Technical Note

Arthroscopic Transosseous Anchorless Rotator Cuff Repair Using the X-Box Technique

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Abstract: We describe a reproducible, step-by-step arthroscopic technique for anchorless transosseous rotator cuff repair using an X-box configuration with the Arthrotunneler device. The technique uses 2 bone tunnels and 4 high-strength sutures and is suitable for medium to large tears of the supra- and infraspinatus that would alternatively need a double-row repair with 4 anchors. Biomechanically, results appear to be similar as for anchored transosseous equivalent techniques. Enhanced biological healing and lower material costs are the possible benefits of this appealing arthroscopic approach that mimics the previous gold standard.

Arthroscopic rotator cuff (RC) repair techniques have significantly evolved during the last decades. In line with this rapid development, suture anchors have become the gold standard of arthroscopic RC repair. The procedure has proven itself to be safe, fast, and efficient.[1] Nevertheless obstacles remain, and the clinical and biomechanical impact of anchor management have been constantly assessed. Occasional knot impingement leading to prolonged postoperative pain, anchor pull-out requiring revision surgery, cyst formation with biological alteration of the tendon—bone interface, problems for additional anchor placement in revision arthroscopy,[2,3] and high financial costs[4] are difficulties that the orthopaedic surgeon has to face.

Transosseous techniques have distinct biological and biomechanical attributes, which tend to differ from anchor fixation. Biological healing in transosseous techniques seems to be enhanced by the maximized contact area between tendon and bone at the humeral footprint.[5] High surface pressure is distributed on an expanded zone of footprint space. Vascularity provided by the bone channels seems to be improved in anchorless techniques.[6]

A variety of techniques for arthroscopic transosseous RC repair have been proposed in the literature, for example, using an anterior cruciate ligament tibial drill guide[2] or a variety of bone needles.[3] Introduced in 2009, the Arthrotunneler (AT) device (Tornier/Wright, Memphis TN) offers significant improvements[3,7] and has rapidly gained in popularity. The purpose of this Technical Note is to describe a reproducible, standardized, and fully arthroscopic technique for anchorless transosseous RC repair using an X-box configuration. The technique is suitable for medium to large (2-4 cm) tears of the supraspinatus (SSP) and infraspinatus (ISP) that can easily be reduced to the footprint and that would alternatively need a double-row repair with 4 anchors.

Surgical Technique

We prefer the beach chair position and use a custom-made soft tissue traction system with 2 kg that maintains the arm in loose anteversion of 30° to 40° allowing free rotation and extension. The patient routinely receives general anesthesia combined with an interscalene block for better intraoperative monitoring of blood pressure and postoperative pain control. After skin marking of the osseous landmarks we proceed to diagnostic arthroscopy and portal placement. Apart from the posterior standard portal, we routinely use 3 portals: anterosuperior, lateral, and posterolateral. Additional percutaneous portals are used as needed for suture management.

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Table 1. X-Box Technique for Anchorless Transosseous Rotator Cuff Repair: 15 Steps

1. Diagnostic arthroscopy; manage biceps and subscapularis as indicated.
2. Preparation, debridement, and measuring of the exposed footprint; multiple channeling.
3. Switch scope to the posterolateral portal into the subacromial space. Perform extensive bursectomy and sparse acromioplasty; test tear configuration and mobility.
4. Insert 2 soft working cannulas into the anterosuperior and lateral portal.
5. Creation of medial bone tunnels manually with the 2.9-mm trocar in 2 clearly defined arm positions and with a camera in the lateral portal. Position A for the anterior tunnel and position B for the posterior tunnel.
6. Introduction of the Arthrotunneler (AT) into the anterior tunnel, arch of the device flush with the footprint, and the arm in position A. Drill lateral tunnel; check for the correct position of 2.4-mm drill with the Nitinol loop, which has to engage.
7. Catching of the Fiberwire (FW) loop introduced with a suture inserter with a Nitinol loop of the AT; anterior FW loop stored in the anterolateral percutaneous portal.
8. Repeat the same procedure with the AT in the posterior bone tunnel and the arm in position B.
9. Pass an anterior FW loop retrograde through the anterior supraspinatus with a Clever hook (CH), scope in the posterolateral portal.
10. Pass a posterior loop through the infraspinatus with a CH including its deep layer; scope is in the lateral portal.
11. Pull through 3 high-strength sutures with different color codes using a posterior FW loop, and store them in the lateral cannula.
12. Introduction of a PEEK cortical reinforcing device through a cannula over these sutures into the posterior tunnel. Remove the cannula and replace, leaving sutures outside.
13. Light blue suture from the top, tiger suture from bottom, and free white suture shuttled conjointly with an anterior FW loop through the anterior bone channel. Tightening of a light blue "box" suture compresses the tendon on the footprint. Check for possible dog ears.
14. Knot tying. All knots are positioned laterally onto the greater tuberosity. The sequence is as follows: (1) white anterior suture, (2) violet posterior suture, (3) light blue suture of "box," (4) tiger suture of X. X-Box repair is complete.
15. Optional: Posterior dog ear can be corrected with a left long white suture before tying the X.

