Technical Note

Arthroscopic Augmentation of Subscapularis Revision Repair Using a Bioinductive Collagen Implant

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Abstract: The overall failure rate of rotator cuff healing after primary repair is high and is even greater in revision cases. This worrisome outcome has spurred the development and use of biological materials to help promote healing potentials. This Technical Note describes an all-arthroscopic technique for the application of a bioinductive collagen patch to augment subscapularis full-thickness tear repair. We describe in detail a stepwise approach to guide surgeons in patient positioning, portal placement, diagnostic arthroscopy, graft preparation, deployment, and fixation.

Isolated subscapularis tears are infrequent and can be easily overlooked, with an estimated incidence of 4.9% of overall cuff tears.[1] Those tears, if unrecognized and untreated, have the tendency to become extensive, representing a technical challenge, characterized by larger defect, muscle atrophy, substantial tendon medial retraction, and greater risk of retear after repair.[2-4] The rate of failure of rotator cuff repair is approximately 20% to 40% after primary repair and is even greater in revision cases.[5] There has been relatively less focus on assessing the outcomes of subscapularis repairs, with reported retear rates across the few available articles ranging from 5% to 13%.[6]

The addition of a bioinductive material has been increasingly used in recent literature. Innovative approaches have described the use of these biologically derived implants to be fixated arthroscopically along the bursal side of the repaired cuff.[7-11] The goal is to provide mechanical support to the repaired tendon, reducing strain on adjacent tissue, and to improve the vascularization, healing response, and regenerative capacity of the tissue. Histologic,[12] radiographic,[10] and clinical evidence has shown beneficial results for its use, with an excellent graft cellular incorporation, biocompatibility, favorable rates of radiographic retear, and substantial functional recovery with follow-up to 2 years.[7-11] Recently, the REGENETEN implant (Smith & Nephew, Andover, MA), a new graft made of reconstituted collagen fibers derived from bovine Achilles tendon, has demonstrated promising results in the repair of various types of rotator cuff tears.[7,11]

Arthroscopic techniques to introduce the augmented graft have solely been studied in the repair of posterosuperior cuff.[7,8,11] A similar arthroscopic technique to augment subscapularis tear repair has never been described. This Technical Note aims to describe a novel arthroscopic approach to augment subscapularis full-thickness tear repair. A bioinductive type 1 collagen material, REGENETEN (Smith & Nephew), is used as an augment graft after a standard repair. The surgical procedure is summarized in Table 1, and the pearls and pitfalls of the technique are summarized in Table 2.

Surgical Technique

Preoperative Assessment

Perform a physical examination of the shoulder to assess cuff integrity using the empty can, drop arm, lift-off, and resisted-rotation tests. Gauge instability by

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Table 1. Surgical Steps Required to Perform Arthroscopic Augmentation to Subscapularis

Tendon repair
1. Position the patient in a 30° lateral decubitus position.
2. Suspend arm with pneumatic arm holder with balanced traction in 60° of abduction and neutral forearm rotation (Fig 3).
3. Establish a posterior viewing portal parallel to the glenoid face and an anteroinferior portal using an inside-out technique.
4. Perform a diagnostic arthroscopy from the posterior portals. This is the primary viewing portal throughout the procedure.
5. Debride the scarred upper edge of subscapularis using an ablator probe.
6. Release the rotator interval using a shaver and ablator.
7. Switch to 70° scope to view over the top of subscapularis (Fig 4).
8. Release the subcoracoid space, coracohumeral ligament, and seperate the conjoined tendon off the subscapularis.
• Position the arm slightly flexed forward to see over the top of the subscapularis, and ensure the arm is adducted to keep the conjoined tendon medial and do all working lateral to conjoined tendon, away from brachial plexus.
9. If previous sutures are loose, remove them with a shaver, and/ or a grasper.
10. Prepare the footprint using motorized shaver.
11. Repair the subscapularis as a standard repair using a single-row anchor (Fig 5).
12. On a side table: open the graft package. The graft is already loaded to the delivery device gun.
13. To introduce the graft arthroscopically, a low lateral portal should be created (Fig 6):
• Pass a spinal needle a few centimeters inferior to the lateral edge of the acromion. The goal of this portal is to ensure staying parallel to the upper edge of subscapularis.
14. To provide wider working space, use a switching stick from a newly created percutaneous anterosuperior portal to retract the deltoid. An assistant must keep the deltoid away from view throughout the graft introduction and fixation (Fig 7).
15. Graft is introduced from the low lateral portal ensuring it is aligned with the upper edge of subscapularis tendon (Fig 8).
16. Graft fixation (Fig 8):
• While keeping the graft held in position by the delivery device, pass the staple gun from the anteroinferior portal.
• The graft is fixed over the repaired subscapularis, starting from lateral to medial edge.
• Do not remove the graft delivery device until at least 2 points of fixation is achieved.
• A total of 5-6 staples is required for a proper fixation.

