Anterior Capsular Reconstruction for Irreparable Subscapularis Tears

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Abstract: Chronic anterior shoulder instability due to structural failure of the subscapularis muscle and the anterior capsule is a rare and challenging diagnosis for surgeons to manage because poor-quality capsular, labral, and rotator cuff tissue often limits effective treatment options. If primary repair is not possible because of retraction and poor tissue quality, reconstruction with an allograft or autograft may be the only joint-preserving option. The purpose of this article is to describe a surgical technique for anterior capsular reconstruction using a human acellular dermal allograft for the treatment of irreparable subscapularis tears.

The shoulder capsule and rotator cuff are the most important static and dynamic stabilizers of the glenohumeral joint. More precisely, anterior glenohumeral stability is maintained by the anterior shoulder capsule and the subscapularis muscle. Concomitant tearing of these structures with progression to irreparable capsular insufficiency is commonly understood as a major contributor to "end-stage" shoulder instability, which can cause devastating functional deficits.[1] It predominantly affects young patients after multiple failed prior instability procedures,[2] especially after previous thermal capsulorrhaphy.[3] In addition, the presence of a hereditary collagen disorder further increases the risk of chronic severe anterior shoulder instability.[4] Patients with prior open shoulder procedures in which the subscapularis muscle is detached may also be at risk.[5]

In general, successful management of these patients is extremely challenging for the surgeon given the inadequate or poor-quality capsular, labral, and rotator cuff tissue, as well as the possible undiagnosed connective tissue disorders that may coexist. In cases in which a repair is not possible, few options remain for the treatment of these patients. Several surgical techniques, both nonanatomic[6] and anatomic,[7-11] have attempted to reconstruct the anterior glenohumeral capsule and the subscapularis muscle in this context. The results have varying rates of success and may be associated with altered biomechanics, high retear rates, and complications such as nerve injury. Optimal graft choices, techniques for graft placement and fixation, and rehabilitation protocols are all controversial.

The purpose of this article and Video 1 is to describe our preferred surgical technique for anterior capsular reconstruction using a human acellular dermal patch to treat irreparable subscapularis tears; advantages and disadvantages of the technique are outlined in Table 1. The allograft used in this procedure may offer additional benefits such as superior mechanical strength compared with the smaller, thinner tendon allografts used previously.[8-10] Moreover, in patient groups with generalized tissue laxity or collagen disorders, allografts from nonaffected donors have the additional benefit of avoiding the pathology inherent to the donor's autograft tissue.

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Table 1. Advantages and Disadvantages of Anterior Capsular Reconstruction

Advantages
More anatomic reconstruction compared with tendon transfer surgery
Faster recovery compared with tendon transfer surgery
Better cosmetic outcome compared with tendon transfer surgery
Lower risk of neurovascular injury compared with tendon transfer surgery
Easier revisions compared with tendon transfer surgery
No harvest-site morbidity with allograft compared with autograft
Disadvantages
Technically challenging
Long-term outcomes unknown

Surgical Technique

Preoperative Assessment

If chronic anterior instability is suspected, a thorough evaluation of the patient's history is indicated. Risk factors may include multiple prior shoulder dislocations or a history of multiple shoulder surgical procedures, including arthroplasty or other open procedures that required takedown of the subscapularis. Previously undiagnosed hereditary collagen disorders also must be excluded.

To detect anterior shoulder instability during the physical examination, the apprehension test for shoulder instability is performed. Next, subscapularis muscle strength is tested with active internal rotation using the lift-off, belly-press, and bear-hug tests. Positive findings, along with relatively unopposed passive external rotation, may suggest chronic anterior shoulder instability with structural failure of the active and passive stabilizers. All examination findings should be compared with the contralateral shoulder. If any of these tests raises suspicion, advanced imaging including standard radiography of the shoulder in 3 planes and magnetic resonance imaging (Fig 1) is recommended. The findings are carefully evaluated for bony anomalies, capsular insufficiency, the presence of a subscapularis tear, and muscle pathology including retraction and fatty infiltration.

