



Superior Capsule Reconstruction Using an Acellular Dermal Matrix Allograft Combined With Remnant Tendon Augmentation for Irreparable Rotator Cuff Tear

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Abstract: Graft fixation sites on the greater tuberosity and the superior glenoid for superior capsule reconstruction (SCR) are prone to graft failure. The graft fixation procedure on the superior glenoid is challenging due to the limited working space, narrow graft attachment site, and difficulties in suture management. This technical note introduces the surgical technique of SCR using an acellular dermal matrix allograft combined with remnant tendon augmentation to enhance graft healing and the suture management technique to prevent suture tangling for the treatment of irreparable rotator cuff tear.

Introduction

Superior capsule reconstruction (SCR) using an acellular dermal matrix (ADM) allograft is technically demanding and various techniques continue to be introduced because of the lack of a standardized technique. Compared with greater tuberosity graft fixation, difficulties in accessing and inserting grafts in the medial glenoid could result in suture management errors and hinder proper graft fixation.¹ In addition, the narrow bone bed and single-row fixation on the glenoid side lead to a smaller graft-to-bone contact area and contribute to the high medial graft failure rate, ranging from 40.0% to 69.2%.^{2,3}

Various surgical techniques to reduce technical difficulty to enhance graft healing on the glenoid side and to maintain the integrity of the reconstructed superior capsule for satisfactory clinical outcomes after SCR have been introduced.^{4,5} To enhance medial graft healing in SCR using an ADM graft in irreparable rotator cuff tear, we present a devised single-row oblique mattress fixation and remnant rotator cuff augmentation technique using a customized portal divider for managing the suture strands of each suture anchor (Video 1).

Surgical Technique

Arthroscopy Portals

With the patient in the lateral decubitus position after general anesthesia and an interscalene block, the operative arm is placed in 30° abduction, 10° forward flexion, and 30° external rotation. A 30° arthroscope is introduced into the subacromial space through the posterior portal, and a lateral portal is established as the main working portal. Following the subacromial decompression to prevent graft abrasion and to expand the working space, the main viewing portal is created at the posterolateral acromial corner. Through additional small incisions, suture anchors are inserted in the lateral border of the acromion for the greater tuberosity anchors, and in the posteromedial border of the acromion for the posterior glenoid anchor, respectively. The Neviaser portal is created for the anterior glenoid anchor.

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Footprint Preparation

After debridement of degenerative tissues, adhesiolysis around remaining rotator cuff tendons and anterior rotator interval slide are performed (Fig 1). The superior glenoid neck is completely exposed using radio frequency to facilitate medial augmentation, and a burr is used to decorticate the bone bed to facilitate graft to bone healing. The same procedure is repeated for the rotator cuff footprint on the greater tuberosity.

Graft Size Assessment and Preparation

To determine the size of the graft, an arthroscopic ruler is used to measure the anatomical lengths that correspond to the glenoid, articular and the greater tuberosity portion of the graft. For medial augmentation with the remaining tendon, an additional 15-mm length from the superior glenoid surface to the medial margin of the graft is included. The direction of graft insertion and suture points are marked on the graft (Fig 2).

Placement of Suture Anchors on the Glenoid and the Greater Tuberosity

On the glenoid side preceding the greater tuberosity, two double-loaded 4.5-mm suture anchors—one (Healix Advance BR; Depuy Mitek, Raynham, MA) at the insertion of the long head of the biceps tendon on the glenoid neck through the Neviaser portal and the other (Healicoil PK; Smith & Nephew, Andover, MA) the 10 o'clock position through the posteromedial