NOTE. The equipment required comprises standard arthroscopic equipment, 70° lens, the bioinductive implant (REGENTEN; Smith & Nephew), 5.7-mm clear cannula (Crystal Cannula; Arthrex, Naples, FL), suture shuttling device, and all-suture double-loaded anchor (Q-FIX; Smith & Nephew).

the anterior apprehension, Jobe relocation, sulcus, and load-and-shift tests. Image the shoulder (Fig 1) with anteroposterior and transscapular Y views as well as magnetic resonance imaging (Fig 2) to visualize the tear characteristics, tear size, level retraction, previous repair site, tissue atrophy, and grade of fatty infiltration. We also prefer to use a patient-specific 3-dimensional—printed model to help us localize specific portal placement. Surgical indications for this technique include repairing any type of subscapularis tear in acute or chronic settings.

Table 2. Pearls and Pitfalls

Pearls	Pitfalls
Proper portal placement is the key for a successful procedure.	Improper portals placement makes visualization difficult.
The use of a 70° scope helps visualize over the top of the subscapularis, which makes it easier to evaluate for anchor placement and tissue tensioning.	Inadequate soft-tissue release impedes visualization and proper graft direction placement.
The use of a cannula expander allows for both good fluid management and smooth insertion of the delivery device, which otherwise gets stuck in small cannulas.	Be aware of the danger of brachial plexus proximity during the subcoracoid interval release. Ignoring proper arm positioning risks injury.
To provide wider working space, use a switching stick from a percutaneous anterosuperior portal to retract the deltoid throughout the graft insertion and fixation.	Removing the graft delivery device before at least 2 points of fixation may cause graft malposition.
Introducing the staples fixation device from the anteroinferior portal is ideal to get a proper trajectory for approximately 90° angle of fixation.	

Patient Positioning and Operative Room Setup

To perform this procedure with the patient in the lateral decubitus position, place a beanbag on the operating table under the patient. Roll the patient into 30° semilateral decubitus to help bring the subscapularis more superior for easier access and place the arm in a pneumatic arm holder (Spider 2; Smith & Nephew) with balanced traction in 60° of abduction and neutral rotation (Fig 3A). Identify the standard skin landmarks, including the acromioclavicular joint, clavicle, acromion, and scapular spine. Create a standard posterior portal. It is important to place the portal as superior as possible toward the acromion to provide the best view of the anterior aspect of the subscapularis and position its angle perfectly parallel to the face of the glenoid (Fig 3B).

Evaluation and Debridement

Perform a diagnostic arthroscopy from the posterior portal (Video 1). Create the anteroinferior portal using an inside-out technique. This anteroinferior portal will be the primary working portal. We then recommend switching to a 70° lens camera to see over the top of the subscapularis (Video 1). In revision cases, more scarring tissue is expected to be found in the rotator interval and subcoracoid space. To address this, start the rotator interval release (including coracohumeral ligament) using a motorized shaver first until the conjoined tendon

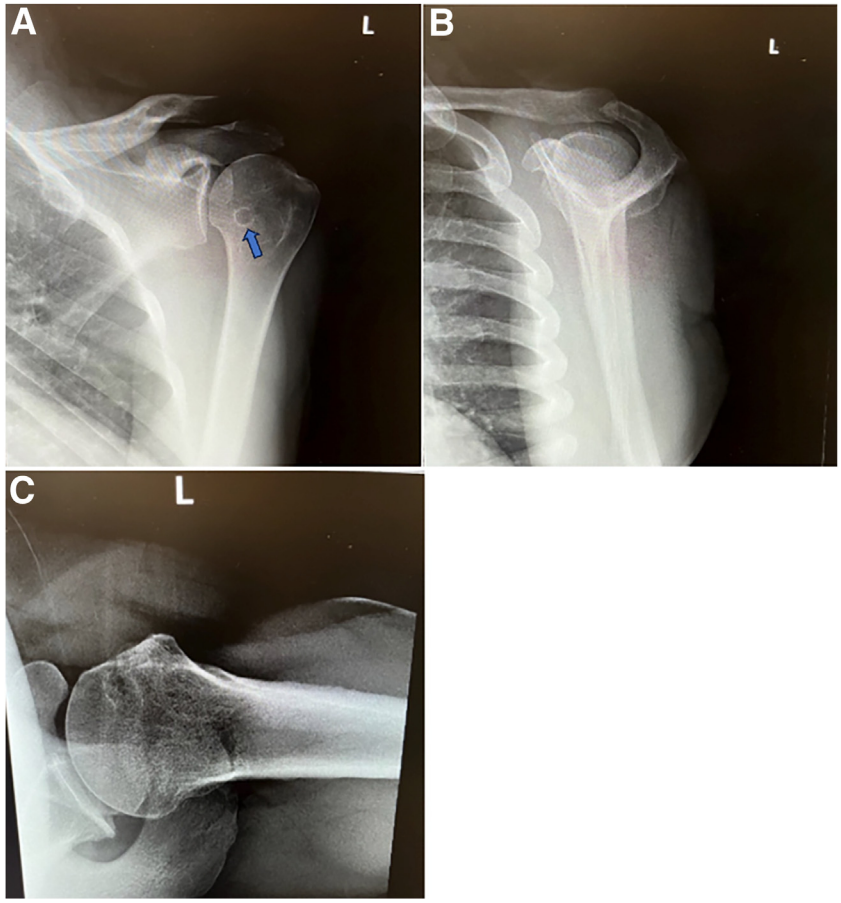

Fig 1. Preoperative radiographic films of the left shoulder. (A) Anteroposterior view showing the previously drilled anchor placement (arrow). (B) The transscapular Y view. (C) Axillary view showing humeral head centricity on the glenoid with no anterior subluxation.

