



Anatomical Dermal Allograft and Autologous Biceps Long Head Superior Capsule Reconstruction for Irreparable Posterosuperior Rotator Cuff Tears

Chih-Hao Chiu, M.D., Ph.D., Chun-Jui Weng, M.D., Hao-Che Tang, M.D., Cheng-Pang Yang, M.D., Shih-Sheng Chang, M.D., Kuo-Yao Hsu, M.D., and Alvin Chao-Yu Chen, M.D.

Abstract: Superior capsule reconstruction (SCR) can be performed using fascia lata, dermal allograft, and long head of the biceps tendon (LHBT). We present a Technical Note combining dermal allograft and autologous LHBT, reconstructing the superior capsule's actual anatomical thickness and augmenting with single-stranded LHBT. The glenoid side consists of intact LHBT insertion and is covered with dermal allograft. The lateral side comprises posteriorly transpositioned LHBT, dermal allograft, and repairable remnant cuff. First, 1 suture-based anchor is used to fix the biceps 5 to 8 mm posterior to the bicipital groove, and tenotomy is done distal to it, while the glenoid side of the biceps is preserved. Second, 2 suture-based anchors are used to fix the dermal allograft at the glenoid side by 1 double-pulley and 2 mattress sutures. Third, 2 SwiveLock anchors are used to fix allograft's lateral side by 2 reverse mattress sutures. The tension and coverage of the graft can be determined by the position of the SwiveLock anchors. In this way, fewer anchors are needed than the conventional dermal allograft SCR and larger footprint coverage can be achieved than LHBT SCR. A better spacer effect may be achieved by combining both biological grafts' thickness, mimicking the intact shoulder's true anatomy.

Superior capsule reconstruction (SCR) was first introduced using fascia lata,¹ continuously evolving with dermal allograft,² and long head of the biceps tendon (LHBT),³ with different thicknesses, configurations, and related biomechanical properties.^{1,4-6} We propose a technical modification combining dermal allograft and autologous LHBT, reconstructing the superior capsule's actual anatomical thickness, and augmenting with single-stranded LHBT. The glenoid

side consists of intact LHBT insertion and is covered with dermal allograft. The lateral side comprises the posteriorly transpositioned LHBT, dermal allograft, and repairable remnant cuff.

Table 1. The Indications and Contraindications for an Arthroscopic Anatomical Dermal Allograft and Autologous LHBT SCR

Indications	Contraindications
Irreparable posterosuperior massive rotator cuff tears with Hamada stage 2 or less	Irreparable posterosuperior massive rotator cuff tears with Hamada stage 3 or greater
The supraspinatus tendon is intraoperatively irreducible (Patte stage III)	Significant glenoid or humerus bone defects
Preoperative good active and passive range of motion without external rotation lag sign, pseudoparalysis, or pseudoparesis	Absence of deltoid, latissimus dorsi, or pectoralis function
Goutallier stage 3 or 4 muscle fatty infiltration	Absent LHBT
Existing LHBT	Shoulder stiffness

LHBT, long head of the biceps tendon; SCR, superior capsule reconstruction.

From the Department of Orthopedic Surgery, Chang Gung Memorial Hospital, Taoyuan (C.-H.C., S.-S.C.); Bone and Joint Research Center (C.-H.C., C.-J.W., H.-C.T., C.-P.Y., S.-S.C., K.-Y.H., A.C.-Y.C.) and Department of Orthopedic Surgery (C.-J.W., C.-P.Y., K.-Y.H., A.C.-Y.C.), Chang Gung Memorial Hospital, Linkou; and Department of Orthopedic Surgery, Chang Gung Memorial Hospital, Keelung (H.-C.T.), Taiwan.

