Technical Note

Surgical Technique for Arthroscopic Rotator Cuff Augmentation With Human Acellular Dermal Matrix

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Abstract: Arthroscopic repair is probably the gold standard for treating large rotator cuff tears. Although positive, the results of this type of intervention depend on many factors such as the size of the tear, the age of the patient, and the number of previous surgeries. To decrease the rate of recurrence, we propose a surgical technique for augmenting the repair using an acellular dermal matrix (ArthroFlex, LifeNet Health). Our technique allows the surgeon to initially suture the tear in a regular fashion without visual interference. Once the tear is repaired, the augmentation is performed in a simple, all-arthroscopic, reproducible, and safe way. Also, we do not use extra implants for the fixation of the graft, so it does not increase the cost of the procedure (leaving aside the cost of the matrix itself).

Rotator cuff pathology is by far the most common cause of shoulder dysfunction and pain. In the presence of a complete tendon rupture, arthroscopic reconstruction is a widely used surgical solution. Although repair leads to better clinical results, and although improvements in surgical technique and postoperative management could improve these results,[1] studies have shown failure rates after arthroscopic repair of up to 94%.[2] Although failure or re-rupture is a multifactorial process, it has been mainly associated with the size of the rupture (dimension, area, and thickness).[3] Other factors associated with a worse prognosis of arthroscopic rotator cuff repair are advanced age, low bone density, female sex, fat infiltration, diabetes mellitus, decreased acromiohumeral interval, previous surgeries, or smoking history.[3-6]

In recent years, research has increased in the use of biological augmentation techniques in rotator cuff repair to improve healing at the tendon–bone interface. It has been described that augmentation with allografts can not only increase the initial resistance of the reconstruction and facilitate the progressive proliferation of the tissue by providing a favorable environment for healing and remodeling, but also protect the tissue during healing, with consequent reduction of the failure rate.[7-10]

Augmentation should be considered in cases of repairs with a high risk of re-rupture or incomplete healing. The indications are not consistent in the literature but generally include large ruptures, repairs of multiple tendons, or low-quality tissue and revision surgery.[11-13]

We present here a surgical technique to perform this reinforcement arthroscopically using a human acellular dermis (ArthroFlex; LifeNet Health, Richmond, VA). We opted for this type of graft because it decreases the immune response in the recipient and provides a collagen matrix that acts as a template for tissue regeneration.[12,14-16] Other techniques previously described to perform augmentation after rotator cuff repair can be very technically demanding or cost inefficient, some requiring the use of extra implants for the augmentation process.[17,18]

Our technique allows completion of the suture of the native cuff initially, showing the correct repair of the footprint–tendon interface without visual obstruction of the graft, and subsequently incorporating the graft. In addition, a hybrid fixation technique in which the graft is fixed by sutures incorporated in the transosseous equivalent repair of the rotator cuff—with sutures from the medial row anchors that cross both the native tendon and the graft, and with sutures of the lateral row anchors—provides an increase in resistance in the load test as reported in biomechanical studies.[19]

Table 1. Advantages and limitations

Advantages
Simple and reproducible technique
Does not require equipment in addition to that necessary for the
   initial repair
Cost reduction with respect to previous techniques (no extra
   implants)
Allows visualization of the correct initial repair of the footprint
   −tendon interface
Hybrid structure that increases biomechanical resistance
Limitations
Surgical time can be higher than nonaugmented repairs
Exposes the patient to increased time under anesthesia
Cost is higher than nonaugmented repairs because of the graft