Preoperatively, patients should be counseled on the potential benefits and risks, and their expectations should be appropriately managed. The surgeon should highlight that this operation is a salvage procedure, and although a high level of postoperative activity should be encouraged, patients should be made aware of the risks of certain activities, particularly contact or overhead sports. In general, the final decision to proceed with a reconstruction over a repair should always be made intraoperatively and is usually determined by a large defect, poor tissue quality, and the presence of limited mobilization of the muscle with retraction despite adequate releases.

Anesthesia and Patient Positioning

After the induction of general anesthesia and placement of a regional interscalene block, the patient is placed in the beach-chair position and subsequently undergoes a physical examination under anesthesia. The side-to-side difference in passive external rotation is measured, as well as a load and shift for instability. The operative extremity is then situated in a pneumatic arm holder (Tenet T-Max Beach Chair and Spider arm positioner; Smith & Nephew, Memphis, TN). The operative shoulder and axilla are prepared and draped by sterile techniques.

Diagnostic Arthroscopy and Debridement

The complete surgical technique is shown in Video 1. A diagnostic arthroscopy is first performed after establishing a posterior standard viewing portal and an anterior standard working portal through the rotator interval. The capsulolabral complex, rotator cuff, anterior glenoid rim, articular cartilage, long head of the biceps tendon, and biceps-labral complex are thoroughly evaluated. For synovectomy and lysis of adhesions, a 4.5-mm shaver and a 3.75-mm suction radiofrequency cautery device (Super TurboVac 90; ArthroCare, Austin, TX) are used. A biceps tenotomy is performed from its origin at the superior labrum if tenosynovitis is present in anticipation of later tenodesis. Afterward, the rotator cuff is carefully examined. Once a subscapularis tear is confirmed, the decision to

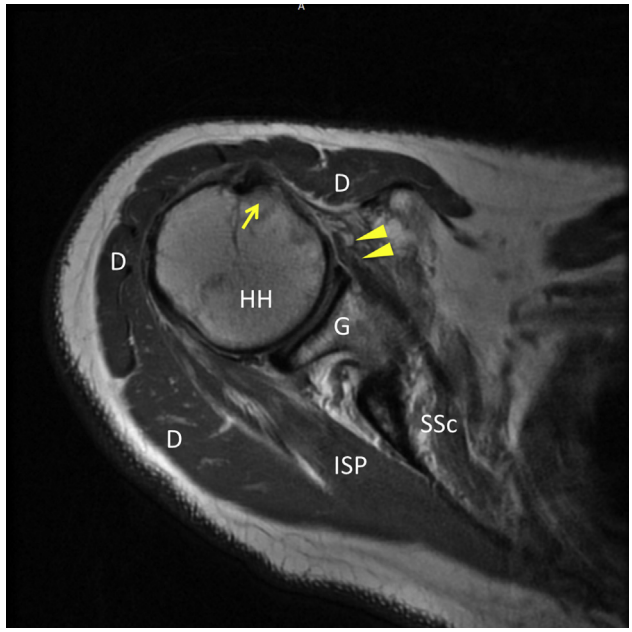

Fig 1. T1 magnetic resonance imaging, axial view, of a right shoulder showing a subscapularis tear. One should note how the subscapularis tendon (arrowheads) has avulsed off the lesser tuberosity (arrow). (D, deltoid muscle; G, glenoid; HH, humeral head; ISP, infraspinatus muscle; SSc, subscapularis muscle.)

repair versus proceed with anterior capsular reconstruction is made based on the size of the defect and the tissue quality.

Subacromial Decompression and Acromioplasty

After analysis of the glenohumeral joint, the arthroscope is introduced into the subacromial space. Bursectomy, synovectomy, and subacromial spur removal can be performed, if indicated, using a 4.5-mm shaver and 3.75-mm suction radiofrequency cautery device (Super TurboVac 90).