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Address correspondence to Chih-Hao Chiu, M.D., Ph.D., Department of Orthopedic Surgery, Chang Gung Memorial Hospital, Taoyuan, Taiwan. E-mail: joechiu0115@gmail.com

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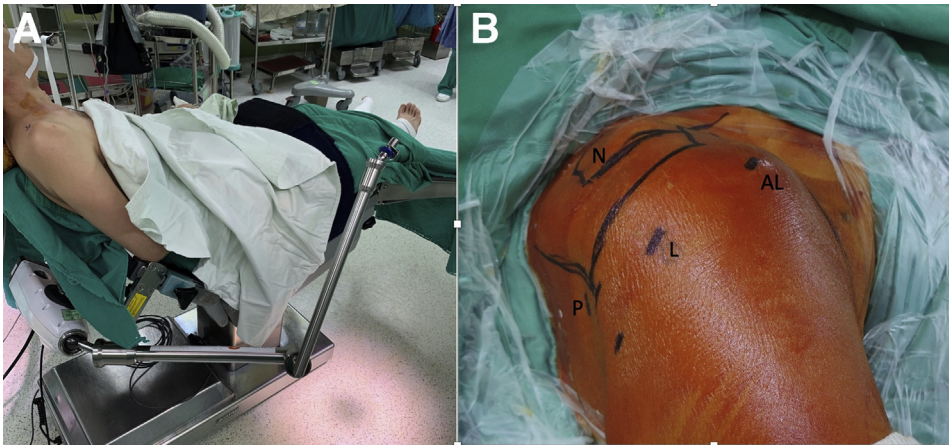


Fig 1. Patient position and arthroscopic portals, right shoulder. (A) All patients had general anesthesia with interscalene nerve block and were placed in the beach-chair position with a traction device. (B) Normally 4 arthroscopic portals are needed. (AL, anterolateral portal; L, lateral portal; N, Neviaser portal; P, posterior portal.)

Operative Technique (With Video Illustration)

Patient Preparation and Arthroscopic Portals

The indications and contraindications for an arthroscopic anatomical dermal allograft and autologous

LHBT SCR are listed in [Table 1](#). All patients receive general anesthesia with interscalene nerve block and are placed in the beach-chair position with a traction device ([Fig 1A](#)). Normally, 4 arthroscopic portals are necessary: posterior, lateral, anterolateral, and Neviaser ([Fig 1B](#)). If the subscapularis is torn and needs