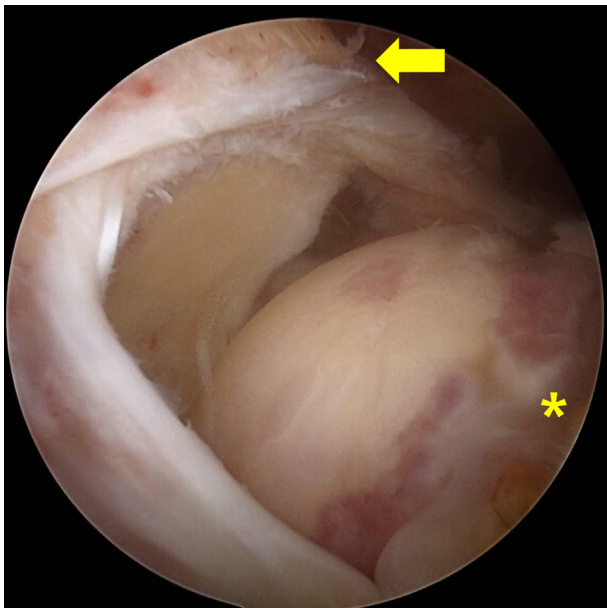


Fig 1. Arthroscopic view of irreparable posterosuperior rotator cuff tear from the posterolateral portal of the right shoulder in the lateral decubitus position. The torn tendon (arrow) was retracted to the glenoid rim and cannot be brought back to the footprint (asterisk).

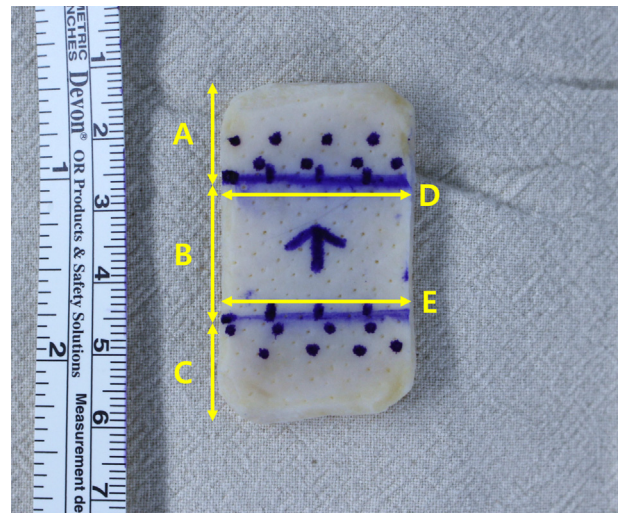


Fig 2. Acellular dermal matrix allograft preparation based on arthroscopic measurements of the tear size. (A) The length of medial portion of the graft, corresponding to superior glenoid neck, is 15 mm. (B) The length from superior glenoid to medial side of footprint of the greater tuberosity. (C) The mediolateral length of the greater tuberosity. (D) The anteroposterior length of superior glenoid. (E) The anteroposterior length of the footprint of the greater tuberosity.

portal—are placed 5 mm medial to the glenoid surface. To secure the graft on the greater tuberosity, two double-loaded 5.5-mm suture anchors for medial row and 2 knotless suture anchors (Multifix; Smith & Nephew, Andover, MA) for lateral row are needed. One suture anchor is placed at the anteromedial margin of the greater tuberosity, and the other suture anchor is placed at the anterior border of the remnant infraspinatus on the cartilage junction.