Open Technique

If the decision has been made to reconstruct the anterior capsule and the subscapularis muscle, a standard deltopectoral incision of approximately 12 cm is made with a No. 10 blade knife, starting just lateral to the palpable coracoid tip. A careful dissection is carried down through the subcutaneous tissue to the fascia in the deltopectoral groove, and the cephalic vein is exposed and retracted laterally to avoid disruption of the venous drainage of the deltoid muscle. The vein may be ligated distally if necessary. The conjoint tendon is identified originating from the coracoid. Care is taken to dissect laterally to the conjoint tendon to retract it medially, thereby protecting the brachial plexus and the brachial vessels. The anterior glenohumeral joint is exposed in this manner, revealing the subscapularis and anterior capsular deficiency that was viewed arthroscopically.

To maximize exposure, a cobra retractor is placed deep to the deltoid to retract it superiorly and laterally and a black-handle retractor is placed to retract the conjoint tendon medially. A Fukuda retractor is then placed into the joint itself to retract the humeral head posteriorly, thereby exposing the glenoid and the anterior glenoid rim (Fig 2A).

Extensive debridement of the remaining cuff and capsular tissue is performed to create a bleeding bed for healing of the allograft tissue. Any residual anterior labrum is removed. The anterior glenoid is prepared with a motorized shaver to further enhance graft-to-bone healing (Fig 2A). Three 3.0-mm knotted BioComposite SutureTak anchors preloaded with FiberWire (Arthrex, Naples, FL) are inserted percutaneously into the anterior glenoid rim at the 5-, 3-, and 1-o'clock positions, beginning inferiorly (Fig 2B).

The size of the tear is measured in the coronal and axial planes with a ruler to determine the size of the patch that will be needed to reconstruct the anterior capsule. The graft is then incised along the long edge of the graft, thereby reducing the graft width according to the measurements of the defect. The length of the graft is not reduced until it is fixed on the glenoid and lesser tuberosity. A 3.5-mm thick human acellular dermal patch (ArthroFlex; Arthrex) is then prepared by marking several parallel lines perpendicular to the length of the graft for reference to ensure that the final graft shape is rectangular.

At this point, the two suture limbs from the middle glenoid suture anchor are passed through the midpoint of the medial edge of the graft with a suture passer (Scorpion Suture Passer; Arthrex) (Fig 3A). One limb from the inferior anchor and one limb from the superior anchor are then passed through the superior and inferior aspects of the graft, respectively.

The graft is shuttled down to the glenoid (Fig 3B) by use of an arthroscopic knot pusher. The middle suture limbs are tensioned and tied. The additional superior and inferior limbs that were not passed through the

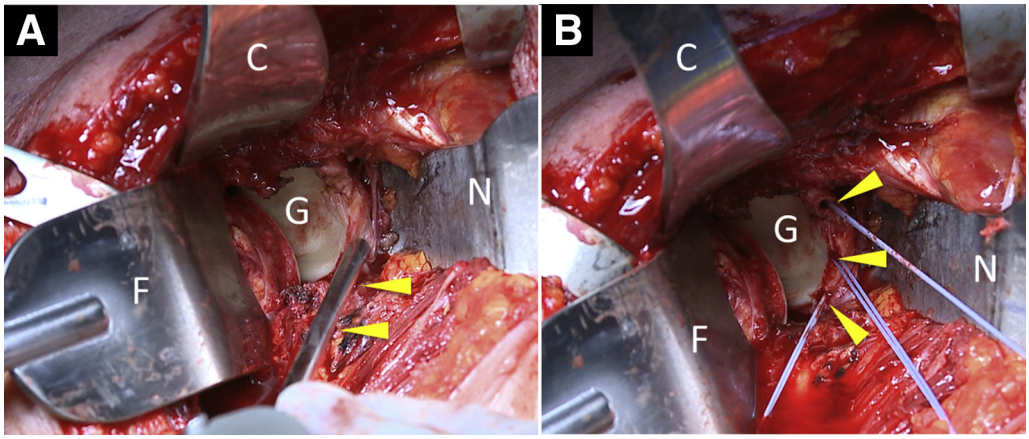

Fig 2. Anterior view of a right shoulder after a standard deltopectoral approach; a Fukuda retractor (F) pulls the humeral head posteriorly, a cobra retractor (C) pulls the deltoid superiorly, and an anterior glenoid neck retractor (N) is used to lever the glenoid (G) into view. (A) The anterior glenoid is prepared with a motorized shaver (arrowheads) to enhance graft-to-bone healing. (B) Three preloaded suture anchors (arrowheads) are inserted into the anterior glenoid rim at the 1-, 3-, and 5-o'clock positions.