The glenohumeral phase includes biceps tenodesis or tenotomy and repair of the subscapularis if necessary. We carefully inspect the articular side of the SSP and ISP and confirm a medium-to-large size tear. Then we proceed to footprint preparation with an aggressive shaver blade creating a facet of bleeding bone typically with an anteroposterior diameter of 2 to 4 cm (Video 1, Table 1). Next, bone marrow stimulation should be performed with the preferred device. Before leaving the joint space, we visualize the posterior cuff from the anterosuperior portal, paying attention to delamination of the ISP. The scope is now switched into the subacromial space where we proceed to a sparse acromioplasty and an extended bursectomy. A soft Passport cannula (Arthrex, Naples, FL) measuring 40 mm in length and 8 mm in diameter is placed in the anterosuperior portal and a second one in the lateral portal. With the scope in the lateral portal, bursectomy continues in the posterior and lateral gutter, which is an important step for later suture passage through the bone tunnels under adequate view. We now test tear configuration and mobility with a suture retriever. The described technique is only used if footprint coverage with no or little tension is readily obtained. Figure 1 shows the working principle of the AT device.

We now manually proceed with the 2.9-mm trocar of the AT instrumentation to the creation of the medial bone tunnels in 2 clearly defined arm positions and with the scope in the lateral portal. Position A (Fig 2) for the anterior tunnel is in full adduction of the arm to the trunk; camera and arm position are secured by the assistant. To obtain position B (Fig 3) for the posterior tunnel, the upper arm is abducted to 45° by the

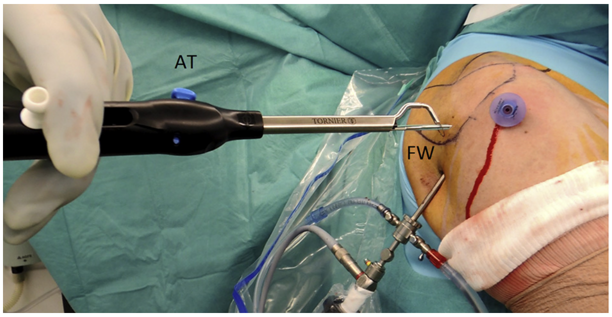

Fig 1. Patient in beach chair position, right shoulder. View of an Arthrotunneler device showing a suture inserter with a Fiberwire loop inside the deployed Nitinol loop. (AT, Arthrotunneler device; FW, Fiberwire loop inside Nitinol loop.)

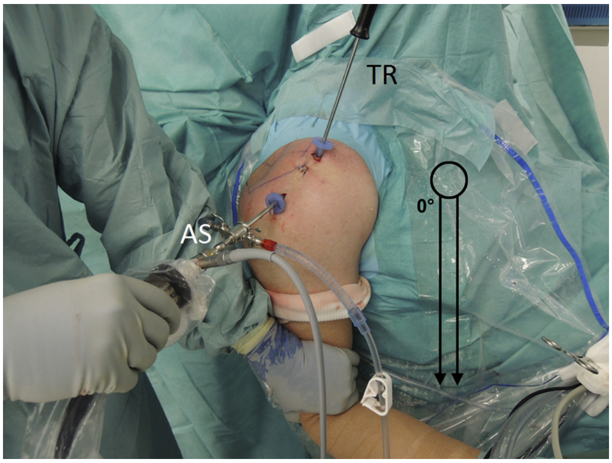

Fig 2. Patient in beach chair position, right shoulder, flexible soft tissue extension, 2 working cannulas in anterosuperior and lateral portal. The assistant holds the arm in position A in full adduction. The arthroscope is in the lateral portal; a 2.9-mm trocar creates an anterior tunnel. (AS, arthroscope; TR, trocar.)