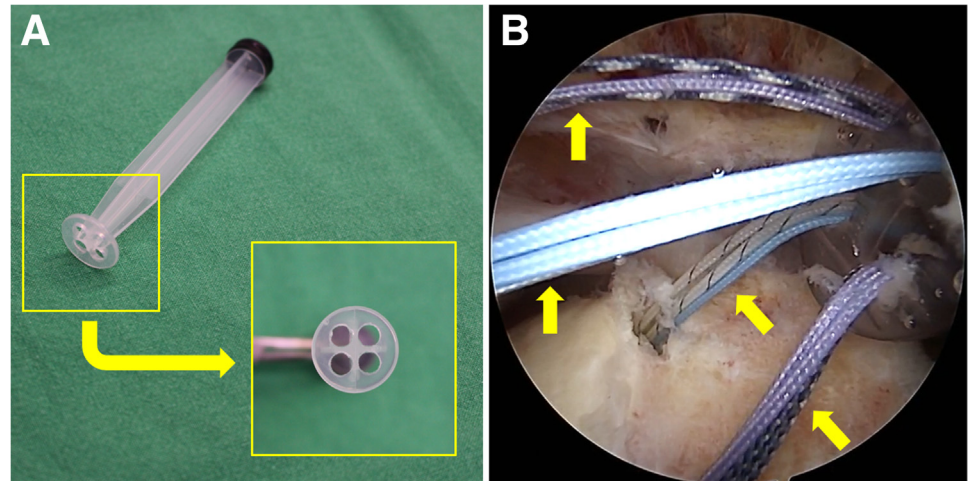
Suture Strand Retrieval

After insertion of suture anchors, all suture strands from the 4 anchors are retrieved through the lateral portal for extracorporeally passing sutures to the graft. To prevent suture entanglement during retrieval, instead of the lateral cannula, we used a customized portal divider that was created by making 4 holes on the lateral end of a plunger of a 5-cc syringe using a 4.0-mm drill bit to temporarily subdivide the main portal into four subportals (Fig 3A). Suture strands of each suture anchor are retrieved through the corresponding quadrant independently to avoid tangling (Fig 3B).

Extracorporeal Suture Management and Graft Preparation

Using an antegrade suture passer or surgical needle, the surgeon retrieves the sutures from each anchor individually through the customized portal divider and passed through the respective premarked site on the graft outside the shoulder in an oblique mattress configuration to increase the graft to bone contact area

Fig 3. Retrieving all suture strands to the lateral portal using the customized portal divider to prevent suture tangling. (A) Customized portal divider made by drilling 4 holes in the lateral end of a 5-cc syringe plunger using 4.0 mm drill bit. (B) Arthroscopic view from the posterolateral portal of the right shoulder in the lateral decubitus position. All suture strands of 4 suture anchors (arrows) are retrieved to outside of body without suture entanglement. There is no suture tangling if one lateral portal is temporarily divided into four lateral portals, and the suture strands of each suture anchor are managed with 4 portals placed in each quadrant.



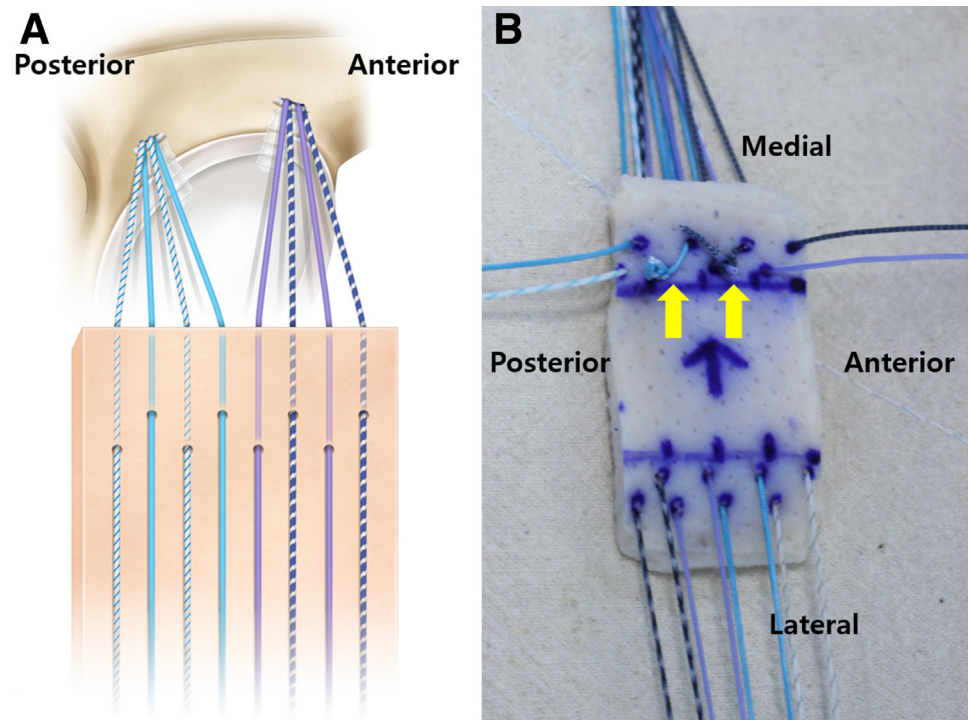
and to secure the gap between the suture strands for prevention of cutting through. On the glenoid side, the different strands from one suture anchor are passed alternately into the graft (Fig 4A). The medial suture pairs of each suture anchor are tightly tied with a square knot by using a dual-pulley technique, wherein the eyelets of each suture anchor function as a single pulley to shuttle the graft into the subacromial space. Following the graft preparation of the glenoid side, the suture strands pass pairwise into the greater tuberosity

