Technical Note

Arthroscopic Superior Capsular Reconstruction Using "Sandwich" Patch Technique for Irreparable Rotator Cuff Tears

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Abstract: The technique of superior capsular reconstruction (SCR) using fascia lata autograft, described by Mihata et al. in 2012, has been an acceptable and effective method for treating irreparable massive rotator cuff tears, especially in cases with severe fatty infiltration and tendon retraction. After the SCR procedure of Mihata et al., it was found that some graft failure occurred with thinning and elongation during the follow-up time, which was called graft "creep." To avoid graft creep and reduce graft failure rates after SCR, we created an arthroscopic SCR technique with a "sandwich" patch augmented with polyethylene terephthalate scaffold interspaced between 2 folded layers of fascia lata autograft.

The treatment of irreparable rotator cuff tears has remained a challenge in recent years because of severe fatty infiltration[1] and tendon retraction,[2] which result in inferior outcomes or surgical failure. Several surgical techniques have been described to restore the function of the rotator cuff for massive ruptures, for example, the partial repair technique,[3] latissimus dorsi transfer,[4] long head of the biceps tendon transfer[5] ("the Chinese way"), reverse total arthroplasty,[6] and the bridging patch technique.[7] However, with further understanding of the anatomy[8,9] and biomechanics[10] of the superior capsule of the shoulder joint, an increasing number of researchers have shown that the superior capsule plays a critical role in the superior stability of the humeral head, and superior capsular reconstruction (SCR)[11-13] or even SCR accompanied by rotator cuff repair[14] is the preferable choice for irreparable rotator cuff tears to restore the superior stability of the humeral head.

SCR has been an acceptable option in recent years for the treatment of irreparable rotator cuff tears, in which a graft (fascia lata autograft[14] or dermal patch[15]) is placed between the superior glenoid and humeral greater tuberosity to restore superior glenohumeral joint stability. Short-term clinical outcomes are encouraging, restoring superior stability, as reported by Mihata et al.[10] and Denard et al.[13] The ideal thickness of the fascia lata autograft is 8 mm rather than 4 mm.[16]

However, short-term graft failure exists using either fascia lata or dermal patch, with reported rates of 4.2%,[14] 18.6%,[13] and 55%.[17] The long-term prognosis of the new bone-graft-bone structure made by SCR is of concern and requires further research. As we know, the healing rate for arthroscopic fixation of the rotator cuff to the footprint is not optimal[18-20] because of lack of blood supply, fatty infiltration, tear size, old age, and other reasons.[21,22] On the basis of our experience and knowledge, these conditions may lead to creep of the graft and, likewise, the bone-graft-bone structure in anterior cruciate ligament reconstruction[23] and eventually to functional failure of the graft.

Polyethylene terephthalate (PET) has high tensile strength with linear stress-strain and can resist forces of up to 3,000 N. It has been used successfully in the knee and shoulder in augmentation reinforcement systems (LARS; Corin Group, Cirencester, England) with promising long-term outcomes.[24,25] PET is a nonabsorbable, biocompatible material with little

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tissue irritability and has excellent affinity for bone and tendon. The use of PET scaffold in an interposition technique for the treatment of irreparable rotator cuff tears has been reported by Nada et al.[26] with optimal short-term outcomes.

Therefore, considering the graft thickness, transformation of graft creep, and graft strength, we created a patch graft for SCR augmented with PET scaffold interspaced between 2 folded layers of fascia lata autograft and called it the "sandwich" patch graft. The manufacturing process for the sandwich patch and our surgical technique are described in this article.