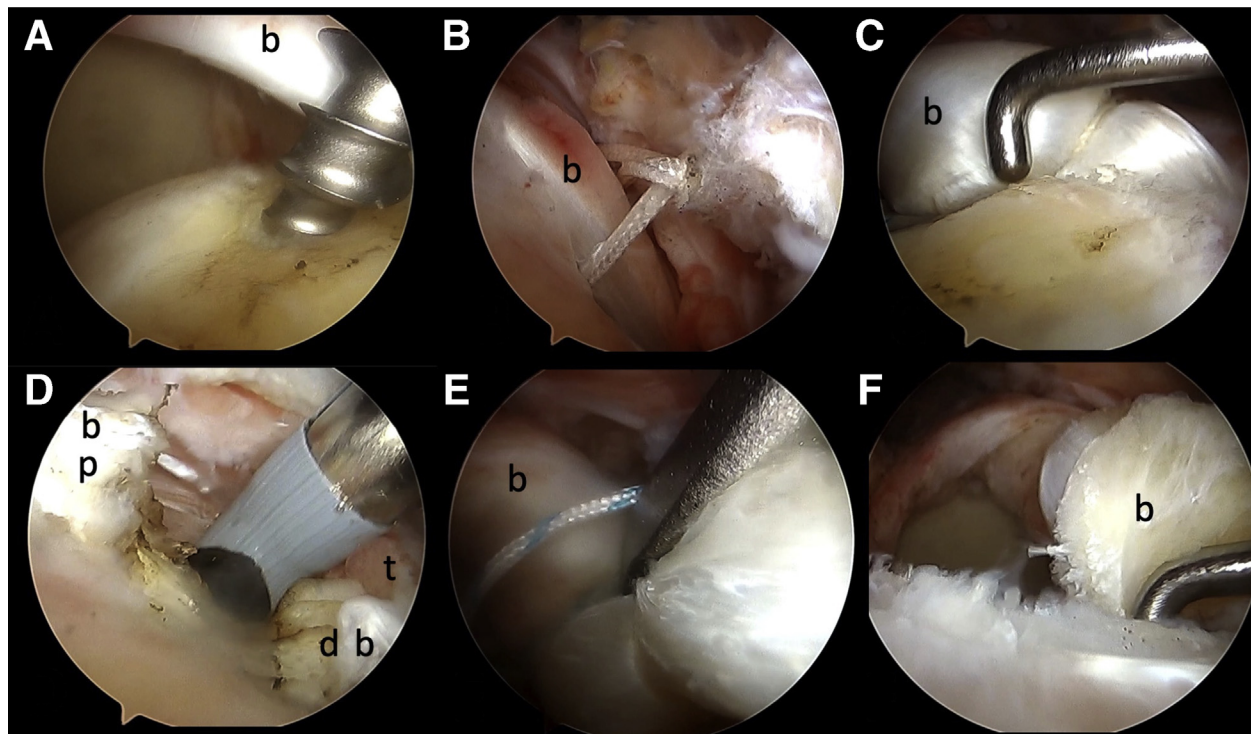
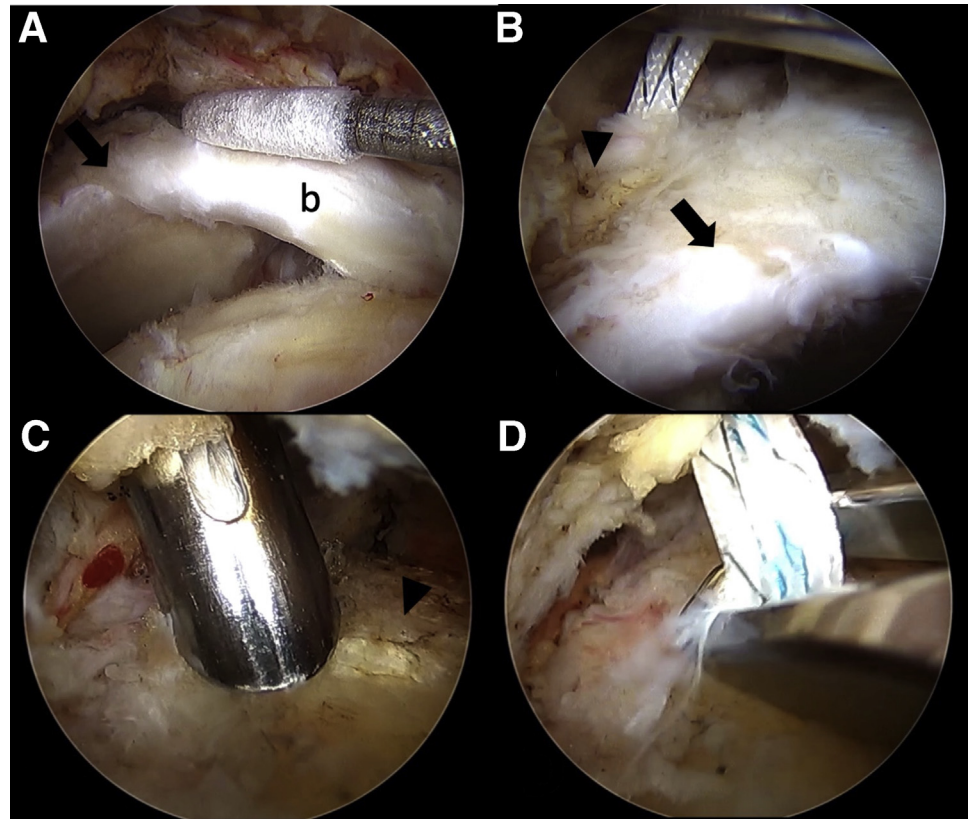


Fig 2. Superior capsule reconstruction with long head of the biceps. Viewing from lateral portal, right shoulder. (A) A suture-based anchor is passed from anterolateral portal and inserted 5-8 mm posterior to the bicipital groove, and near the cartilage of humerus. (B-C) One lasso-loop is made and fixed provisionally. (D) A radiofrequency cauterity device is used to cut the fixed biceps tendon at the entrance of the bicipital groove as biceps tenotomy, keeping the integrity of transverse humeral ligament. (E) Tension of the LHBT can be made by penetrating the intra-articular LHBT in a more medial position by the second and third lasso-loop. (F) The proximal attachment of the biceps on the glenoid side is preserved, providing the native fixation. The lateral part of the LHBT is rerouted posteriorly, proving a strong spacer effect. (b, biceps; d, distal part of biceps; LHBT, long head of the biceps tendon; p, proximal part of biceps; t, transverse ligament.)