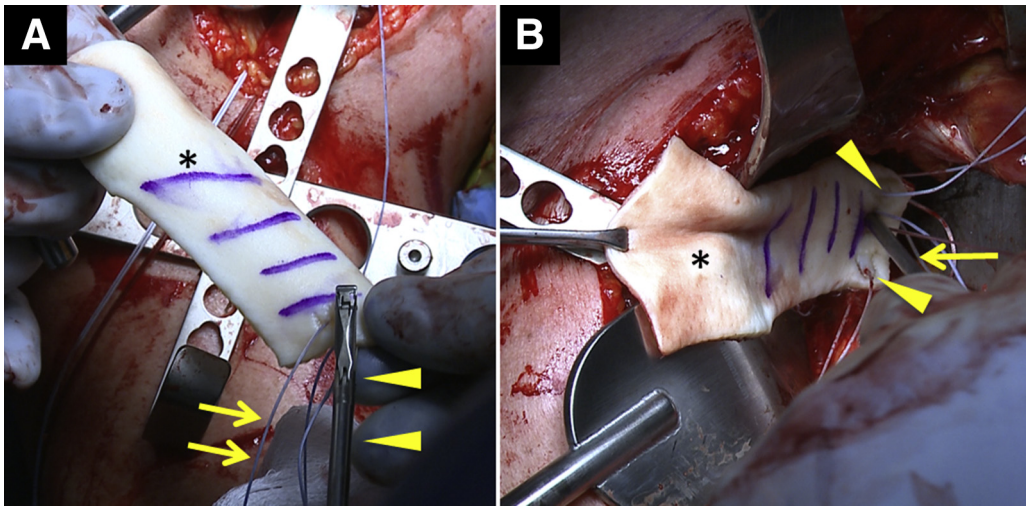

Fig 3. Anterior view of a right shoulder after a standard deltopectoral approach, showing medial-sided graft preparation and insertion. (A) The first suture limb (arrows) from the middle glenoid suture anchor is passed through the midpoint of the medial edge of the graft (asterisk) with a suture passer (arrowheads); after this step, the second limb is passed through the inferior side of the midpoint (not pictured). (B) After one limb from each of the inferior and superior suture anchors has been passed through the respective inferior and superior aspects of the medial edge of the graft (arrowheads), the graft (asterisk) is shuttled down to the glenoid with an arthroscopic knot pusher (arrow).

graft are passed through the adjacent tissue and tied to their counterpart limb and tensioned, thus preventing "dog-ear" formation on the inferomedial and superomedial corners. This technique secures the graft along the anterior glenoid rim and surrounding structures. Careful attention to suture management is critical while retrieving and passing the sutures. The remaining excess suture is cut with a suture cutter and discarded.

The lesser tuberosity is then prepared with a motorized shaver to expose a bleeding bony bed to optimize healing (Fig 4A). Typically, a hybrid double-row bridging repair (SpeedBridge kit; Arthrex) with 4 anchors is performed (2 medial and 2 lateral anchors) for the lateral humeral-sided fixation. Unlike the tendon footprint of the supraspinatus, the subscapularis footprint does not resemble a square but rather a trapezoidal shape,[12] meaning that to optimize biomechanical load distribution, the superior-medial anchor is placed more medially than the inferior-medial anchor, resulting in a skewed double-row repair to fully cover the footprint. We recommend maintaining a superior-inferior bone bridge of about 10 mm in an inferior-lateral direction between each medial anchor. An arthroscopic punch is used to create a bone socket to accommodate the inferior-medial anchor approximately 1 to 2 mm lateral to the articular margin. A