Preoperative Evaluation and Surgical Indications

All selected patients have undergone conservative therapy, including medication treatment and intra-articular steroid injections, with ineffective results before surgical treatment and have persistent pain and weakness. Evaluation by magnetic resonance imaging (MRI) and radiographs in the planes of the anteroposterior view and scapular Y view shows a full-thickness, massive rotator cuff tear. The inclusion criteria are an irreparable rotator cuff in which the tendon cannot reach the original footprint, evaluated as grade III by the Patte classification[27] during arthroscopy, with or without a partial- or full-thickness tear of the infraspinatus or subscapularis that is repairable. The exclusion criteria include glenohumeral arthritis, dislocation, irreparable subscapularis tears, cervical nerve palsy, and combined injury of the infraspinatus and teres minor. Radiography and MRI are performed before surgery, at 3 days postoperatively, and at 6 months postoperatively, as well as yearly thereafter.

Surgical Procedure

Patient Positioning, Portal Setup, and Arthroscopic Examination

General anesthesia is used, along with a supplementary suprascapular nerve block (brachial plexus anesthesia). The SCR procedure is performed with the patient in the lateral decubitus position. The portals are the same as those used for routine shoulder arthroscopy: posterior, lateral, anterolateral, anterior, and Neviaser portals (Fig 1).

Long Head of Biceps Tendon Preparation and Subscapularis Tendon Evaluation

A typical diagnostic arthroscopy is performed (Video 1). A routine tenotomy of the long head of the biceps is performed. If a partial or total subscapularis tendon tear coexists, an intra-articular or subacromial tendon repair is performed first.

Subacromial Space Evaluation and Defect Measurement

The subacromial space is inspected through the posterior and lateral portals; subacromial decompression or acromioplasty is performed at the same time. Bony spurs in the anterior and lateral part of the clavicle are removed, but the surgeon should try to retain part of the coracoid ligament.

Glenoid Preparation. The superior glenoid bone bed from the 10- to 1-o'clock position is cleared of soft tissue including the superior labrum and SLAP complex using a radiofrequency device and lightly freshened with a burr to enhance graft-to-bone healing (Fig 2A). Younger patients undergo an additional microfracture of the glenoid graft attachment region. In patients with osteoporosis, only microfracture is performed, without freshening, to avoid anchor loosening.

Greater Tuberosity Preparation. A radiofrequency device is used to remove all soft-tissue remnants; then, the surface is freshened and any "charcoal" appearance of the bone is removed by a burr.

Defect Sizing and Preparation. The dimensions of the defect are measured using a PDS thread (Ethicon, Somerville, NJ) (Fig 2B) or arthroscopic ruler (Fig 2C). The length of the graft is measured from 1.0 cm medial to the glenoid edge to the lateral margin of the

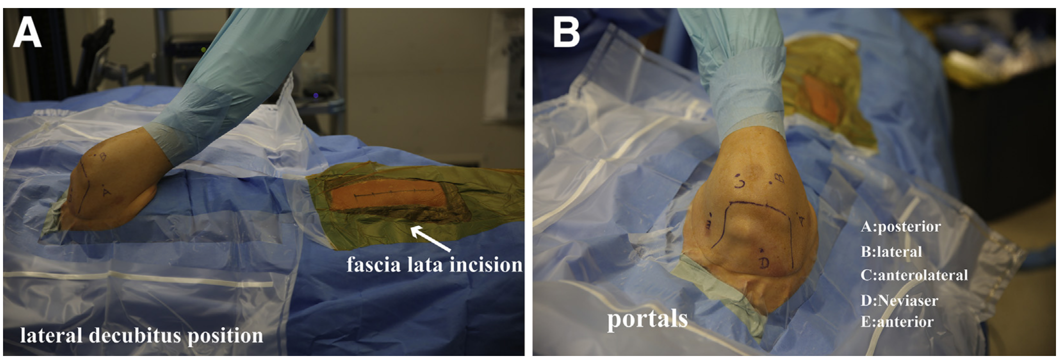

Fig 1. (A) Patient positioning. (B) Portal setup.