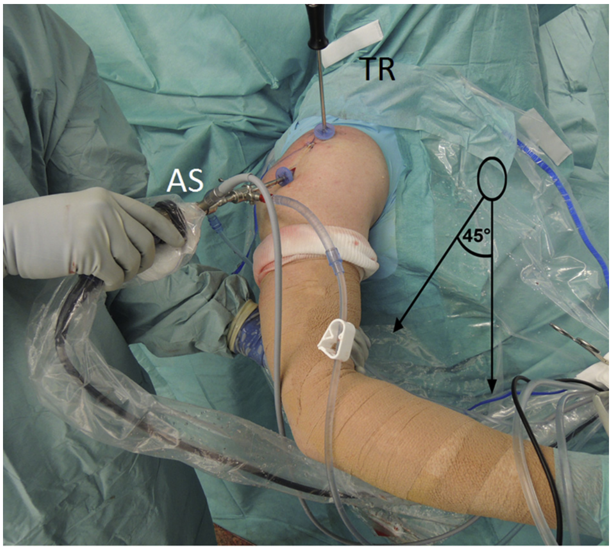

Fig 3. Identical setup as in Figure 2, but the assistant holds the arm in position B with 45° of abduction for the posterior tunnel. (TR, trocar; AS, arthroscope.)

assistant. This results in a 1 to 2 cm more posterior entry point (Fig 4A).

The AT device is now introduced from the lateral portal so that the tip engages the anterior tunnel and the arch is flush with the footprint (Fig 4B). The arm is secured in position A, while the surgeon is drilling the 2.5-mm intersecting lateral tunnel and checks drill engagement with the Nitinol loop of AT. The suture inserter with a Fiberwire (FW) loop (Arthrex, Naples, FL) replaces the drill; the Nitinol loop is firmly pulled back and thus catches the suture. The FW loop is retrieved by lifting the AT out of the tunnel (Fig 4C), pulled out of the joint, and stored in a percutaneous anterolateral portal to avoid suture tangling. With the arm in position B, the same procedure is repeated for the posterior tunnel, leaving 2 FW loops in place (Fig 5A). A Clever hook (DePuy Mitek, Raynham, MA) is used to pass the anterior loop through the anterior cuff tissue first and then the posterior loop through the posterior cuff, including its deep layer (Fig 5 B, C).

