al. reported that anterior glenoid bone loss above 13.5% (subcritical bone loss) led to a clinically significant decrease in Western Ontario Shoulder Instability Index scores, which indicates an unfavorable outcome.[11] However, not only glenoid bone loss but also a concave glenoid leads to an increase in the loss of stability ratio.[12] Moroder et al. proposed that current glenoid bone loss measurements are unable to provide an adequate estimation of the actual biomechanical effect of glenoid defects because the relation between the glenoid defect size and its biomechanical effect is nonlinear.[13] In another study from the same group, 3 observers confirmed the impreciseness of scapula positioning for the creation of an en-face view of the glenoid as well as varying best-fit circle measurements.[13] Therefore, glenoid bone loss measurement is not always precise. Given that arthroscopic Bankart repair with remplissage provides similar outcomes for patients with >15% glenoid bone loss,[14] it is rational to augment Bankart repair with DAS and remplissage in patients with subcritical glenoid bone loss and on-track Hill-Sachs lesion, especially in high-functional-demand patients. DAS has been proven to provide less relative anterior translation than an isolated Bankart repair in 10% to 20% of anterior glenoid bone loss.[15]

This report has described a technique to stabilize the humeral head without sacrificing the coracoid, providing a stronger construct than the arthroscopic Bankart plus remplissage procedure in patients at high risk for recurrent shoulder instability, such as those with subcritical glenoid bone loss and on-track Hill-Sachs lesions.

Table 2. Surgical Steps, Tips, and Pearls of the Described Technique

Surgical Steps	Tips and Pearls
Patient preparation and arthroscopic portals	1. All patients are placed in beach-chair position.
	2. The traction device should be adjustable during the surgery because different shoulder and elbow positions are required for this procedure.
	3. Four arthroscopic portals are created: posterior, posterolateral, anterior, and anterolateral.
	4. Normally a cannula is not needed.
	5. The anterior portal should be low and medial for the drilling guide to aim at 4:30 of glenoid at right shoulder (7:30 in left shoulder).
Confirmation of the glenoid bone loss, Hill-Sachs lesion, and other soft tissue injuries	1. The rotator interval (RI) and subcoracoid space are widely opened, facilitating further long head of the biceps tendon (LHBT) passage.
	2. The subscapularis split is performed in the middle of the subscapularis muscular part.
	3. The extent of anterior glenoid bone loss, the reparability of the remnant labrum and inferior glenohumeral ligament integrity, the presence of a Hill-Sachs lesion, and the presence of a SLAP tear can be further assessed.
	4. Passing the LHBT through the split is crucial to the surgery; therefore, the split should be clear enough to visualize the conjoint tendon from the posterior portal.
Remplissage procedure	1. The arthroscope is shuttled to the subacromial space to clear the bursa within before inserting the anchor.
	2. The arthroscope is introduced into the glenohumeral joint through the RI from the anterolateral portal.
	3. A double- or triple-loaded suture-based anchor is inserted through the posterolateral portal, aiming at the deepest part of the Hill-Sachs lesion.
	4. The sutures are passed through the infraspinatus infraspinatus musculotendinous junction.
	5. After passing the sutures through the infraspinatus tendon, the sutures are left in place without tying.
Anterior glenoid preparation	1. Viewing from the anterolateral portal, a low anterior portal is created.
	2. A 6-mm drill is used to prepare a hole at the edge of the anterior glenoid at 4:30 for the right shoulder (7:30 for the left shoulder).
	3. The hole is 6 mm wide and 20 mm deep.
	4. The remnant labrum can be repaired in a manner similar to a conventional Bankart repair.
	5. The suture passed around the labrum can be pulled through the posterior portal for further use.
	6. The anterior portal should be low and medial for the drilling guide to aim at 4:30 of glenoid at right shoulder (7:30 in left shoulder)
	7. The drill should be aimed at the edge of the glenoid, otherwise the bone void will not be sufficient.
LHBT preparation	1. The transverse humeral ligament can be released to facilitate LHBT mobility.
	2. LHBT tenotomy is released at the most proximal part of the supraglenoid tubercle, providing the longest possible distance of the LHBT.
	3. The LHBT is exteriorized through the anterior portal and secured using a SpeedWhip technique with a No. 2 Ultrabraid suture 20 mm from the proximal tendon.
	4. Some trimming of the end of the LHBT can be done to fit the glenoid hole just created without compromising the sutures on the LHBT.
LHBT tenodesis to anterior glenoid	1. The sutured LHBT can then be retrieved through the muscle split from the anterior part of the subscapularis to the posterior part of the glenohumeral joint.
	2. The LHBT can then be retrieved anteriorly again from the RI through the anterior portal, ensuring that it passes through the subscapularis split.
	3. The 2 suture limbs fixing the LHBT are then shuttled through the eyelet of the Bio-Tenodesis Screw.
	4. The LHBT, passing through the subscapularis split, is fixed into the glenoid hole with the Bio-Tenodesis Screw entering through the rotator interval.
	5. The additional suture passed through the labrum can be used to fix onto the glenoid, through the Fiberwire inside the Tenodesis Screw, to complete a Bankart repair.
	6. The sutured 20 mm of the LHBT is inserted into the glenoid hole for better fixation.

Table 3. Advantages, Risks, and Limitations of This Technique

Advantages
1. Only 4 incisions
2. Sling effect but no coracoid transfer
3. No nerve dissection
4. No graft overhang
5. No graft resorption
6. Intact pectorais minor to avoid scapular dyskinesis
7. Biopolar lesion can be treated simultaneously
8. SLAP lesion can be treated simultaneously
Risks
1. The drill should be aimed at the edge of the glenoid, otherwise the bone void will not be sufficient
2. Trimming of the end of the long head of the biceps (LHBT) could compromise the sutures on the LHBT
3. Biceps tenotomy is associated with cosmetic deformity, cramping, and weakness
4. Elongation of the biceps muscle-tendon unit after rerouting may happen if biceps tenotomy is not done, which potentially leads to an increase in the tension and anchor pullout
Limitations
1. Not available for >20% glenoid bone loss
2. Not available for spontaneous biceps rupture
3. Not available for previous biceps tenotomy/tenodesis
4. Not available for associated subscapularis lesion

Disclosures

The authors (J.C-H.C., A.G-A., A.L.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

The authors gratefully thank the Taiwan Minister of Science and Technology and Linkou Chang Gung Memorial Hospital for the financial support of this study (Grant: MOST 111-2628-B-182A-016, NSTC112-2628-B-182A-002, CMRPG5K0092, CMRPG3M2031, and CMRPG5K0211).

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