Fig 3. Glenoid preparation and anchor placement. Viewing from lateral portal, right shoulder. (A) The intra-articular biceps tissue on the glenoid side is preserved. (B) The anterosuperior glenoid anchor is placed at the coracoid base, just anteromedial to the origin of the LHBT. The posterosuperior glenoid anchor is placed at the posteromedial margin of the glenoid. (C) Double-loaded, all suture anchors (1.8-mm Y-Knot Flex; CONMED Linvatec) are preferred because of their flexibility during introduction into the glenohumeral joint. (D) All sutures from the 2 glenoid anchors are shuttled to the anterolateral portal for further usage. Arrow, superior labrum; Arrow-head, glenoid. (b, biceps; LHBT, long head of the biceps tendon.)



to be repaired, an additional anterior portal will be made.

SCR With LHBT

Viewing from lateral portal, a double-loaded or triple-loaded suture-based anchor is passed from anterolateral portal and inserted 5 to 8 mm posterior to the bicipital groove and near the cartilage of humerus (Fig 2A). We use a suture manipulator and Cuff Hook (Stryker, San Jose, CA) to perform 2 or 3 “lasso-loop” (Fig 2 B and C) according to the type of anchor used.¹ In brief, one lasso-loop is made first. Then, the radio-frequency cautery device is used to cut the fixed biceps tendon at the entrance of the bicipital groove (Fig 2D) as biceps tenotomy, keeping the integrity of the transverse humeral ligament. No further tenodesis is performed regarding the distal part of the LHBT. The other sutures of the anchor will be used to finish the second and third lasso-loop. Tension of the LHBT can be made by penetrating the intra-articular LHBT in a more medial position by the second and third lasso-loop (Fig 2E). Finally, the proximal attachment of the biceps on the glenoid side is preserved, providing the native fixation. The lateral part of the LHBT is rerouted posteriorly, proving a strong spacer effect (Fig 2F).²

Glenoid Preparation and Anchor Placement

The bone bed on the superior glenoid is prepared to a bleeding surface. Care must be taken to preserve the proximal attachment of the LHBT on the glenoid, which is close to the native capsular attachment site. Unlike Burkhart et al.,³ who debrided and removed most of the meaningful bone attachments of the LHBT on the glenoid and created an unstable biceps root, the idea of the current technique is to maintain the intra-articular biceps tissue along with a dermal allograft, which will be covered on top of the intra-articular biceps autograft (Fig 3A). The anterosuperior glenoid anchor is placed at the coracoid base, just anteromedial to the origin of the LHBT. The posterosuperior glenoid anchor is placed at the posteromedial margin of the glenoid (Fig 3B). Both anchors are placed 3 mm medial to the corner of the glenoid to optimize the contact area between graft and bone and not penetrate the articular surface. Yet, they have to be lateral enough to avoid jeopardizing the suprascapular nerve. We use a Neviaser portal to introduce 2 anchors on the glenoid side. Double-loaded, all-suture anchors (1.8-mm Y-Knot Flex; CONMED Linvatec, Largo, FL) (Fig 3C) are preferred because of their flexibility during introduction into the glenohumeral joint. All sutures from the 2 glenoid