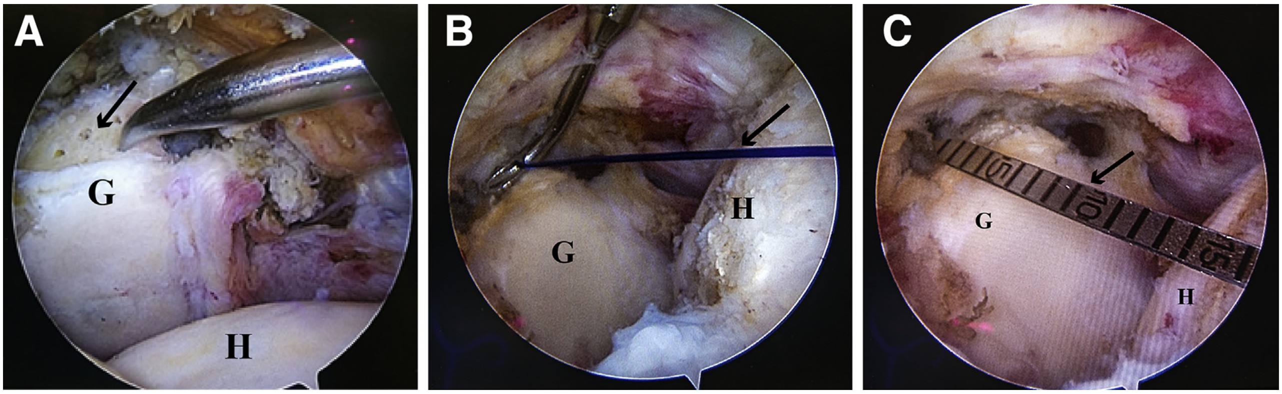

Fig 2. Subacromial space evaluation and defect measurement. (A) Glenoid bone bed given microfracture as the black arrow shows. (B) Defect measurement with a PDS thread (black arrow). (C) Defect measurement with an arthroscopic ruler (black arrow). (G, glenoid, H, humeral head.)

tuberosity-cuff footprint. The width of the graft is measured between the subscapularis and residual infraspinatus.

Suture Anchor Placement

Glenoid Anchor Placement. For fixation of the medial side of the graft, 2 suture anchors (Bio-Corkscrew; Arthrex, Naples, FL) are used, each inserted in the 10- to 11-o'clock and 12- to 1-o'clock positions of the superior glenoid. One 4.5-mm anchor is placed at the base of the coracoid using the anterior portal, and one 3.5-mm glenoid anchor is placed in the posterior glenoid through the lateral portal (Fig 3A).

Medial-Row Anchor Placement in Greater Tuberosity. Two 4.75-mm anchors (BioComposite SwiveLock C Vented, 4.75 × 19.1 mm; Arthrex) are inserted in the medial footprint of the greater tuberosity for fixation of the lateral side of the graft (Fig 3B).

Graft and Sandwich Patch Preparation

Fascia Lata Harvest and Preparation. A vertical incision is made over the ipsilateral thigh from 4.0 cm superior and 8.0 cm inferior to the greater trochanter, and a section of fascia lata—with the length being twice the defect length plus 2.0 cm and the width being the same as the defect width plus 1.0 cm—is harvested. On average, a 12.0 × 3.5—cm section of fascia lata is harvested, and spare fat and muscle tissues are removed (Fig 4A).

Synthetic PET Scaffold Preparation. According to the measurement of the defect, a synthetic scaffold (LARS with PET material; Corin Group) is prepared with an average size of 2.5 × 5.5 cm. Small holes on the scaffold are pre-performed with scissors, with 2 holes approximately 1.0 cm from each medial and lateral margin, as well as several holes at 0.5-cm intervals in the middle (Fig 4B).