is identified. Keep the middle glenohumeral ligament intact. Then, use an ablator to coagulate bleeders around the conjoined tendon and to further separate it from the subscapularis (Fig 4). This step is done very meticulously. Position the arm slightly flexed forward to see over the top of the subscapularis and ensure the arm is adducted to keep the conjoined tendon medial and release lateral to the conjoined tendon, away from the brachial plexus. Performing a proper soft-tissue release is important to allow for full visualization of the anterosuperior portions of the subscapularis, which is necessary to evaluate for both anchor placement and repair tension. The arm can also be pulled posteriorly with the elbow pushed anteriorly to maximize the view of the footprint of the subscapularis muscle.

After removal of previous sutures, if loose, use an arthroscopic ablator to debride the lesser tuberosity footprint from remaining scar tissue and residual tendon flap, and use a shaver to instigate healthy bleeding bone. Perform a standard repair of the subscapularis tissue using a single-row technique (Video 1). Fix a 2.8-mm double-loaded all-suture anchor (Q-FIX; Smith & Nephew, Memphis, TN) to the footprint. Pass the loaded sutures into tissue using a shuttling device (Spectrum; CONMED, Largo, FL) in a modified Mason-Allen stitch configuration and tie it down (Fig 5).

Graft Passing and Fixation

Creation of the Low Lateral Portal. To allow the insertion of the graft in a parallel angle to the subscapularis, create a secondary working portal along the upper edge of the subscapularis (Video 1). Create the portal using an outside-in technique, where a spinal needle is passed through the lateral shoulder, a few centimeters from the anterolateral edge of the acromion, parallel and superior to the subscapularis tendon fibers (Fig 6). This technique ensures introducing the graft in a parallel angle to the subscapularis to achieve the goal of adequate augmentation over the repaired subscapularis tissue. Place a slotted cannula into the portal and use a large channel dilator to dilate the portal bluntly to allow for easy passage of the graft.

Graft Insertion. We used a bioinductive implant (REGENTEN; Smith & Nephew) for this arthroscopic reconstruction. Once the package is open, the graft is already loaded into the delivery device gun. Before the insertion of the graft, create a percutaneous anterosuperior portal to introduce a switching stick to

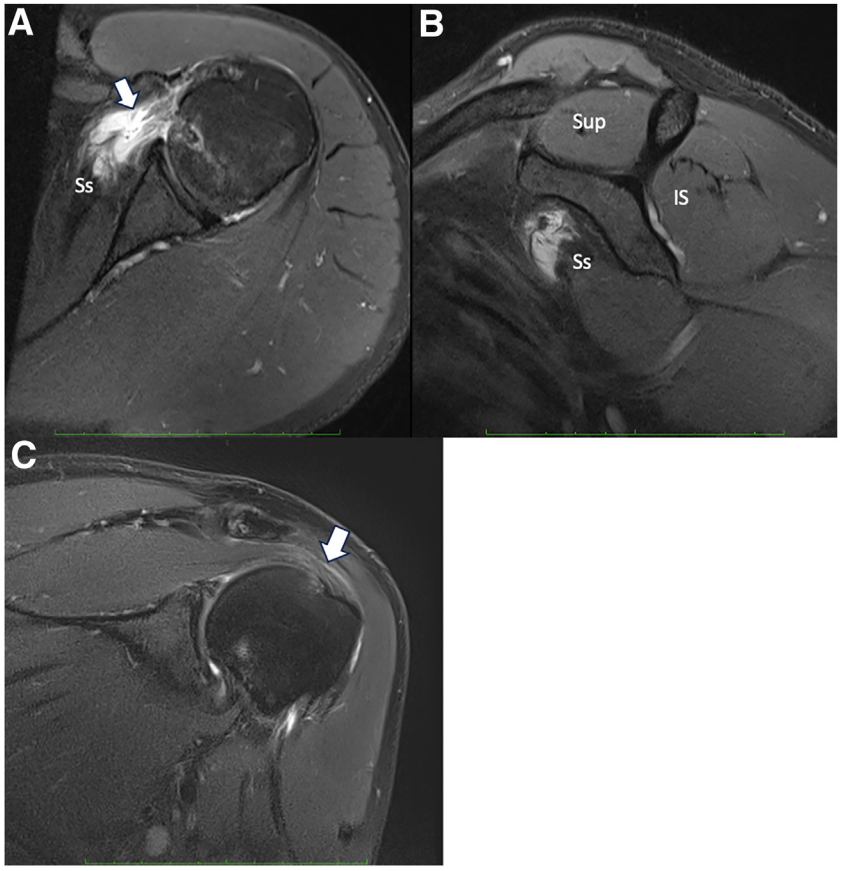

Fig 2. T2-weighted magnetic resonance imaging of the left shoulder. (A) Axial cut showing failed subscapularis (Ss) tendon repair at intrasubstance level (arrow). (B) Sagittal cut showing retracted and atrophied subscapularis tissue (Ss) in comparison to good muscle bulk of posterosuperior cuff (supraspinatus [sup] and infraspinatus [IS]). (C) Coronal cut showing intact posterosuperior cuff footprint (arrow).