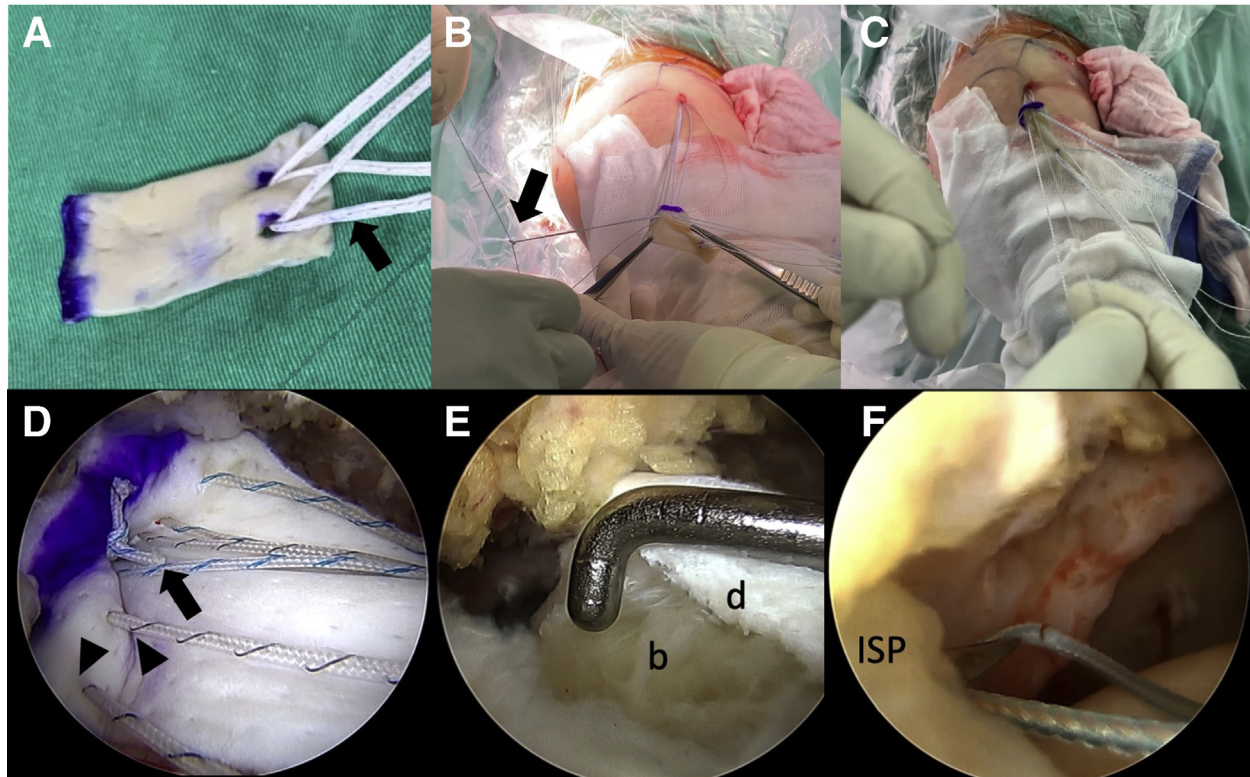


Fig 4. Preparation, shuttling, and fixation of the dermal allograft, right shoulder, viewing from lateral portal. (A) Two FiberTapes (Arthrex) are first retrieved from 2 SwiveLock C anchors, providing 2 reverse mattress sutures (arrow). (B) One double-pulley suture construct and 2 mattress sutures are made on the medial side of the dermal allograft from the sutures of the 2 glenoid anchors outside the joint (arrow). (C) The graft and all sutures are introduced into subacromial space by pulling the free ends of the 2 suture pairs of double-pulley until it touches the glenoid beds. (D) Viewing from lateral portal, 6-throw surgeon's knots are made both for the double-pulley construct (arrow) and the 2 mattress sutures (arrowheads). (E) The combination of biceps and dermal allograft provides a thick biological spacer in the subacromial space. (F) The No. 2 FiberWire sutures from 2 SwiveLock anchors are used to repair the torn infraspinatus. (b, biceps; d, dermal allograft; ISP, infraspinatus.)

anchors are then shuttled to the anterolateral portal for further usage (Fig 3D).

Dermal Allograft Preparation

The size of the decellularized dermal allograft (LifeNet Health OrACELL, Virginia Beach, VA) is 2×4 cm with a thickness of 1.26 to 1.75 mm. A calibrated probe is used to measure the size of the defect spanning from the medial-to-lateral as well as anterior-to-posterior the distance between each pair of suture anchors. The graft is not cut, trying to provide as much soft-tissue coverage as possible. Four anchors (2 double-loaded anchors at glenoid side, and 2 BioComposite SwiveLock C anchors [Arthrex, Naples, FL] at greater tuberosity) are used to fix the dermal allograft. Two FiberTapes (Arthrex) are first retrieved from 2 SwiveLock C anchor, providing 2 reverse mattress sutures (Fig 4A).