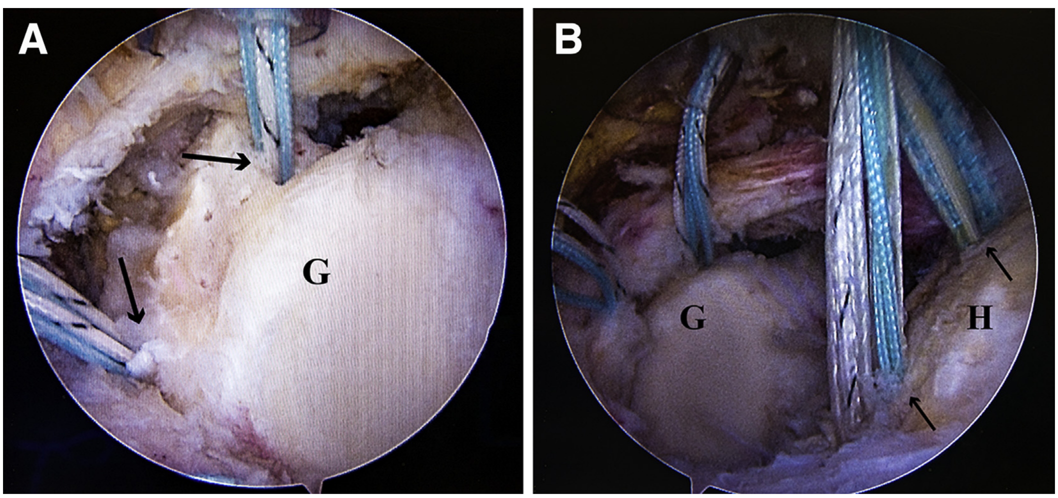

Fig 3. (A) Glenoid anchor placement (arrows). (B) Medial-row anchors (arrows) in humeral head. (G, glenoid; H, humeral head.)

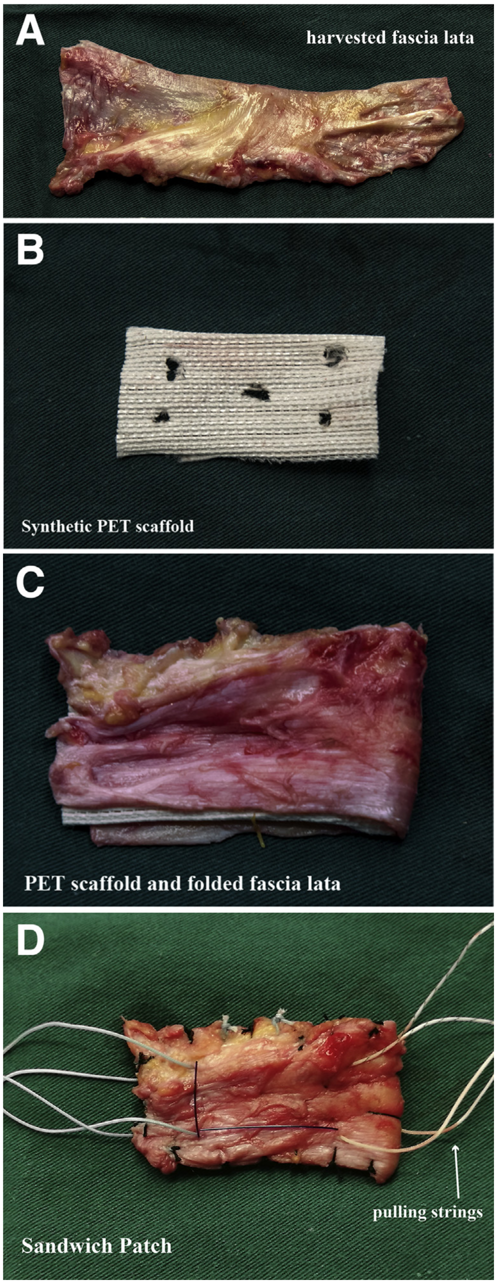

Fig 4. Sandwich patch preparation. (A) Fascia lata harvest and preparation. (B) Synthetic polyethylene terephthalate (PET) scaffold preparation. (C, D) Sandwich patch preparation.