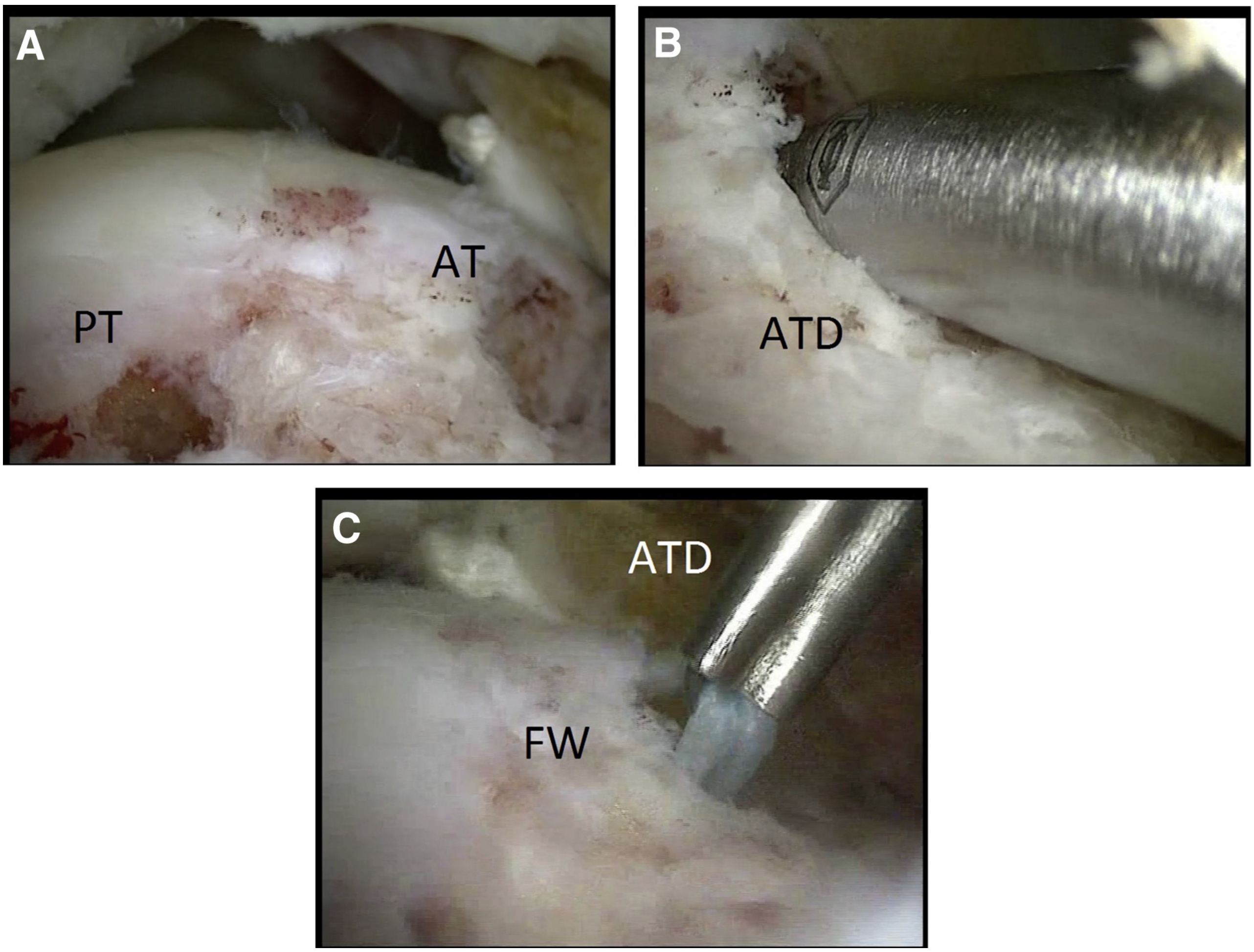

Fig 4. Right shoulder, posterolateral viewing portal. (A) Medial tunnels adjacent to articular cartilage 1 to 2 cm apart. (B) The Arthrotunneler is introduced into the anterior tunnel, and the arch flush with the footprint. (C) The Arthrotunneler retrieves the Fiberwire shuttle loop. (AT, anterior tunnel; ATD, Arthrotunneler device; FW, Fiberwire loop; PT, posterior tunnel.)