Fig 3. Arm positioning and portal placement. (A) The patient is placed in the lateral decubitus position at 30° from vertical for easy access to the left anterior shoulder. (B) The left arm is secured in a pneumatic arm holder. Standard surgical landmarks are identified. The sites for portal placement include 1, posterior portal; 2, anteroinferior portal; 3, low lateral portal (graft placement portal); and 4, anterosuperior portal.

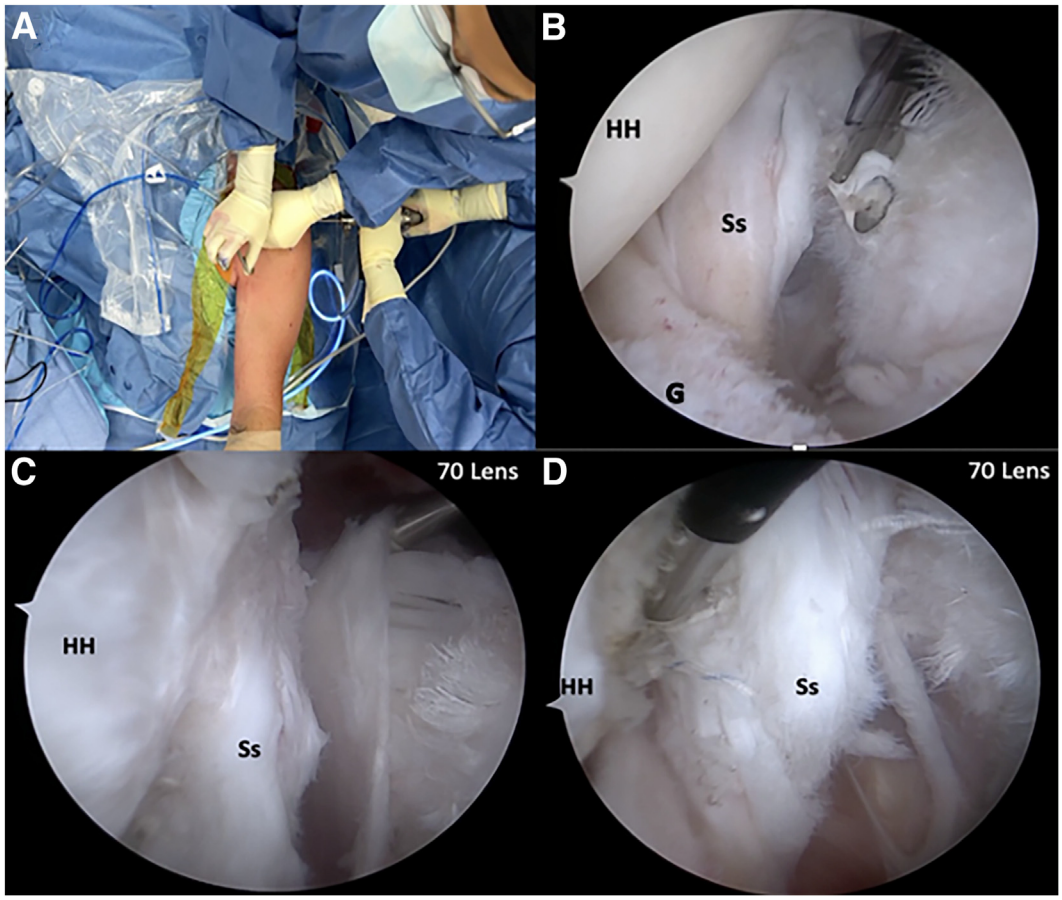

Fig 4. Diagnostic arthroscopy initial assessment. (A) The patient is placed in the lateral decubitus position with the left arm placed in a pneumatic arm holder with balanced traction in 60° of abduction and neutral rotation. The scope is introduced through the standard posterior portal. (B) The glenohumeral joint is viewed from the posterior portal in lateral decubitus orientation using 30° lens. The humeral head (HH) is at the left upper corner of the image. The glenoid (G) (not fully shown) lies at the bottom left corner of the image. The subscapularis (Ss) lies in vertical orientation in relation to the glenohumeral joint in the lateral decubitus view. (C) Switching to a 70° lens provides an over-the-top view to the subscapularis (Ss) tendon. (D) Previous repair sutures are removed with a grasper and a shaver. The failed tissue is torn medial to the previous sutures.

retract the deltoid, keeping it away from the field (Fig 7). Pass the graft delivery device from the cannula of the low lateral portal, ensuring that it is positioned at a parallel angle with the subscapularis tendon (Fig 8 A and B).