Sandwich Patch Preparation. The fascia lata section is folded in half, and the artificial scaffold is placed between the 2 fascia lata layers (Fig 4C). Every edge and corner of the patch should be stitched with 4-0 Mersilk (Ethicon) and an additional 2 rows are used to secure the middle part of the patch to ensure a firm combination of fascia lata and artificial scaffold. The distance of the suture to suture and suture to the region of the patch is 5 mm. A 3-layer fascia lata—scaffold—fascia lata patch is obtained: the sandwich patch (Fig 4C). The 4 corners of the patch are shuttled with FiberWire sutures (Arthrex) as pulling strings to keep the patch from unfurling when introduced into the shoulder from the lateral portal. The medial 2 strings are pulled out through the anteromedial and posteromedial sides of the skin over the superior glenoid (Fig 4D).

SCR With Sandwich Patch

Patch Delivery Passage Preparation. The anterolateral portal is enlarged to 4.0 cm. The sharp part of a 10.0-mL injector cannula is cut off, and a longitudinal notch is made in the cannula for easy introduction of the patch into the subacromial space of the shoulder (Fig 5A). Eight sutures from the superior glenoid anchors are then shuttled through the medial part of the patch anteroposteriorly in 1 row 5.0 mm lateral to the edge (Fig 5B).

Suture Management. The glenoid anchor sutures are pulled out in order anteroposteriorly and passed through the medial part of the sandwich patch. The 2 medial-corner leading FiberWires are then brought into the shoulder and pulled out anteromedially and posterolaterally to the superior glenoid with a lumbar puncture needle and PDS II suture (Ethicon). Two strands of anchor sutures from the humeral head footprint are pulled out from the anterior portal and posterior portal in case of suture winding.

Patch Insertion. The sandwich patch is introduced into the subacromial space slowly along the direction of the glenoid anchor suture through the cannula with the aid of the anteromedial and posteromedial pulling strings, which keep the patch from unfurling (Fig 5C).

Medial Fixation. Each of two sutures of the anchor in the glenoid are tied through the lateral portal to fix the patch medially. A side-to-side suture is added between the graft and the remaining infraspinatus or residual anterior supraspinatus tendon to improve force coupling in the shoulder joint but without suturing between the patch and subscapularis tendon. Then, the 2 medial-corner strings of the patch can be pulled out or sutured with the remaining end of the torn supraspinatus.

Lateral Fixation. A double-pulley technique is applied for the 4 medial-row sutures, and a SpeedBridge construct (Arthrex) with SutureTape (Arthrex) is used for the 2 lateral-row anchors.

Postoperative Rehabilitation and MRI Findings

Use of an abduction pillow (Airbags; Nakamura Brace, Shimane, Japan) for 6 weeks after SCR is recommended. Passive exercises are initiated to promote "scaption" (scapular-plane elevation) after the

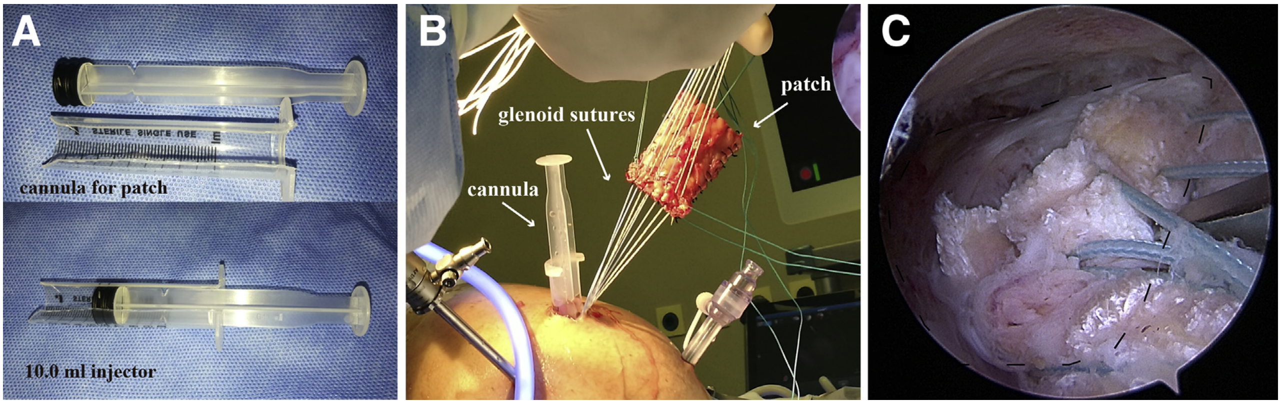

Fig 5. Superior capsular reconstruction with sandwich patch. (A) Cannula made from 10-mL injector. (B) Sutures of patch. (C) Sandwich patch fixation.