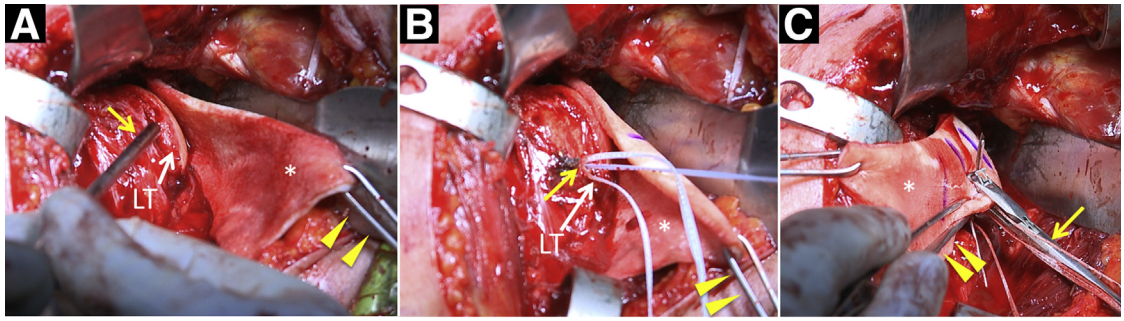

Fig 4. Anterior view of a right shoulder after a standard deltopectoral approach and medial-sided graft fixation, showing lateral-sided graft preparation and insertion with the graft (asterisks) being manipulated with forceps (arrowheads). (A) The lesser tuberosity (LT, white arrow) is prepared with a motorized shaver (yellow arrow). (B) After creation of a bone socket with an arthroscopic punch (not visualized), the inferior-medial vented preloaded suture anchor (yellow arrow) is inserted approximately 1 to 2 mm lateral to the articular margin. (LT, lesser tuberosity [white arrow].) (C) With a suture passer (arrow), each limb of the suture tape and one strand of FiberWire suture are passed through the inferior aspect of the graft; the distance along the length of the graft is determined by the size of the defect and the appropriate level of tension.

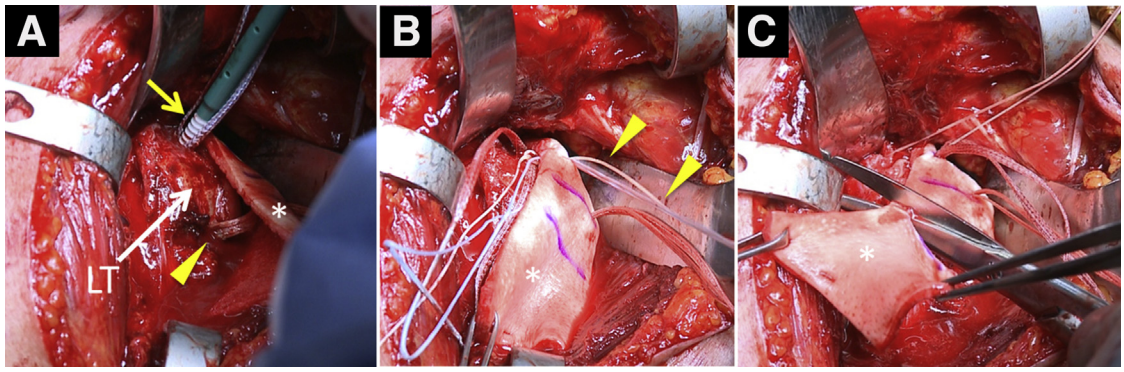

Fig 5. Anterior view of a right shoulder after a standard deltopectoral approach, showing placement of the medial row of suture anchors for lateral-sided double-row graft (asterisks) fixation. (A) The superior-medial vented preloaded suture anchor (yellow arrow) is inserted 10 mm superior to the inferior suture anchor (arrowhead). (LT, lesser tuberosity [white arrow].) (B) Each limb of the suture tape (arrowheads) and one strand of FiberWire suture have been passed through the inferior aspect of the graft with a suture passer (not visualized). (C) The graft is cut along its width about 1 cm lateral to the medial row of suture anchors.