Graft Fixation. Fix the graft into the underlying cuff tendon with absorbable staples using the staples loaded delivery instrument. Insert all staples from the anteroinferior portal. This portal is used because of the desired direction of 90° to the graft to achieve maximum staple compression. Place the first staple along the medial border of the graft in a perpendicular angle of insertion (Fig 8C). Once the position of fixation is satisfactory, depress the insertion trigger, and deploy the staple. Repeat this process until the medial and lateral edges of the graft are attached (Fig 8D). Do not retrieve the graft gun device until the graft is fixed with at least 4 points of fixation. Use the staple cannula to help stabilize the graft while removing the deployment device to prevent the graft from migrating. A total of 5 to 6 staples are typically used. The final construct is shown in Figure 8E (Video 1).

Postoperative Protocol

It is important to notice that the graft has no structural strength properties and, therefore, the rehabilitation protocol depends on the type of tendon tear. In this case, a direct repair is done and therefore, we advise to follow a standard rotator cuff repair protocol. If the augmentation is done for a partial tear without tendon direct repair, you may follow a faster rehabilitation. Our protocol is to initially immobilize the patient in a sling for the first 6 weeks and to encourage elbow, wrist, and hand range of motion. At 2 weeks, pendulum exercises are introduced while out of the sling. At 6 weeks, shoulder active-assisted range of motion is started in all planes. At 10 to 12 weeks, and when satisfactory range of motion is achieved, the patient may start gentle, progressive strengthening of rotator cuff and

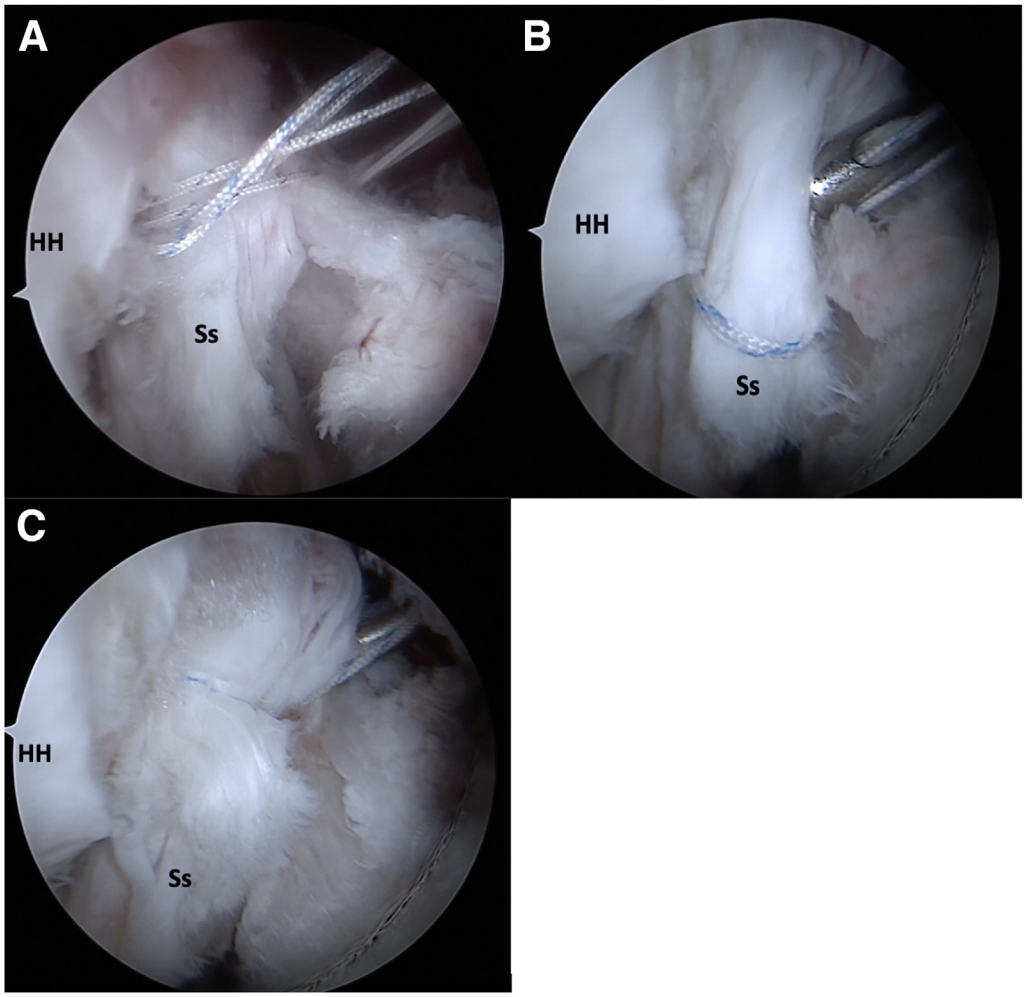

Fig 5. Subscapularis standard repair viewing the glenohumeral joint of left shoulder in lateral decubitus position from the posterior portal using a 70° lens. A standard subscapularis repair is performed. (A) A single all-suture double-loaded anchor is placed into the footprint after its preparation. (B) Delaminated tissue is passed using the suture shuttling device in a modified Mason-Allen configuration. (C) Standard repair is completed. (HH, humeral head; Ss, subscapularis.)