Shuttling and Fixation of the Dermal Allograft

Before the dermal allograft is introduced into the glenohumeral joint, 2 glenoid anchors are placed as mentioned previously. Unlike the technique proposed

by Burkhart et al.,³ no medial row anchors are used in this technique. Instead, we use the SpeedFix method (Arthrex), avoiding too many anchors in the supraspinatus footprint's entheses. First, one double-pulley suture construct and 2 mattress sutures are made on the medial side of the dermal allograft from the sutures of the 2 glenoid anchors outside the joint (Fig 4B). The double-pulley suture will be used to bring the graft into the subacromial space. Second, the graft and all sutures (1 double-pulley and 2 mattress sutures medially, and 2 reverse mattress sutures with FiberTape laterally) are introduced into subacromial space by pulling the free ends of the 2 suture pairs of double-pulley until it touches the glenoid beds (Fig 4C). Once the graft is in contact with the superior glenoid, the 6-throw surgeon's knot will be made by the knot pusher both for the double-pulley construct and the 2 mattress sutures (Fig 4D). Third, after 2 sockets are punched into the anterolateral and posterolateral greater tuberosity, the reverse mattress sutures are tensioned, and 2 SwiveLock anchors are placed into the bone socket fixing the sutures and graft. This completes the SpeedFix configuration on

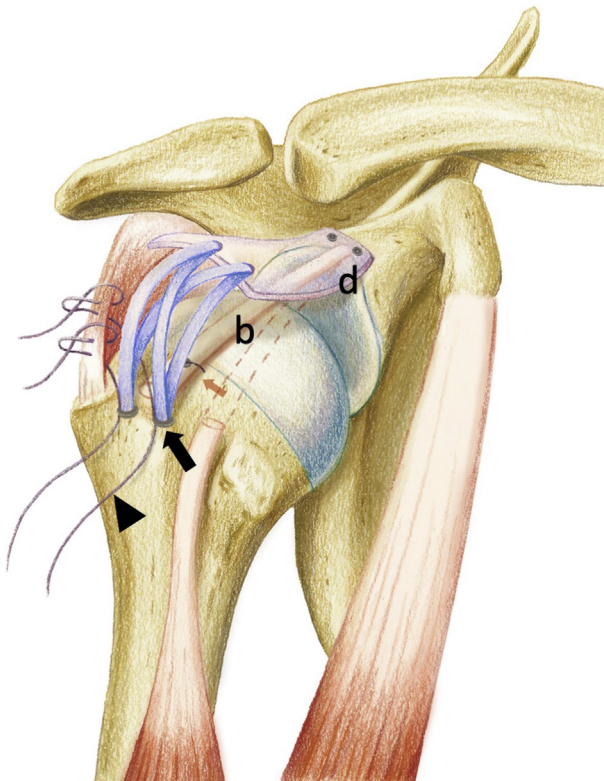


Fig 5. The final construct of anatomical dermal allograft and autologous biceps long head superior capsule reconstruction for irreparable posterosuperior rotator cuff tears, right shoulder. Two suture-based anchors are placed in the glenoid side to fix the medial border of the dermal allograft. One suture-based anchor is placed 5-8 mm posterior to the bicipital groove to fix the biceps as superior capsule reconstruction with the long head of the biceps. Two SwiveLock C anchors are used to fix the lateral part of the dermal allograft by fixing the 2 reverse mattress sutures (FiberTape, blue). Two No. 2 sutures from the SwiveLock C anchors can be used to repair the infraspinatus. (orange arrow, suture-based anchor used for biceps SCR; blank arrow, SwiveLock C anchor used to fix dermal allograft with FiberTape suture; arrowhead, FiberWire suture from SwiveLock C anchor, used to fix infraspinatus. (b, biceps; d, dermal allograft.)).