vented 4.75-mm suture anchor loaded with No. 2 suture tape and FiberWire sutures is placed in this inferior-medial socket (BioComposite SwiveLock anchor with FiberTape and FiberWire; Arthrex) (Fig 4B). With an arthroscopic grasper and suture passer (QuickPass SutureLasso; Arthrex), each limb of the suture tape and one strand of FiberWire suture are passed through the inferior aspect of the graft, at a distance along the length of the graft that is determined by the size of the defect (Fig 4C). One strand of FiberWire suture is not passed through the graft but is instead sutured to the surrounding rotator cuff tissue for additional stability. Next, preparation of the superior-medial anchor is performed in an identical fashion (Fig 5 A and B), with care taken to maintain a 10-mm bone bridge relative to the first medial anchor. The graft is cut along its width (Fig 5C) 1 cm lateral to the point where the graft has been sutured to the medial row, and the excess is discarded.

Two strands of FiberWire suture are passed through the inferolateral and superolateral corners of the graft by use of a suture passer (Scorpion Suture Passer; Arthrex) and hand tied with a simple knot (Fig 6A). An arthroscopic punch is then used to prepare the inferior-lateral bone socket approximately 15 mm lateral to the corresponding medial anchor. Limbs of suture tape from the two medial anchors are crossed and then loaded with the FiberWire sutures from the lateral corners of the graft into the first lateral-row anchor (4.75-mm BioComposite SwiveLock anchor with FiberTape and FiberWire; Arthrex). The suture tapes are pulled to achieve adequate tension, thus securing the allograft patch laterally and completely covering the lesser tuberosity footprint (Fig 6B). The suture tails are cut. This method is repeated for the superolateral anchor to complete the SpeedBridge construct (Fig 6C).

Two margin convergence sutures are then placed at the lateral part of the superior aspect of the graft into

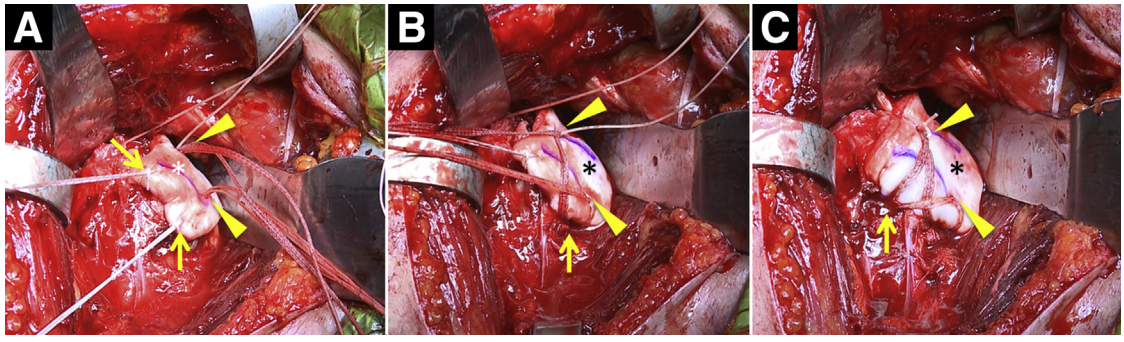

Fig 6. Anterior view of a right shoulder after a standard deltopectoral approach and medial-row anchor placement (arrowheads) for lateral-sided double-row graft (asterisks) fixation. Placement of the lateral row of suture anchors is shown. (A) Two sutures (arrows) are passed through the inferolateral and superolateral corners of the graft by use of a suture passer and hand tied with a simple knot. (B) After placement of the inferior-lateral bone socket 15 mm lateral to the corresponding medial-row anchor, limbs of suture tape from the two medial-row anchors are crossed and then loaded into the first lateral-row anchor and inserted into the bone socket (arrow). (C) The process is repeated for the superolateral anchor (arrow), and the suture tails are cut, completing the SpeedBridge construct.