immobilization period. Active overhead motions or exercises to strengthen the rotator cuff and scapular stabilizers are not allowed until 4 months after surgery. Active motion exercises are expanded gradually from 6 months postoperatively and are not limited at 1 year after surgery.

By comparison with the preoperative MRI scan in the coronal plane, the postoperative scan shows that the sandwich patch graft has healed well. At 6 months' follow-up, the hybrid patch is found to have become thicker than at 3 days after surgery, with a partial increase in signal intensity (Fig 6).

Discussion

The common symptoms of irreparable rotator cuff tears include subacromial pain, muscle weakness, and elevation limitation. These symptoms are mainly attributed to superior stability loss of the glenohumeral joint, which results from the deficiency of the supraspinatus and superior capsule. This can lead to an unbalanced force couple in the coronal plane and instability of the shoulder rotation axis. Despite the great advancements in shoulder arthroscopic techniques achieved recently, treatment of massive irreparable rotator cuff tears remains a challenge. Warner[28] reported that the prevalence of massive irreparable rotator cuff tears was more than 30%. Retear rates after massive irreparable rotator cuff tear repair of 20% to 90% have been reported[29,30]—or even higher, with a rate of 94% reported by Galatz et al.[31]—even though varied surgical techniques have been developed and applied.

In a cadaveric study performed in 2012, Mihata et al.[10] verified that a supraspinatus tear significantly increased superior translation of the humeral head, which led to increased subacromial contact pressure and decreased glenohumeral compression. In 2014, Ishihara et al.[32] found that a superior capsule tear increased anterior and inferior translation compared with an intact capsule. On the

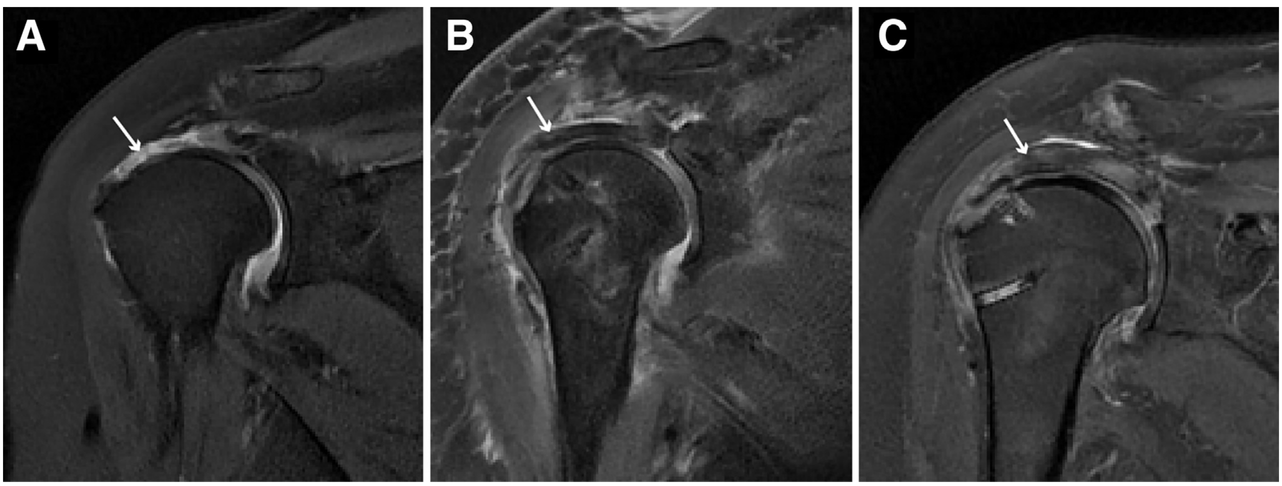

Fig 6. (A) Preoperative magnetic resonance imaging (MRI). The arrow indicates a massive tear of the rotator cuff. (B) Postoperative MRI at 3 days. The arrow indicates the sandwich patch graft. (C) Postoperative MRI at 6 months. The arrow indicates the sandwich patch graft.