aspect of the graft with oblique mattress configuration (Fig 4B).

Graft Insertion Into the Subacromial Space

By simultaneously pulling the free ends of the suture pairs of the glenoid side and pushing the grasper holding medial end of the graft, the graft is inserted into the subacromial space through the lateral portal (Fig 5A). Four suture pairs on the greater tuberosity side maintain tension to facilitate graft sliding (Fig 5B).

Fig 4. Extracorporeal management of sutures on the graft. (A) The configuration of suture passing through the glenoid side of the graft. The different strands from one suture anchor are passed through the graft in pairs in an alternating sequence in oblique mattress configuration. (B) Completion of the extracorporeal suture strands passing process through the graft. On the medial side, two suture strands of each suture anchor become one after tying medial suture pairs of each suture anchor (arrows). The knot of different strands of the same suture anchor makes a suture pair, ensuring that the graft can slide into the shoulder by pulling on free ends of strands. On the greater tuberosity side, suture strands are passed pairwise through the graft with an oblique mattress configuration.



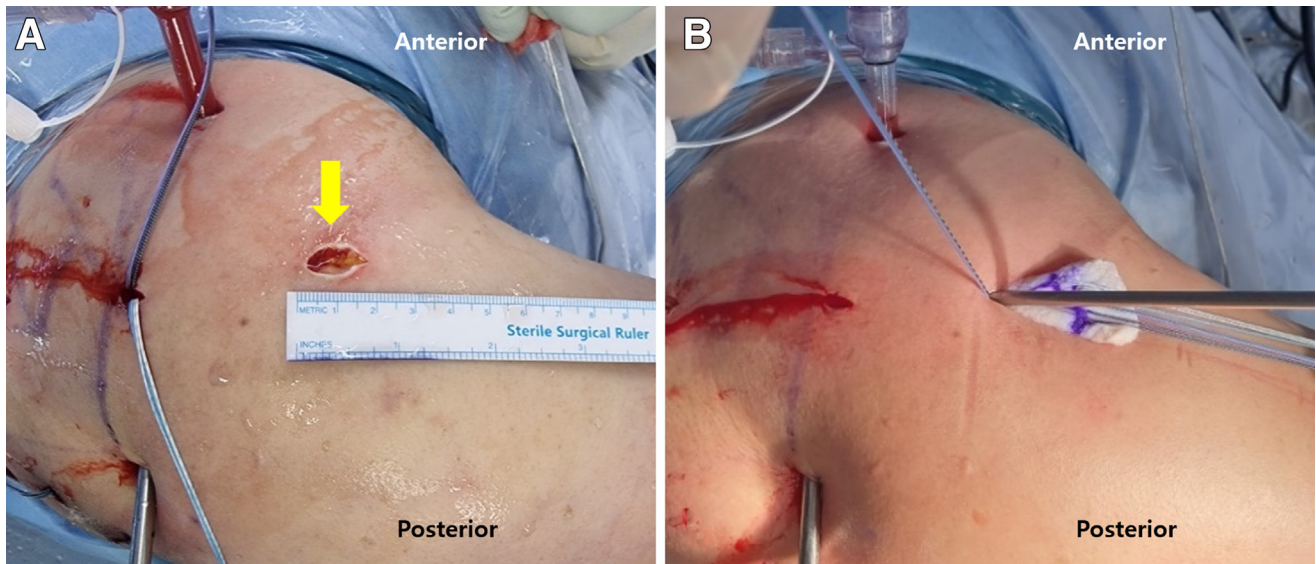


Fig 5. Graft shuttling into the subacromial space of the right shoulder in the lateral decubitus position. (A) The graft is inserted into the subacromial space through the 15 mm-long lateral portal (arrow). (B) To insert the graft into the subacromial space, the free