the lateral tuberosity. In this technique, the graft's tension and coverage can be determined by the position of the 2 SwiveLock anchors. Normally, the posterior rerouted biceps tendon is now beneath the reconstructed dermal allograft. The combination of biceps and dermal allograft provides a thick biological spacer (the thickness of the biceps plus dermal allograft, Fig 4E) in the subacromial space. Fourth, the remaining No. 2 FiberWire sutures (Arthrex) from 2 SwiveLock anchors can be used to repair the torn infraspinatus or partially repair supraspinatus with lasso-loop⁴ stitches (Fig 4F). The infraspinatus tendon is not repaired with the dermal allograft's posterior margin to prevent overtension of the graft and surrounding tissues. In general, the infraspinatus tendon will cover above the dermal allograft

after fixing the lasso-loop sutures. The final construct is shown in Figure 5. The whole surgical procedure is shown in Video 1. The pearls and pitfalls of the surgical steps are shown in Table 2. The advantages, risks, and limitations of this technique are shown in Table 3.

Discussion

The optimal graft choice of SCR is still controversial because of the potential donor-site morbidity, graft reactions, graft failures, and complex techniques.⁵ The advantages of autologous fascia lata SCR⁶ are the cost and thickness of the introduced graft. However, the thicker the graft, the more complex the surgical technique. Six suture anchors and a graft 6 to 8 mm thick are warranted for favorable outcomes. A Pass-Port cannula (Arthrex) or 10-mL syringe is needed to insert the graft into the subacromial space, causing additional cost and bigger wounds.⁷ The advantages of dermal allograft SCR³ are no donor-site morbidity and easier to introduce the thinner graft (from 1 to 3 mm).⁸ However, 6 anchors are still mandatory, and graft failures are common on the glenoidal side in allografts than with autografts.⁵ The other trend toward augmenting the massive irreparable rotator cuff using the autologous LHBT as a graft for SCR is appealing because it is available locally and free of additional costs, is less technically demanding, and provides an average thickness of LHBT comparable with the fascia lata graft. Another potential advantage of using the proximally attached LHBT is its remaining biological viability, which could avoid glenoidal graft failure and improve healing at the interface between the graft and the incorporated remnant rotator cuff.⁹

However, the quality of LHBT is not always adequate to provide a sufficient "spacer effect" because it is frequently absent or seriously degenerated in cases of chronic irreparable rotator cuff tears.¹⁰ Therefore, we developed a modified technique using both dermal allograft and LHBT to recreate a superior capsule. It may provide a better spacer effect by combing the thickness of LHBT and dermal allograft together. Fewer anchors are needed than a conventional dermal allograft. It also provides better footprint coverage than LHBT SCR alone. The glenoidal part of LHBT is preserved and will be covered by the glenoid part of the dermal allograft above. As the healing within homogeneous tissues (bone-to-bone or tendon-to-tendon) shows better healing quality than that taking place between the heterogeneous tissues (bone-to-tendon),¹¹ this technique provides less failure both in the glenoidal and humeral side. In conclusion, we developed a technique to provide dermal allograft and LHBT SCR at the same time, with fewer anchors needed than conventional dermal allograft SCR and larger footprint coverage than LHBT SCR. A better spacer effect may be