Our goal is to create a simple and reproducible technique for augmentation of the rotator cuff that can be easily adopted by arthroscopic shoulder surgeons, is
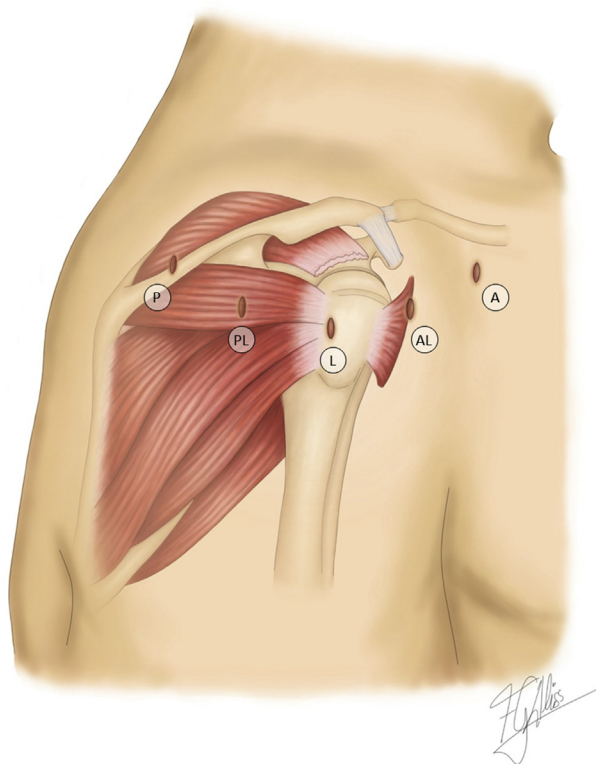
Fig 1. Arthroscopic portals used in the described technique. Patient is positioned in beach chair position or lateral decubitus, according to the surgeon's preference. The posterior vision portal (P) is used in the initial evaluation of the joint and for the visualization of the graft during its implantation. The lateral portal (L) is used as a vision portal during repair and as a working portal for augmentation, being used for the augmentation of the graft through the use of the cannula. The anterolateral (AL) and posterolateral (PL) portals are used as working portals for the initial repair with the transosseous equivalent technique, to recover sutures and guide the introduction of the graft by pulling them, and for graft fixation. The anterior portal (A) is used as a working portal in both phases of the surgical procedure.

resistant from the biomechanical point of view, and does not increase the cost per patient above the cost of the graft itself. A summary of its advantages and limitations can be seen in Table 1.

Surgical Technique

Preparation of the Patient

The patient is placed in a beach chair position (used by the author) or lateral decubitus, according to the surgeon's preference. Surgery is carried out under general anesthesia, although it is advisable to associate it with an interscalene block to control postoperative pain. After marking anatomic landmarks on the skin, the surgical field is prepared in the usual way for an arthroscopic technique. The author uses continuous traction through a hydraulic beach chair positioner.

Approach

For arthroscopic exploration and double-row repair of the tendon, 3 to 5 arthroscopic portals are used (Fig 1), according to the needs of each case and according to the outline in Table 2. For the insertion of the reinforcement and its fixation, 4 portals are used, also described in Table 2. In the lateral portal, we use an 8 × 65-mm adjustable flexible cannula (ARC; ConMed Corp., Utica, NY), which allows insertion of the graft throughout the surgery (Video 1).

Initial Repair

Initial Evaluation

After a standard arthroscopic exploration (Fig 2), the rupture pattern is evaluated, and its repair is planned to ensure that the passage of sutures in the tissue restores its tension in a balanced way. Next, the surface of the