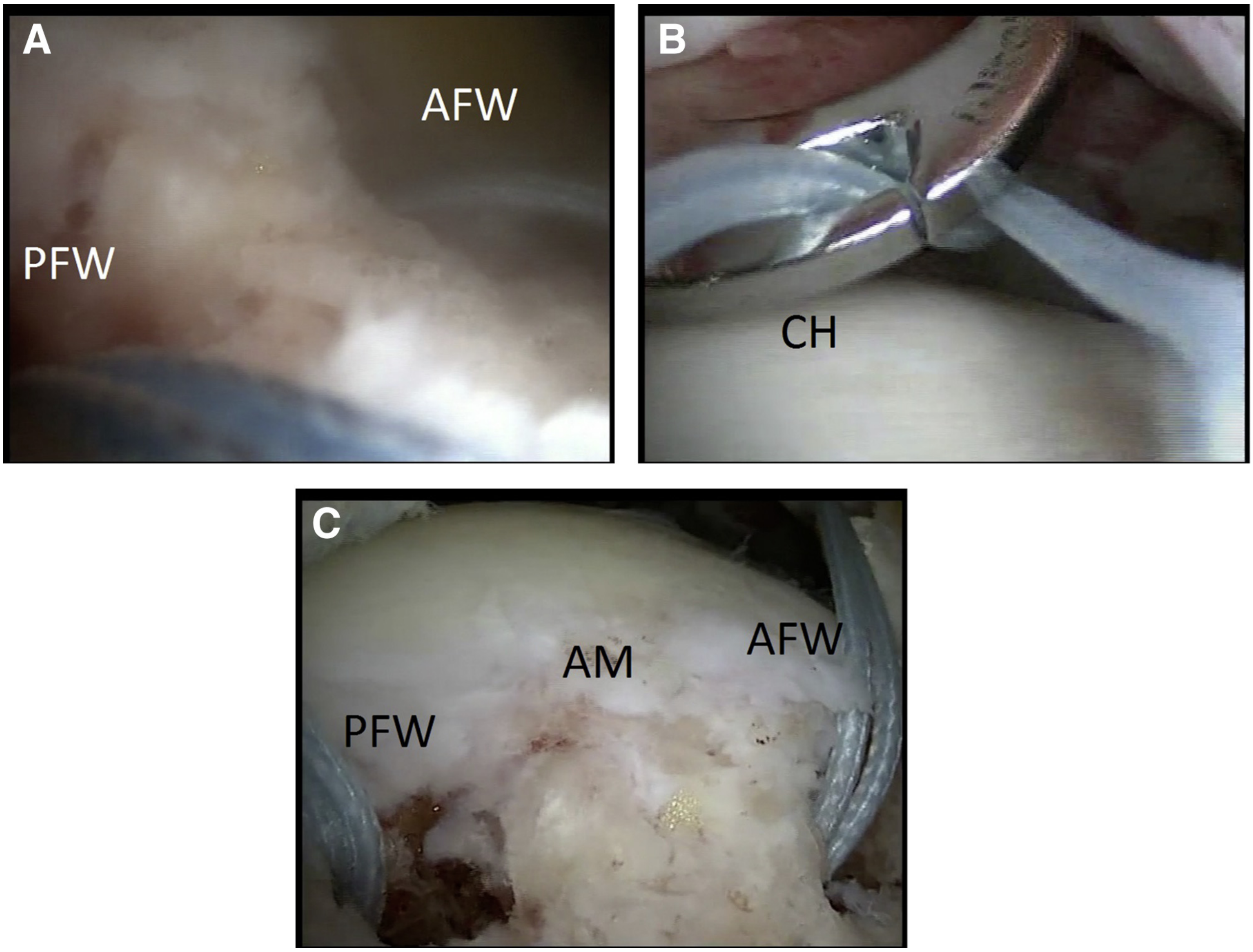

Fig 5. Right shoulder, posterolateral viewing portal. (A) Both Fiberwire loops have been pulled through bone tunnels. (B) Clever hook catching the posterior Fiberwire loop. (C) Both shuttling loops have been pierced through the cuff anteriorly and posteriorly. (AFW, anterior Fiberwire loop; AM, articular margin; CH, Clever hook; PFW, posterior Fiberwire loop.)

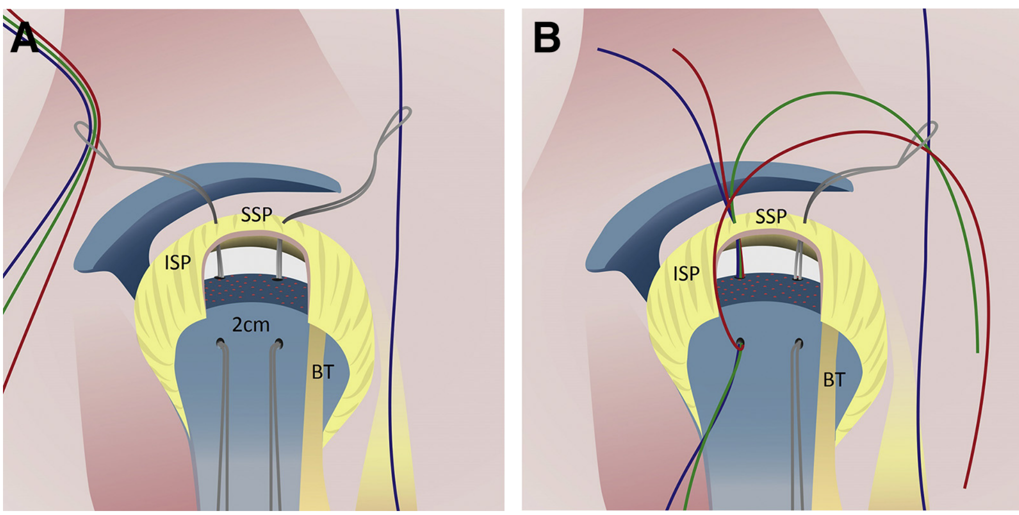

Fig 6. (A) Right shoulder, lateral view. Diagram showing shuttle loops ready to pull 3 color-coded high-strength sutures through the posterior tunnel. Tunnels are about 2 cm apart. (BT, biceps tendon; ISP, infraspinatus; SSP, supraspinatus.) (B) Diagram showing suture management for the anterior shuttling maneuver.