ends of the 2 suture pairs of glenoid side are pulled, and the grasper holding medial end of the graft is used to push the graft through the lateral working portal. Four suture pairs of the greater tuberosity side maintain tension to facilitate graft sliding.

After the graft delivery into the subacromial space, the arthroscope is advanced under the graft to check for any suture tangles or loose strands underneath the graft. Thereafter, the medial side of the graft is inserted into the space between the superior glenoid and the remnant rotator cuff to cover the glenoid side graft by the torn tendon. Then the sutures from the glenoid anchors are tied with a Revo knot, and two pairs of strand remnants are saved for augmentation (Fig 6A). The sutures from the greater tuberosity anchors are tied, and suture bridge fixation is performed using 2 knotless suture anchors (Fig 6B).

Augmentation Using Remnant Cuff Tendon

Following graft fixation, medial augmentation is performed using the remnant sutures of the glenoid side by passing suture strands through the stump of the retracted rotator cuff that covers the graft and tying them with a Revo knot (Fig 7A). Side-to-side suturing between the posterior edge of the graft and the remaining infraspinatus tendon is performed with a free suture strand (Fig 7B). The pearls and pitfalls of each surgical step are summarized in Table 1. Table 2 presents the advantages and disadvantages of this technique.

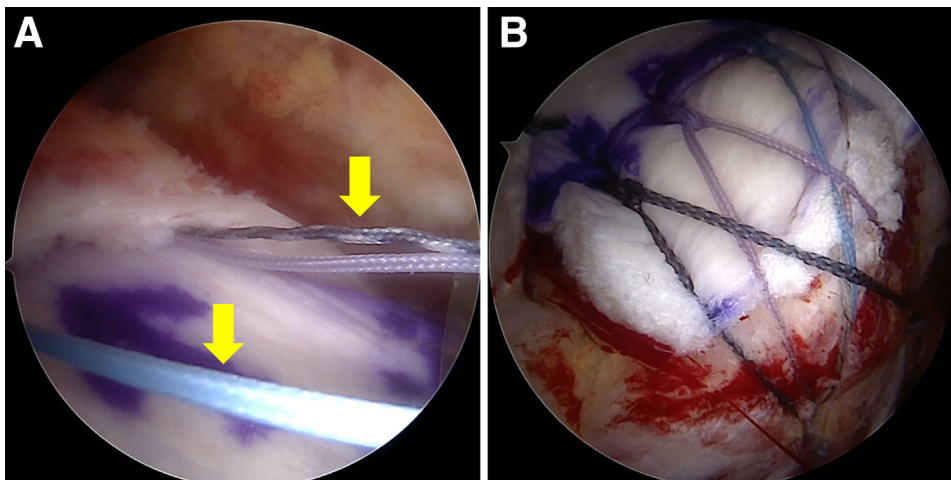
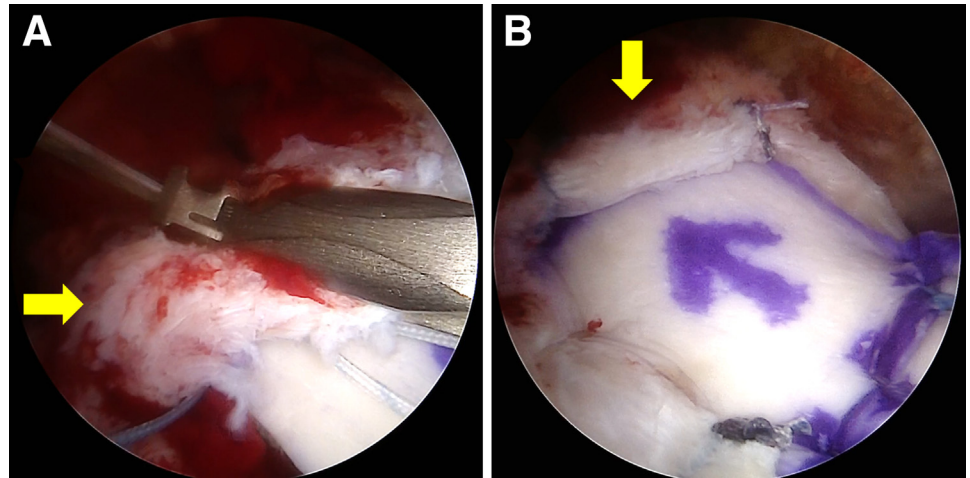