Table 2. Arthroscopic portals

Portal	Use
Arthroscopic examination and double-row repair of the tendon	
Posterior	Initial vision of the joint
Lateral	Vision of the subacromial space for repair
Anterior	Work portal
Anterolateral	Work portal (optional)
Posterolateral	Work portal (optional)
Reinforcement of the repair by graft of human acellular dermis	
Lateral	Introduction of the graft
Posterior	Vision
Anterolateral	Work portal
Posterolateral	Work portal
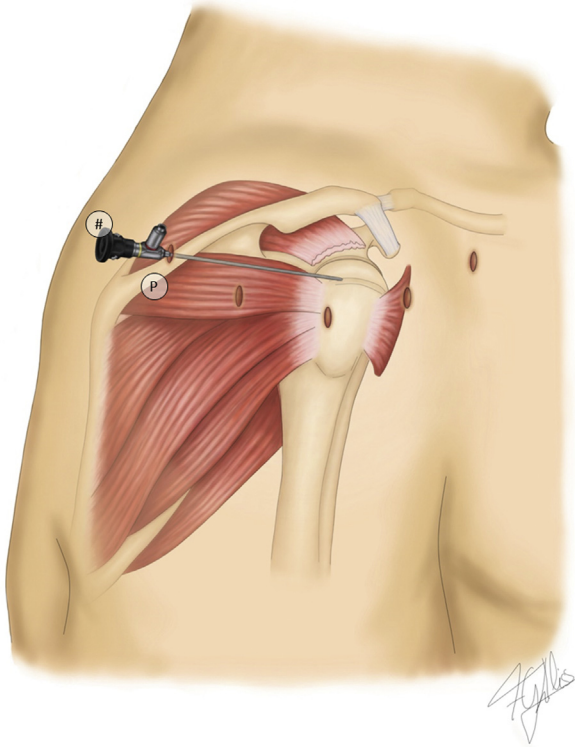
Fig 2. An initial evaluation of the joint is performed, inserting the arthroscope (#) through the posterior portal (P). It is important to analyze the magnitude of the tendon damage and check if there are other associated lesions.

tendon humeral footprint is prepared. We use a synoviotome with the objective of debriding, cleaning residual soft tissues, and regularizing the bone surface (Fig 3A, B). For the initial repair, we use a standard equivalent transosseous suture technique with PEEK threaded implants (CrossFT; ConMed Corp.) loaded with 2 sutures each.

Initial Preparation

Once the rupture pattern has been evaluated, we begin implanting the 2 anchors for the medial row. Each anchor is loaded with 2 sutures. One will be used to fix the tendon, and the other will serve to introduce and fix the allograft (Fig 4).

The 4 ends of sutures of each anchor are passed through the tendon from anterior to posterior. The most anterior suture of the anterior anchor is recovered through the anterolateral portal, and the most posterior suture of the posterior implant is recovered through the posterolateral portal (Fig 5A, B).

Initial Repair

The remaining sutures are used for the repair itself, crossing a strand from each implant and leaving the remaining in parallel for a cross configuration. These sutures are recovered and loaded in 2 knotless anchors (CrossFT Knotless; ConMed Corp.), which are used to fix the lateral row. As in the medial row implants, these anchors are also loaded with an "extra" suture each, which will be used to fix the lateral edge of the graft (Fig 6A, B).

Measurement and Preparation of the Graft

Measurement of the Graft

After double-row repair, the distance between the 4 implants is measured using an arthroscopic ruler in the order indicated in Table 3. Use the anterior portal to measure the anteroposterior borders of the graft and the lateral portal to measure the medial to lateral border length.