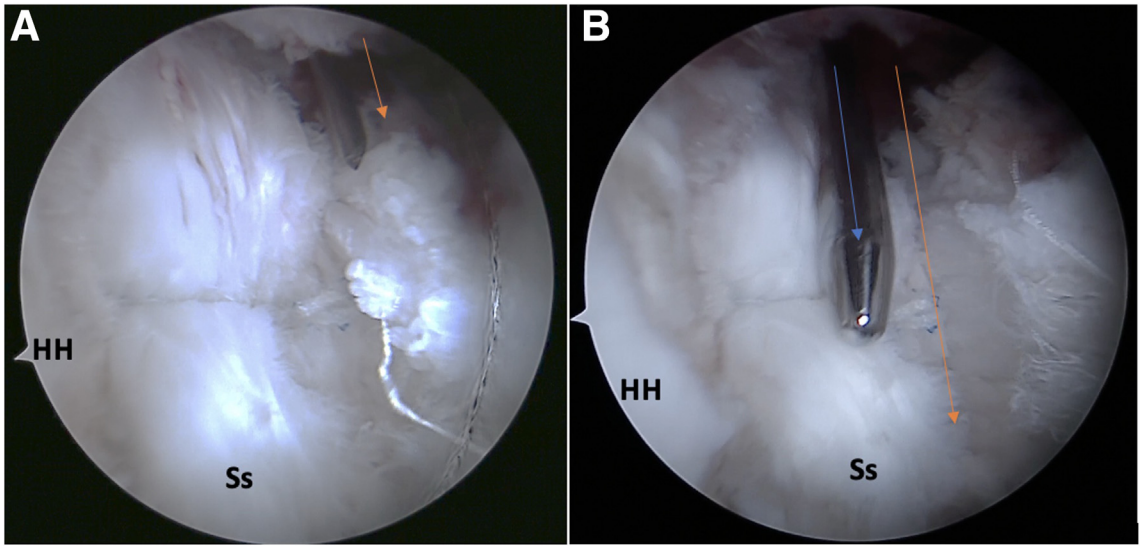

Fig 6. Creation of the low lateral portal (graft insertion portal), viewing the glenohumeral joint of left shoulder in lateral decubitus position from the posterior portal using 70° lens. (A) Spinal needle is inserted a few centimeters lateral to the acromion along its anterior half just above the upper border of the subscapularis in line with its insertion (orange arrow). The trajectory of the portal is of critical importance. (B) Switching stick is then introduced to ensure proper trajectory (blue arrow). (HH, humeral head; Ss, subscapularis.)