Fig 6. Arthroscopic view from the posterolateral portal of the right shoulder in the lateral decubitus position. Graft fixation on glenoid and greater tuberosity sides. (A) Graft fixation on the glenoid side. After the sutures from the glenoid anchors are tied, a pair of strand remnants (arrows) are saved for augmentation using the remaining tendon. (B) Suture bridge fixation of the graft on the greater tuberosity side.

Fig 7. Arthroscopic view from the posterolateral portal of the right shoulder in the lateral decubitus position. Augmentation using medial remnant rotator cuff. (A) The remnant strand after tying sutures of the glenoid side is passing through medial remnant rotator cuff (arrow) over the graft using antegrade suture passer. (B) Final structure of superior capsule reconstruction using an acellular dermal matrix allograft. Medial augmentation using remnant rotator cuff tendon covering on the glenoid side graft (arrow).



Discussion

Graft fixation on the glenoid side constitutes one of the most challenging steps during SCR.¹ Glenoid side fixation was performed previously using single-row fixation, mainly with a double-pulley technique.^{5,6} However, the graft to bone contact area that was created between the two anchors on the glenoid side was smaller than that created by suture bridge fixation on the greater tuberosity, which increased vulnerability to graft failure when mediolateral tension was applied to both the glenoid and greater tuberosity aspects.

Therefore, we preferred single-row oblique mattress configuration to enhance glenoid side graft healing, and the dual-pulley technique for easy and secure graft insertion into the subacromial space. Oblique mattress sutures widened the graft to bone contact area and facilitated an increased number of sutures and a wider gap between the stitches.⁷

Compared with the graft area on the greater tuberosity, the smaller 5-mm suture graft margin gap of the glenoid side may contribute to pullout strength, as demonstrated in recent biomechanical studies.^{8,9}