Preparing the Graft

These measurements are used to mark the graft and cut it later. We also mark the point at which the sutures will be anchored in the 4 corners of the graft. This marking should be made 3 to 5 mm from the edge of the graft, with the aim of leaving some margin to tighten and flatten it at the time of application (Fig 7A,
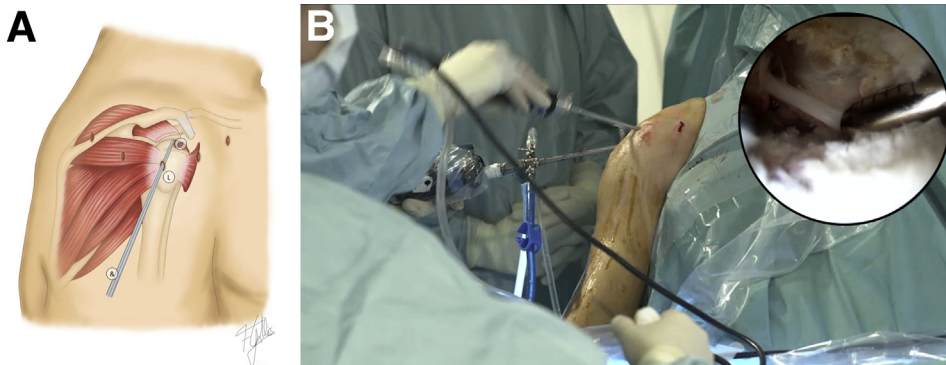
Fig 3. (A and B) With a view from the posterior portal, after analyzing the rupture pattern, a synoviotome (&) is used through the lateral portal (L) for the preparation of the humeral footprint (@). It is important to perform careful debridement, eliminating residual soft tissues and regularizing the bone surface to achieve a good substrate for integration of the tendon.
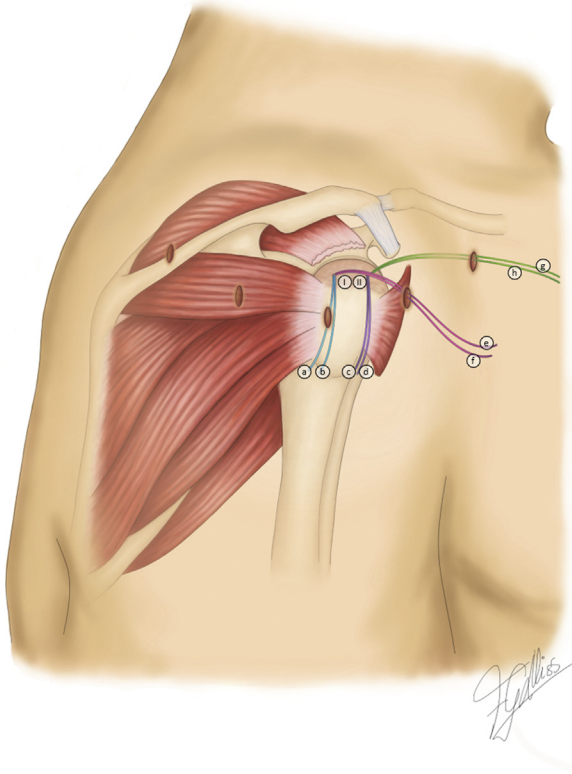
Fig 4. First step of the double-row repair (transosseous equivalent). Two threaded anchors (I and II) are implanted for the medial row, loaded with 2 sutures each (4 ends). One suture from each anchor (a, b, c, d) will be used to repair the tendon, and the remaining sutures are used for the introduction and posterior fixation of the medial edge of the acellular dermis graft (e, f, g, h).

B). Finally, indicate the glossy epidermal side of the graft to facilitate its arthroscopic view and positioning in cranial orientation.

Introduction and Fixation of the Graft
Graft Insertion

The prepared graft is inserted through the 8 × 65-mm adjustable flexible cannula (ARC;ConMed Corp.) in the

lateral portal. To accomplish that, we first retrieve the remaining sutures from the medial row anchors to use as traction-guide sutures. We retrieve 1 end of each suture through the cannula of the lateral portal, leaving the other end in its corresponding portal. These recovered sutures strands are passed exteriorly through the graft. Specifically, they cross the 2 ends of the graft that will be located medially once in final position (Fig 8A, B).

Once the graft is crossed, a thick (mulberry) knot is made to serve as a stop when the graft is brought into position by traction. For this, traction is applied on the free end of the sutures, and simultaneously, the graft is progressively introduced through the cannula with the help of an arthroscopic tissue grasper. This allows its guided introduction on the repair to subsequently tie the sutures and fix the medial portion of the graft (Fig 9A, B).

Fixation of the Medial Aspect of the Graft

To suture the medial end of the graft, the top knot is recovered and externalized again with an arthroscopic tissue grasper. Once outside the joint, the knot is cut to have a free suture end. Then we proceed to the conventional knotting of the threads, thus fixing the medial edge of the graft on the repair.

Fixation of the Lateral Aspect of the Graft

The lateral portion is sutured arthroscopically in the subacromial space using the remaining suture of each anchor of the lateral row of the repair. After retrieving it through the lateral portal, it is loaded in the suture passing device (Spectrum™ suture hook device; Conmed Corp.) and passed through the marks made in the 2 lateral corners of the graft. After these knots are tied, the graft is definitively applied to the double-row repair previously performed (Fig 10A, B).