basis of these findings, Mihata et al. developed an SCR technique to fully restore superior glenohumeral stability. They proposed that a patch should be attached medially on the superior glenoid instead of attachment on the supraspinatus. In a subsequent clinical research study, they reported on SCR with fascia lata autograft in a series of 23 patients with a mean age of 65 years who received a single row fixed on the superior glenoid, a double row on the humeral greater tuberosity, and side-to-side suturing with infraspinatus procedures and showed satisfactory results at follow-up.[11] After a minimum follow-up period of 2 years, abduction muscle strength significantly improved. Postoperative MRI showed that 83% of patients had no progression of muscle atrophy and osteoarthritis.

We started a series of cases of SCR using the technique of Mihata et al.[10] 2 years ago, but we found that the autogenous fascia lata became stretched and deformed on MRI in some patients at follow-up. In some cases, the humeral head migrated superiorly again because the glenohumeral compression force decreased after the graft stretched, which may result in unsatisfactory clinical effects. We called this phenomenon "patch creep"; it may lead to SCR failure. In our experience, the characteristics of the fascia lata varied among patients. Even in young patients, the strength of the fascia lata was still no stronger than an artificial patch or ligament. With movement of the affected shoulder after SCR, the fascia lata patch was stretched so frequently that patch creep occurred. On the basis of the previous clinical observation, patients were limited to performing active forward flexion and abduction with a positive drop-arm test even though the pain was alleviated after SCR with autogenous fascia lata.

The term "creep" comes from materials science and means a change in a material's length under repeated mechanical stresses. To obtain an SCR patch with better biomechanical properties, it is necessary to find a satisfactory material instead of fascia lata patch or to remold the current patch. Some U.S. researchers[15] were prone to use xenogeneic dermal patch substitute for fascia lata, which provided sufficient biomechanical strength. Considering the better healing of autogenous tissue and stronger mechanical properties of artificial material, we created a hybrid sandwich graft by combining autogenous fascia lata with the LARS patch to reduce patch creep and promote healing in the early phrase after SCR.

Our SCR technique has some limitations. Accidental side effects of pain or functional loss at the donor site of the fascia lata autograft can occur. The PET patch increases the cost to the patient. Moreover, the sandwich structure requires complicated manual work and a longer operative time. Artificial materials commonly have a potential risk of local inflammatory reaction or material abrasion when impingement with bony structures occurs. The graft might be abraded under the acromion during repetitive elevation during daily life[33] when the acromiohumeral distance does not change after SCR. Our sandwich patch structure avoids direct contact between the artificial material and the acromion. As an additional advantage, the increased graft thickness might improve the acromiohumeral distance owing to a spacer effect. Makovicka et al.[34] described a technique of SCR with the addition of an acromial acellular dermal allograft spacer allowing for arthroscopic acromial resurfacing, as well as effectively doubling the thickness of the spacer function of the graft. A technique using a balloon spacer maximized the spacer effect between the acromion and humeral head. In a laboratory study, Singh et al.[35] reported that the balloon and SCR with a 4- to 6-mm dermal graft both provided mechanical effects that restored the humeral head position from the superiorly migrated location. However, all these techniques partially aiming to restore the relative position between the humeral head and glenoid still need long-term follow-up and a larger sample observation of clinical results. We will report our results at short- and longer-term follow-up but we are optimistic about our early findings; SCR with the sandwich patch may be a preferable alternative for patients with massive irreparable rotator cuff tears.

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