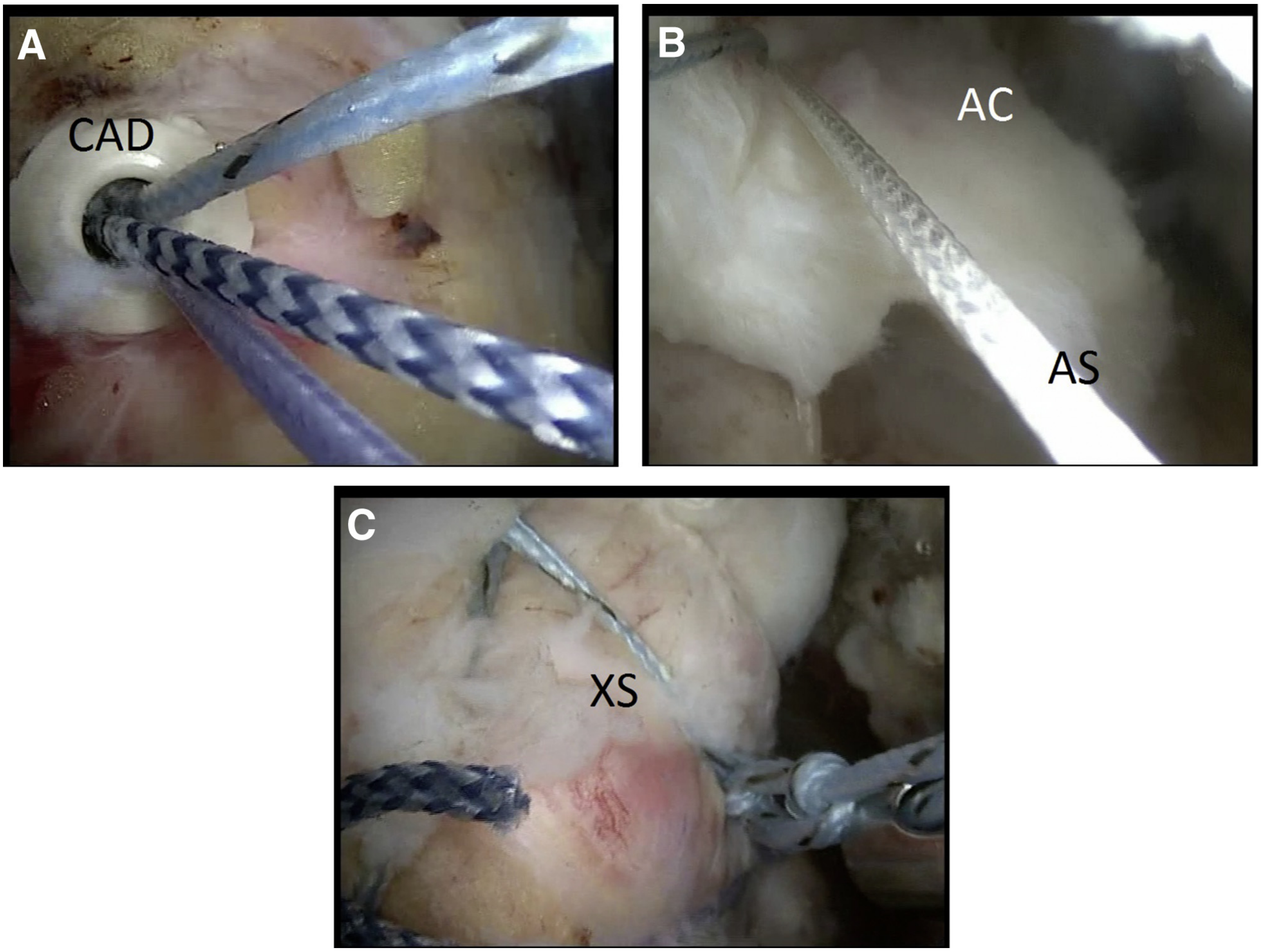

Fig 7. Right shoulder, posterolateral viewing portal. (A) Posterior tunnel with cortical augmentation device and 3 different sutures (light blue, violet, tiger). (B) The anterior white suture is tied first. (C) The tiger suture of the X is tied last. (AC, anterior cuff; AS, anterior suture; CAD, cortical augmentation device; XS, X suture.)