Rehabilitation Protocol

Right after surgery, the arm is placed in a sling with and abduction pillow that limits elbow and wrist movement exclusively to passive and active range of

Fig 5. (A and B) All ends (a, b, c, d, e, f, g, h) are passed through the tendon, and the "extra" sutures of the anchors of the medial row (g, h, e, f) are recovered to be used for introduction of the graft through the anterolateral (AL) (anterior suture of the anterior implant; g, h) and posterolateral (PL) (posterior suture of the posterior implant; e, f) portals.

Fig 6. (A and B) A suture of each implant is used to perform the initial repair with the equivalent transosseous technique (ends a, b, c, d). For this, 1 strand of each implant (b, c) is crossed, and the remaining strand is left in parallel (a, d). After recovering the sutures, these are loaded into 2 knotless anchors that are used for the lateral row. In the same way that occurred in the medial row, these anchors (III and IV) are also loaded with an "extra" suture each, used to fix the lateral edge of the graft.
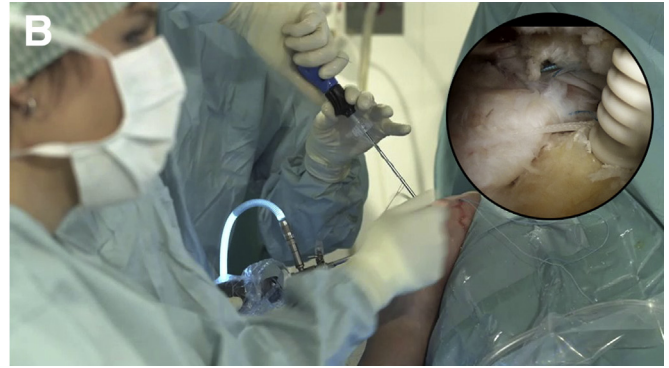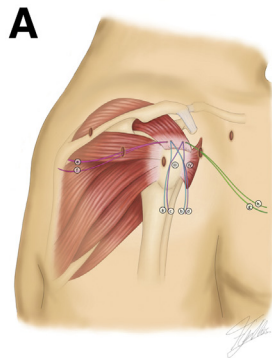
motion, and that of the shoulder to pendular movements. Three weeks after surgery, self-assisted passive mobilization of the operated shoulder is introduced with flexion and rotating movements. Sling removal takes place at postoperative week 6, when physiotherapy is initiated. Extreme caution is needed during the rehabilitation process, since the treated tears are usually very large or retears.

Discussion

In an attempt to revert the high failure rates of rotator cuff repair and improve tendon healing, many types of reinforcement have been proposed with promising results, including dermal allografts, xenografts, synthetic grafts, and autografts such as biceps autograft augmentation,[20] fascia lata,[21] or subacromial bursa,[22] among others.

Several studies have reported that augmentation with allografts, usually acellular dermis, can increase the initial resistance of the reconstruction and facilitate the progressive proliferation of the tissue by providing a favorable environment for healing and remodeling. Moreover, this technique can protect the tissue during the healing process, with consequent reduction of the failure rate and avoidance of the associated morbidity at the autograft donor site.[7-10]

Bailey et al.,[8] in their systematic review, performed a meta-analysis of 5 studies with rotator cuff repair or reconstruction with augmented tissue or matrix. The results showed that graft augmentation or interposition appeared to provide a lower retear rate and improved American Shoulder and Elbow Surgeons (ASES) scores compared with repair alone. The authors also concluded that future prospective, randomized, controlled, and appropriately powered trials are needed for more definitive recommendations.

Barber et al.,[11] in their prospective, multicenter, randomized controlled trial of patients who underwent single-row repair of large, 2-tendon tears with or without augmentation with acellular dermal allograft,

reported that both groups had improved ASES, Constant, and University of California, Los Angeles (UCLA) scores; but the augmented group showed significantly more improved ASES and Constant scores. Also, when gadolinium-enhanced magnetic resonance imaging (MRI) scans were performed, 85% of repairs in the augmented group showed intact cuffs, compared with 40% in the nonaugmented group.