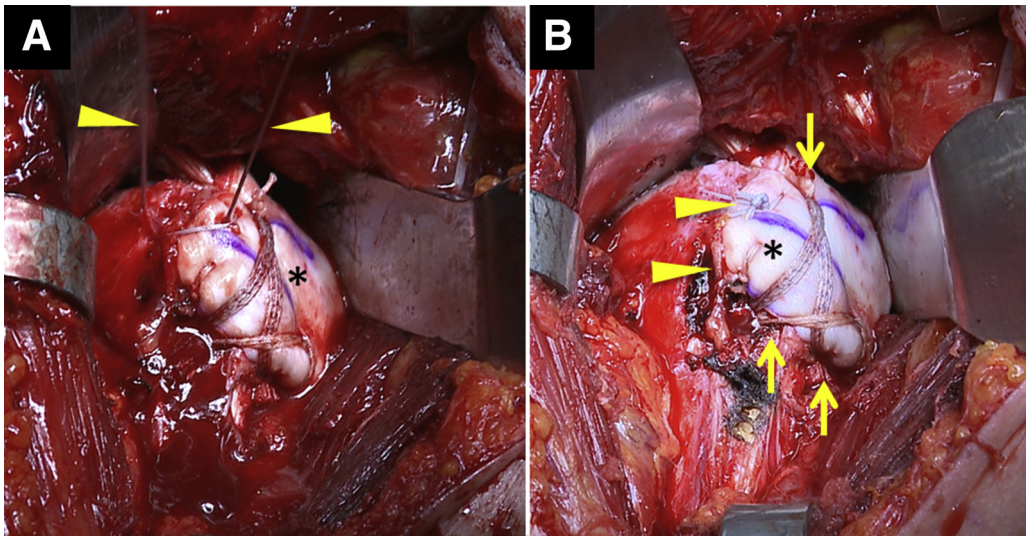

Fig 7. Anterior view of a right shoulder after a standard deltopectoral approach and completion of medial and lateral fixation of the anterior graft (asterisks). (A) A margin convergence suture (arrowheads) is placed at the superolateral part of the graft into the leading edge of the supraspinatus tendon; care is taken to leave the rotator interval open. (B) Visualization of the final anterior capsular reconstruction; one should note the SpeedBridge construct (arrows) and margin convergence sutures (arrowheads).

the leading edge of the supraspinatus tendon that can be identified in the recess of the glenohumeral joint (Fig 7). Care is taken to leave the rotator interval open. A margin convergence suture can also be placed along the inferior aspect of the graft to secure it into the native cuff tissue, if present, to provide additional stabilization.

All suture tails are cut, and the wound is thoroughly irrigated. Before wound closure, a complete dynamic evaluation is performed with particular emphasis on testing stability in the abducted and externally rotated position to ensure adequate stability and security of the repair. Pearls and pitfalls of the complete surgical technique are listed in Table 2.

Postoperative Rehabilitation

Postoperatively, patients must follow a strict subscapularis tendon repair rehabilitation protocol beginning with shoulder immobilization in a sling with external rotation limited to neutral for 2 weeks and then to 30° through week 6. If a biceps tenodesis is also performed, resisted elbow flexion should be restricted for 6 weeks. Wrist and hand exercises are permitted during this time. Pendulum exercises are initiated at 6 weeks. Active range of motion is started at 6 to 8 weeks. Return to activity is expected after 6 months when full range of motion and strength have been achieved. Patients are counseled that there is the potential for some loss of external rotation and forward

Table 2. Pearls and Pitfalls of Anterior Capsular Reconstruction

Surgical Steps	Pitfalls	Pearls
Diagnostic arthroscopy	Missing concomitant lesions	Performing a thorough and standardized examination allows for identification of concomitant lesions.
Medial-row anchor insertions	Dog-ear formation	The surgeon should start with the middle anchor and fix the graft on the inferior and superior edges with suture loops.
Preparation of ArthroFlex patch according to defect size	Incorrect size measurement, resulting in a graft that is too large or too small	The surgeon should use a template or an arthroscopic ruler beforehand (arthroscopic measurement probe, 220 mm, 60°).
Medial-row anchor insertions	Dog-ear formation	The superior-medial anchor should be placed more medially than the inferior-medial anchor owing to the trapezoidal shape of the SSC footprint.
Lateral-row anchor insertions and fixation	Insufficient room	A radiofrequency device can be used to mark the location for the anchors to be inserted.
	Soft bone	The surgeon should assess bone quality with a punch. If the bone is soft, a 5.5-mm BioComposite SwiveLock should be used.
Postoperative rehabilitation	Postoperative stiffness	The patient should be allowed early passive range of motion for 4 wk with restricted range of motion, with progression to full passive motion and start of active and active-assisted motion at 6 wk postoperatively.