Table 1. Surgical Steps With Pearls and Pitfalls

Surgical Steps	Pearls	Pitfalls
Footprint preparation	Medial remnant rotator cuff tissue should be preserved for medial augmentation.	Medial dissection of remnant rotator cuff tissue could injure the suprascapular nerve.
Graft size assessment and graft preparation	Long-tailed medial side of the graft enlarges graft to bone contact area and prevents cutting through of the graft.	Overestimation of length from the glenoid surface to medial side of the footprint of the greater tuberosity could result in tension mismatch of the graft.
Placement of suture anchors on the glenoid and the greater tuberosity aspects	Using suture anchors with different colors of suture strands makes suture management easier.	Suture anchor insertion entry on the glenoid side should be placed at 5 mm medial from the articular surface, and the direction of suture anchor insertion should be toward medial side to avoid intra-articular penetration.
Retrieval of suture strands	Suture strands are retrieved in the corresponding quadrant of each suture anchor via isolated holes of a customized portal divider to ensure that sutures are not tangled during retrieval and passing of the graft.	The position of the portal divider should be maintained while passing the sutures through the graft to prevent the sutures of each anchor from twisting.
Extracorporeal management of sutures and graft preparation	Passing sutures in single row oblique mattress configuration to enlarge graft to bone contact area Make 2 suture pairs of each suture anchor of glenoid side become a pair to use dual-pulley technique to shuttle the graft into the subacromial space.	Care should be taken not to entangle the strands from different anchors when transferring the strands from the portal divider to the graft. The knot should be tied firmly in dual-pulley technique. Failure of square knot-tying results in the graft fixation failure after the graft insertion in the subacromial space.
Augmentation using medial remnant rotator cuff	The antegrade suture passer can be used to penetrate the suture through the graft in the subacromial space.	Additional time is needed for medial augmentation and the technically demanding procedure in a limited space.

Table 2. Advantages and Disadvantages

Advantages

- Single row oblique mattress configuration provides firm graft fixation on the glenoid side.
- Dual pulley technique is used for easy and secure insertion of the graft into the subacromial space.
- Long tail of the graft on the glenoid side prevents cutting through and enlarges graft to bone contact area.
- Augmentation using medial remnant rotator cuff tendon to enhance biological healing response of the graft
- Customized portal divider prevents suture entangling while maintaining the number of sutures passing through the graft.
- Passing all sutures extracorporeally reduces operation time and simplifies procedures.

Disadvantages

- Relatively complicated procedure than simple single row graft fixation
- Longer operation time while passing increased number of sutures of the glenoid side
- Making a long tail could be difficult if an acellular dermal matrix allograft of the appropriate size is unavailable.
- Bone bed preparation on the glenoid side may be difficult due to the remnant posterosuperior rotator cuff.
- Extracorporeal procedure can potentially increase the incidence of postoperative infection.

Therefore, cutting through the graft may occur more frequently on the glenoid side, which has a shorter border, than that of the greater tuberosity. With the proposed technique, the long tail of the graft on the glenoid side prevented graft failure at the suture graft interface and enlarged the graft to bone contact area. Soft tissue augmentation using the remaining rotator cuff tendon to enhance the biological healing response to the ADM also provided a biologic scaffold for graft bone healing and increased the strength of the reconstructed superior capsule.¹⁰

Suture management is another challenging procedure of SCR, and preventing suture tangling is key to success in SCR. Various techniques, such as tightening sutures during retrieval and reducing the number of sutures passed through the graft before the graft insertion into the subacromial space, have been introduced.^{5,8} However, when the sutures are passed through the graft after the graft insertion, it is difficult to secure a working space, and pass the sutures through thick graft tissue using the suture passer. Therefore, we proposed the technique that reduces the chances of suture entangling when multiple anchors are retrieved through one portal, while maintaining the number of sutures and passing all sutures extracorporeally through the graft. The main reason for suture tangling was that suture strands from multiple anchors were retrieved through one portal that has the chance to cross the sutures inside the portal. In this our technique, one lateral portal was temporarily divided into four portals with a customized portal divider comprising a 5-cc syringe, and sutures from each quadrant were

managed independently without intraportal crossing of sutures to the point corresponding to the graft, thereby simplifying the surgical procedure.

Conclusion

SCR using ADM combined with remnant rotator cuff augmentation enhances firm graft fixation of the glenoid side. Long tail of graft at the glenoid side increased the graft to bone contact area and a customized portal divider prevented suture tangling.

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