Agrawal,[12] in a retrospective case series of clinical and structural outcomes of arthroscopic rotator cuff repair with acellular human dermal graft reinforcement in patients with large to massive rotator cuff tears and revision cases, reported that MRI evaluation revealed that 85% of the repairs were intact, with significant improvements in postoperative Constant scores and pain scores. However, the study lacked a control group, so the true clinical significance is difficult to determine. Regarding reactions to allograft tissue, there have been no reported immunogenic complications from the graft in any clinical studies using acellular dermis allograft.[23,24]

Compared with previous reported augmentation techniques with dermal allograft, we believe our technique has important advantages, as stated in Table 1. First, the use of the same anchors needed for the primary rotator cuff repair limits the costs of the procedure, with no additional anchors needed for the augmentation. It also does not require equipment added to that necessary for the initial repair, except for the graft itself. Another advantage is that our technique allows completion of the suture of the native cuff first, initially showing the correct repair of the

Table 3. Arthroscopic portals to measure the size of the graft

| Portal	Measurement
Anterior	AB distance
	CD distance
Lateral	BD distance
	AC distance
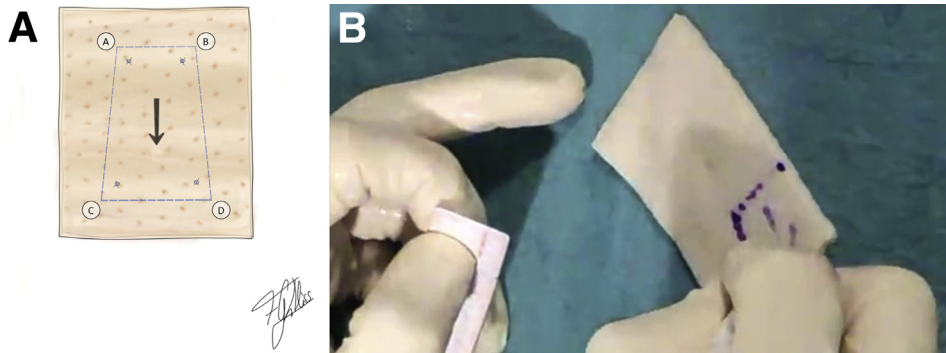
Fig 7. (A and B) Matrix of acellular human dermis prepared for insertion. The graft has been cut according to the measurements taken between the anchors (AB, CD, BD, AC) and is marked according to the point at which the sutures will be anchored at the ends of the graft, ∼5 mm from the measured edges of the graft. The epidermal side of the graft and its cranial orientation are also indicated by an arrow.