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

Surgical Steps	Tips and Pearls	Pitfalls
Arthroscopic portals	<ol style="list-style-type: none"> 1. Four arthroscopic portals: posterior, lateral, anterolateral, and Neviasser. 2. An additional anterior portal is needed for subscapularis repair. 	<ol style="list-style-type: none"> 1. Normally, the cannulae is not needed because of the thin graft.
SCR with LHBT	<ol style="list-style-type: none"> 1. Viewing from the lateral or posterior portal. 2. A double-loaded or triple-loaded, suture-based anchor is passed from the anterolateral portal and inserted 5-8 mm posterior to the bicipital groove near the cartilage of the humerus. 3. One lasso-loop is made by a suture manipulator and cuff Hook. 4. The radiofrequency cautery device is used to cut the fixed biceps tendon at the entrance of the bicipital groove as biceps tenotomy. 5. Tension of the LHBT can be made by penetrating the intra-articular LHBT in a more medial position by the second and third lasso-loop. 6. The proximal attachment of the biceps on the glenoid side is preserved, providing the native fixation. 7. The lateral part of the LHBT is rerouted, proving a strong spacer effect. 	<ol style="list-style-type: none"> 1. Be careful not to cut the sutures by the radiofrequency cautery device when doing the biceps tenotomy.
Glenoid preparation and anchor placement	<ol style="list-style-type: none"> 1. The bone bed on the superior glenoid is prepared to a bleeding surface by an electrocautery ablation and a motorized shaver blade. 2. A Neviasser portal is used to introduce 2 anchors on the glenoid side. 3. The anterosuperior glenoid anchor is placed at the base of the coracoid, just anteromedial to the origin of the LHBT. 4. The posterosuperior glenoid anchor is placed at the posteromedial margin of the glenoid. 5. All sutures from the 2 glenoid anchors are shuttled to the anterolateral portal for further usage. 	<ol style="list-style-type: none"> 1. The proximal attachment of the LHBT on the glenoid should be preserved to avoid an unstable biceps root. 2. Both anchors should be placed 3 mm medial to the corner of the glenoid, preventing penetrating the articular surface.
Dermal allograft preparation	<ol style="list-style-type: none"> 1. A decellularized dermal allograft is used. 2. The graft is not cut, trying to provide as much soft tissue coverage as possible. 3. Two FiberTapes are retrieved from 2 SwiveLock C anchors, providing 2 reverse mattress sutures. 	<ol style="list-style-type: none"> 1. Be careful not to cut the thin dermal allograft when passing the 2 reverse mattress sutures with FiberTape.
Shuttling and fixation of the dermal allograft	<ol style="list-style-type: none"> 1. One double-pulley and 2 mattress sutures are made on the medial side of the dermal allograft. 2. The graft and all sutures are introduced into subacromial space by pulling the free ends of the 2 suture pairs of double-pulley. 3. A 6-throw surgeon's knot will be made both for the double-pulley construct and the 2 mattress sutures. 4. The reverse mattress sutures are tensioned and fixed with 2 SwiveLock anchors at the greater tuberosity. 5. The combination of biceps and dermal allograft provides a thick biological spacer in the subacromial space. 6. No. 2 FiberWire sutures from 2 SwiveLock anchors can be used to repair the torn infraspinatus with simple or lasso-loop stitches. 	<ol style="list-style-type: none"> 1. Tension of all sutures should be maintained when introducing the graft into the joint to prevent suture strangulation. 2. The infraspinatus tendon is not repaired with the posterior margin of the dermal allograft to prevent over-tension of the graft and surrounding tissues.

LHBT, long head of the biceps tendon.

Table 3. Advantages, Risks, and Limitations of Anatomical Dermal Allograft and Autologous Biceps Long Head SCR for Irreparable Posterosuperior Rotator Cuff Tears

Advantages	<ol style="list-style-type: none"> 1. Easier introduction of dermal allograft than thick fascia lata. 2. Fewer anchors needed. 3. Treat biceps lesion simultaneously with dermal allograft SCR. 4. Provides a better spacer effect by combing the thickness of dermal allograft and biceps long head. 5. Less donor-site morbidity than fascia lata. 6. Better footprint coverage than LHBT SCR alone 7. Healing within homogeneous tissues (proximal biceps insertion and dermal allograft) shows better healing quality than that taking place between the heterogeneous tissues (bone-to-tendon) 8. More anatomical reconstruction of the rotator cable.
Risks	<ol style="list-style-type: none"> 1. Overtension of the dermal allograft and the surrounding tissues. 2. Popeye deformity of the forearm after biceps tenotomy. 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	<ol style="list-style-type: none"> 1. No full reconstruction of the footprint. 2. Possible degenerated biceps tendon. 3. Extensive arthroscopic technique. 4. Further clinical and radiologic follow-up should be done.

LHBT, long head of the biceps tendon; SCR, superior capsule reconstruction.

achieved by combining both biological grafts' thickness, mimicking the true anatomy of the intact shoulder.

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