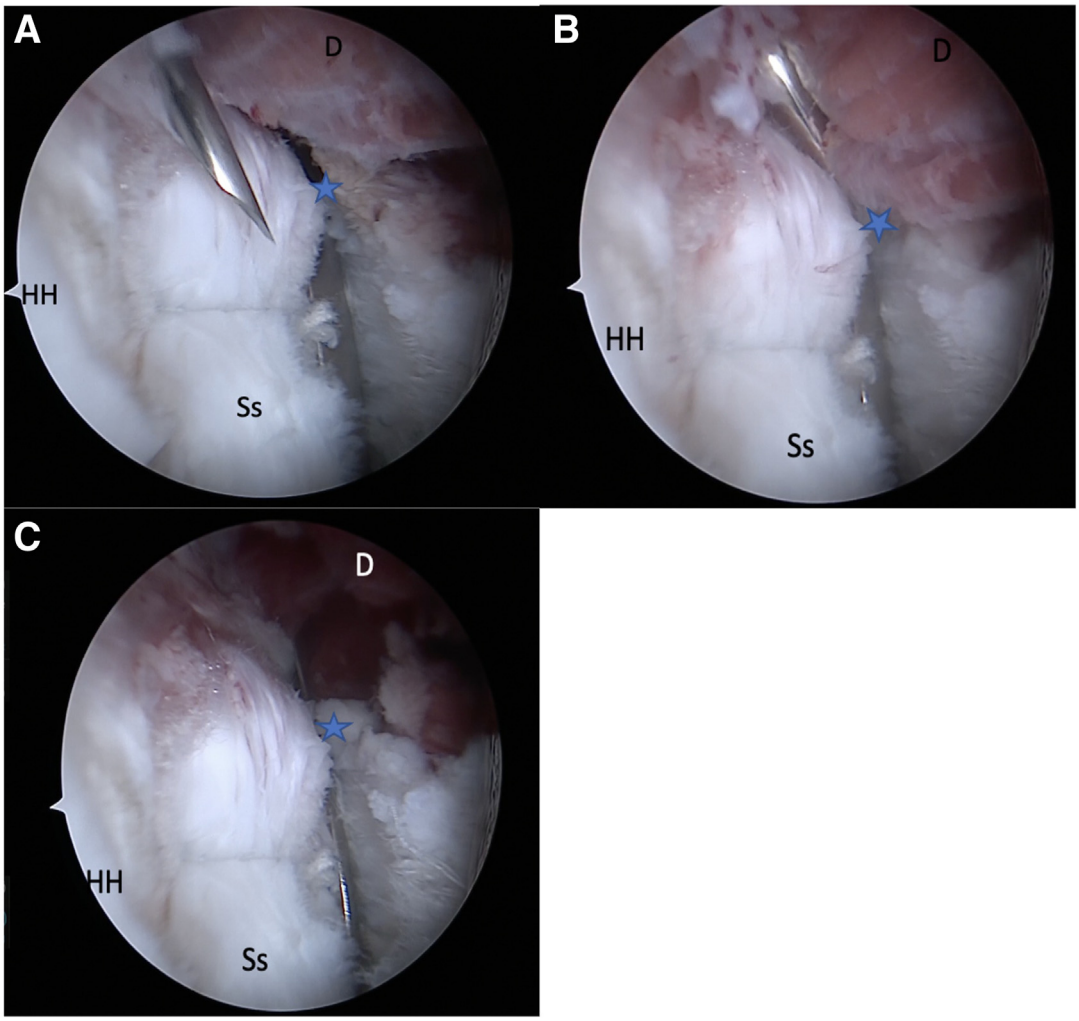

Fig 7. Creation of the anterosuperior portal (tissue retraction portal), viewing the glenohumeral joint of left shoulder in lateral decubitus position from the posterior portal using 70° lens. (A) Spinal needle is inserted underneath the deltoid muscle and just above the subscapularis. (B) A switching stick is introduced. (C) The switching stick is used to retract the deltoid (D) from view. The deltoid is now retracted providing wider working space. Star indicates low lateral portal that was previously created. (D, deltoid; HH, humeral head; Ss, subscapularis.)

periscapular muscles and is allowed to perform daily activities.

Discussion

This technique describes an all-arthroscopic augmentation of isolated subscapularis tendon repair using a bioinductive implant in the revision setting. In addition to offering cosmetically pleasing results, this technique eliminates the added morbidity of an open approach to the shoulder. The risks related to any shoulder arthroscopic procedure[13] and additional risks specific for managing subscapularis tendon repair arthroscopically apply to this technique. [14]

Recent literature has shown a growing trend toward incorporating bioinductive materials along the bursal side of the posterosuperior mended cuff.[7-11] Creative techniques have emerged, demonstrating arthroscopic fixation of these implants with encouraging results. [9-12] However, the literature is deficient in describing techniques to augment the subscapularis tendon repair. We came across one article that described an open approach to augment subscapularis tendon repair using a synthetic scaffold in an acute traumatic setting.[15] In their series, 80% (8 of 10 patients) had satisfactory results at 2 years with a mean Disabilities of Arm, Shoulder, and Hand score of 12.63% and overall retear rate of 10%. A similar arthroscopic approach to augment subscapularis tear repair has never been described.

Arthroscopic techniques to manage subscapularis tendon tear are deemed advanced skills in our opinion for 3 particular reasons: (1) familiarity, (2) exposure, and (3) danger of proximity (Table 3). First, although open repair was previously considered the gold standard for addressing subscapularis tendon