SSC, subscapularis.

flexion; however, the goal is to obtain a stable shoulder with at least 45° of external rotation and 140° of forward flexion.

Discussion

In this technical review, we describe a method for anterior capsular reconstruction using a human acellular dermal patch for irreparable massive subscapularis tears. This procedure provides an alternative option to other reconstructive techniques, tendon transfer, arthroplasty, and arthrodesis.

Several techniques have been used to reconstruct the anterior capsule with varying rates of success. Dewing et al.[10] evaluated minimum 2-year outcomes in patients with severe capsular deficiency after anterior capsular reconstruction with a tibialis anterior allograft or a semitendinosus autograft placed on the anterior glenoid rim. They showed that in 45% of patients treated with this technique, the shoulder remained stable. Iannotti et al.[7] reported a series of 7 patients who received revision treatment with autograft or allograft iliotibial band placed in a Z pattern to re-create the anterior capsule and middle glenohumeral and anterior-inferior glenohumeral ligaments. There were no subsequent shoulder subluxations or dislocations in this cohort, and American Shoulder and Elbow Surgeons scores improved from a mean of 30 preoperatively to 55 postoperatively. Alcid et al.[9] reported a series of 15 patients at a minimum 2-year follow-up after anterior capsular reconstruction with hamstring autograft and tibialis anterior allograft. Although no patients reported recurrent dislocation, one-third had symptomatic recurrent subluxations.

Pectoralis major tendon transfer may be a reasonable treatment for irreparable subscapularis tears. Shin et al.[13] reviewed 8 studies that reported on the outcomes of this procedure in the literature; the studies showed an overall improvement in Constant scores from 37.8 ± 6.8 preoperatively to 61.3 ± 6.5 postoperatively and an overall improvement in pain scores. In addition, subcoracoid transfers produced better outcomes than supracoracoid transfers. It is interesting to note that the authors found the outcomes were less favorable in patients with other concomitant massive rotator cuff tears. This finding may be due to the fact that this nonanatomic procedure fails to re-establish normal shoulder kinematics by only partially restoring the balanced force couple in the transverse plane of the glenohumeral joint. Although the complication rate of postoperative nerve palsy with this technique was found to be low in the included studies, one study using cadaveric specimens has suggested the musculocutaneous nerve may be at risk.[14]

Alternative procedures such as shoulder arthrodesis produce severe functional limitations, and reverse shoulder arthroplasty is often not attractive to younger patients because of the limited longevity of the prosthesis. In addition, despite Ek et al.[15] showing significant functional and subjective improvement with reverse shoulder arthroplasty in patients younger than 65 years at between 5 and 15 years postoperatively, they reported a complication rate of 37.5%, with 25% of the total cohort requiring partial or total component exchange, conversion to hemiarthroplasty, or removal. They concluded that the risks and benefits should be carefully considered in this patient group.

Human grafts have been used in previous reports for superior capsular reconstruction or augmentation procedures in the context of massive rotator cuff tears and have produced promising early results.[16,17] The dermal allograft offers a significantly larger surface area of contact between the graft and the humeral head compared with tendon and muscle allografts and autografts used in previous reconstructive attempts.[7,9,10] Furthermore, we expect the dermal allograft to replicate the anatomic anterior capsule more closely and to uniformly dissipate the anteriorly directed forces responsible for recurrent dislocations, thus increasing the force threshold needed for dislocation. Anterior capsular reconstruction using this open technique may be a reasonable treatment option in younger patients with irreparable subscapularis tears wishing to avoid tendon transfer or reverse total shoulder arthroplasty; however, further clinical trials are needed to investigate the benefit of this technique.

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