Fig 8. (A and B) After preparing the graft (G), it will be introduced through the lateral portal (L) using as guides the traction sutures recovered from the implants of the medial row (g and f). For this, 1 end of each suture is recovered through the lateral portal, leaving the remaining in its corresponding portal. The recovered ends will cross the 2 medial ends of the graft and will be attached to it by means of a thick knot that will serve as a stop when positioning the graft by traction.
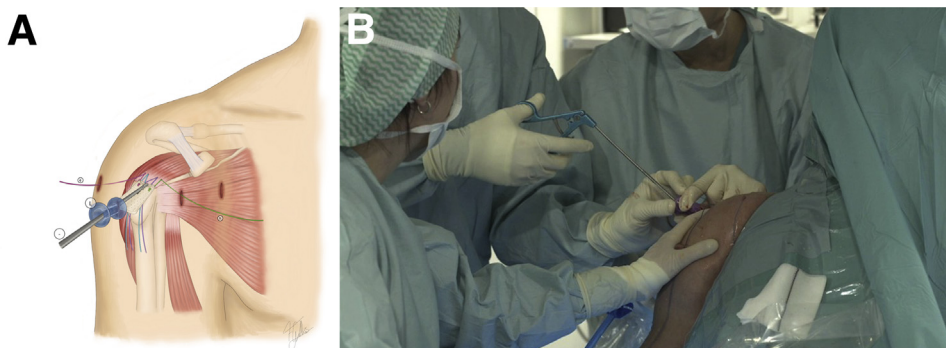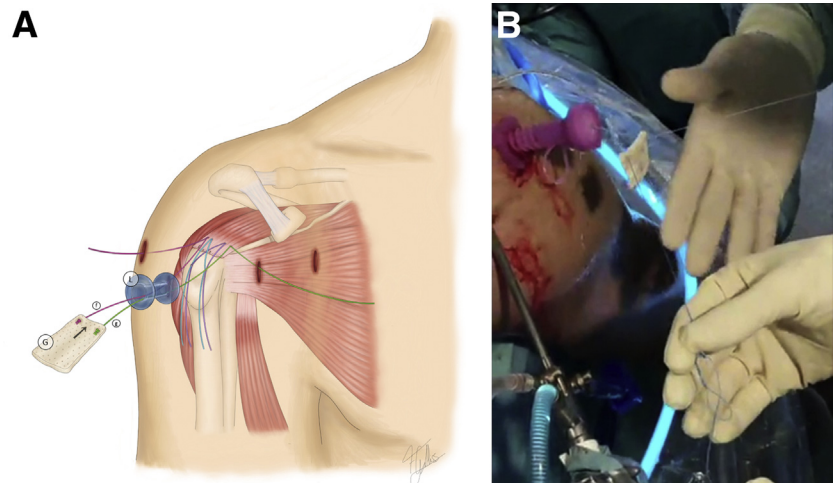
Fig 9. (A and B) Graft insertion is performed by applying traction from the free end of the sutures (e, h). We also use an arthroscopic tissue clamp (−). In this way, the graft is placed in its final position on the previous tendon repair. The first side that is fixed is the medial side. For this, the knots that were the top are externalized and cut to eliminate them. Then, conventional knotting is performed to fix the medial end of the graft on the repair.

Fig 10. (A and B) The lateral part of the graft is sutured in its final position using the additional ends that were loaded in the implants of the lateral row of the repair. After recovery, they are loaded in clamps for tissue passage and passed through the marks made in the lateral corners of the graft. Once these ends are knotted, the graft is definitively fixed on the previous double-row repair.
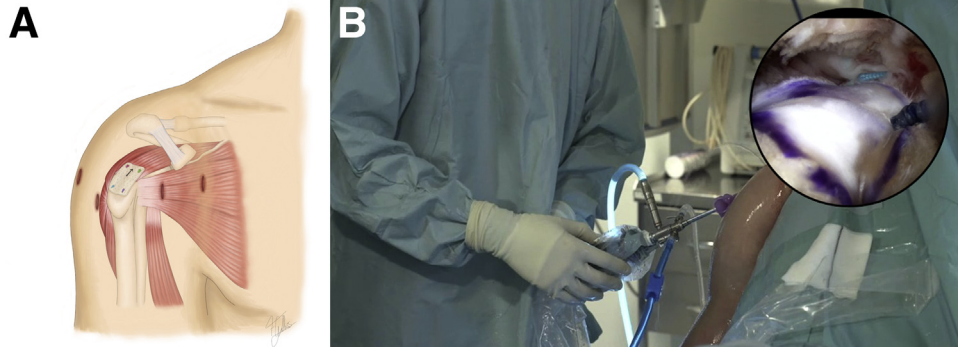
footprint–tendon interface without visual obstruction of the graft. In addition, when using a hybrid fixation technique in which the graft is fixed by sutures incorporated in the transosseous equivalent repair of the rotator cuff, it provides an increase in resistance in the load test as reported in biomechanical studies.[19]

There are limitations associated with this technique. Even though we consider it to be simple and reproducible, initially it can increase operating room time, and it exposes the patient to increased time under anesthesia. It can raise the costs of the repair, but only because of the cost of the allograft itself. Although there are risks associated with the use of cadaveric tissue, as discussed earlier, no immunogenic complications have been reported to date.

We present this technique hoping it will help other surgeons who, by knowing its advantages and limitations, can better design their patient-oriented clinical strategies. However, we are aware that prospective, randomized, controlled trials are needed to prove the technique's superiority to other rotator cuff repair surgical interventions.

Acknowledgments

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