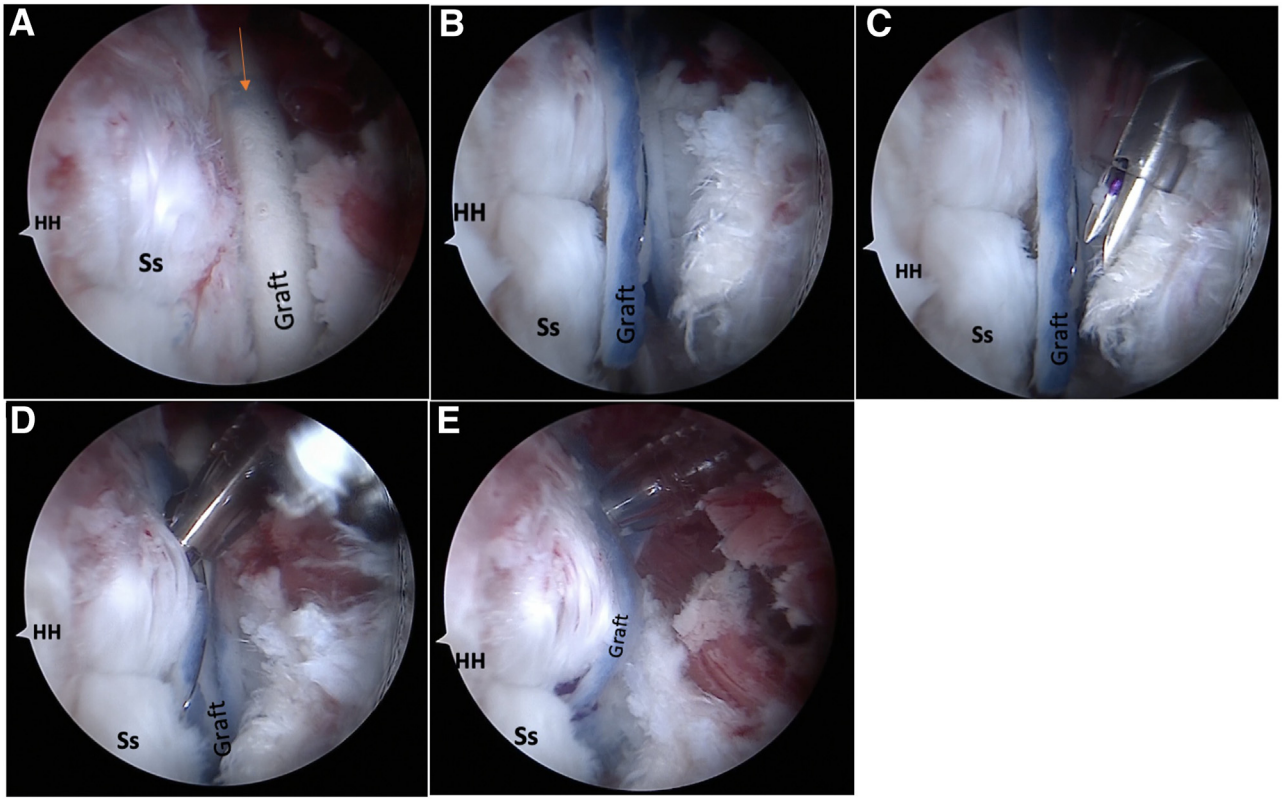

Fig 8. Insertion and fixation of the graft, viewing the glenohumeral joint of left shoulder in lateral decubitus position from the posterior portal using 70° lens. (A) The graft is inserted from the low lateral portal in line with the subscapularis fibers. (B) Positioning of the graft along the subscapularis repair ensuring maximum coverage. (C) While keeping the graft aligned from the low lateral portal, the staple device is introduced from the anteroinferior portal and deployment of staples begins from medial to lateral of footprint. (D) This step is repeated until 5-8 staples are fixed. (E) The finished construct is viewed from the posterior portal. Arrow indicates the angle of insertion. (HH, humeral head; Ss, subscapularis.)

tears, arthroscopic techniques have only been popularized recently after showing encouraging outcomes.[1,16] Some surgeons, particularly the inexperienced arthroscopist, may not be familiar with or comfortable working in that territory. Second, unlike the superior cuff, where there is a potential decent working area provided by the subacromial space, the subscapularis tendon resides between crowded structures. The conjoined tendon is in the way and restricts portal placement. Portals have to be in very specific angles; otherwise, accessibility to repair and/or add an augment would be more difficult. In addition, the anterior deltoid hides the superior most aspect of the tendon and thus must be retracted while inserting an augment. Third, the anatomical proximity of neurovascular structures—axillary nerve, anterior circumflex artery, and its venae comitantes when going too inferior[17] and brachial plexus when going too medial[18]—can make arthroscopic subscapularis tendon repair a nerve-racking experience.

Table 3. Additional Risks and Limitations of the Surgical Technique

Risks	Limitations
Risk of injuring axillary nerve, and, or anterior humeral circumflex artery, and its vena comitans when releasing inferior to the lower edge of subscapularis.	Requires familiarity with the surgical anatomy and proficiency in arthroscopic skills of shoulder pathology to achieve all-arthroscopic technique.
Risk of injuring brachial plexus when releasing medial to conjoined tendon.	

In our technique, we pay special attention to address these 3 concerns. For familiarity, we recommend proper preoperative planning. We prefer to use a patient-specific 3-dimensional printed model for every case to help us decide the graft insertion portal placement in relation to the lesser tuberosity, and the posterior portal placement in relation to the lateral edge and anterolateral corner of acromion. This is important to ensure that the 70° scope can be brought all the way to the anterior joint for both appropriate visualization and creation of the anterior accessory portal. For exposure, we recommend releasing both rotator

interval and subcoracoid space, to use a 70° lens for a better over-the-top panoramic view, and to retract the anterior deltoid by a switching stick introduced from a percutaneous anterosuperior portal. For danger proximity, we ensure working as lateral as possible while keeping the arm adducted and slightly forward flexed to keep the brachial plexus away and to stay superior within the subscapularis tendinous portion to avoid the axillary nerve. Meticulous attention to details when performing the described surgical technique is essential for success.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: I.W. reports consulting or advisory and speaking and lecture fees from DePuy Mitek, Smith & Nephew, and CONMED Corp and speaking and lecture fees from Bioventus LLC. I.W. is an editorial board member for the *American Journal of Sports Medicine* and *Arthroscopy* and is a board or committee member for AANA, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine, and Arthroscopy Association of Canada. All other authors (J.A., C.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.

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