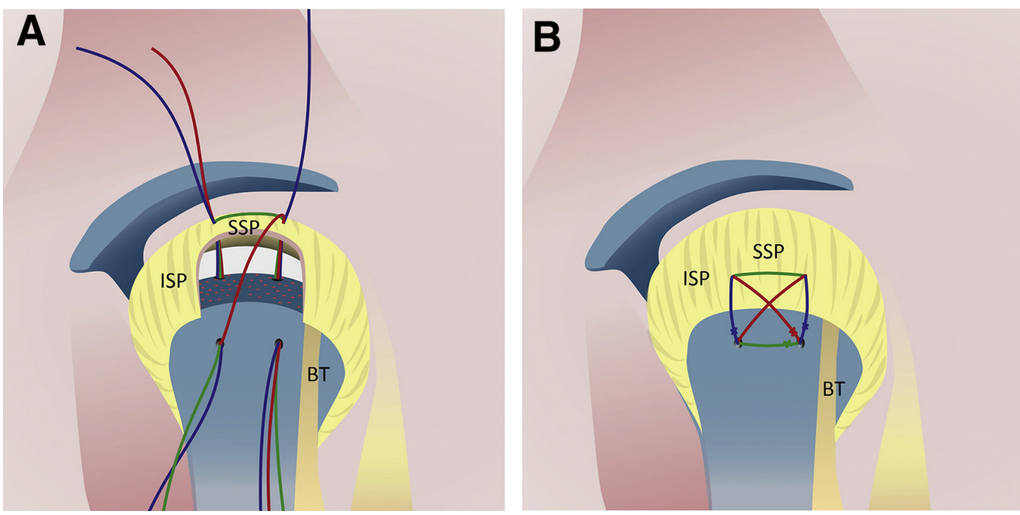

Fig 8. (A) Right shoulder, lateral view. Diagram after shuttling of all 4 permanent sutures through the 2 tunnels. (BT, biceps tendon; ISP, infraspinatus; SSP, supraspinatus) (B) Diagram after knot tying, X-box is complete; all knots are flush on the bone of the greater tuberosity.

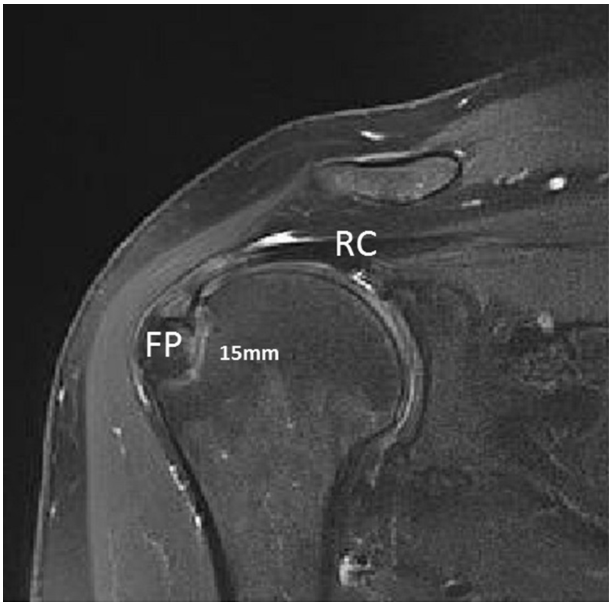

Fig 9. Coronal magnetic resonance imaging scan of patient 2 years postoperatively. Tunnel with a 15-mm bone bridge and recreation of the footprint are clearly appreciated. Sugaya type II tendon. (FP, footprint; RC, rotator cuff.)

With the help of the posterior loop, 3 color-coded high-strength sutures (FW, and Orthocord, DePuy Mitek) are now shuttled through the posterior tunnel (Fig 6 A, B), which we routinely reinforce with a cortical augmentation device from PEEK (polyether ether ketone) inserted into the greater tuberosity (Fig 7A). One suture from the top and 1 from the bottom are retrieved inside the working cannula together with the anterior loop, and a fourth high-strength suture is added into this loop before performing the shuttling maneuver anteriorly (Fig 8A). We are now ready for knot tying. Sequential knot tying begins with the straight anterior suture (Fig 7B; blue in diagram/white in video), which can be left long for posterior dog ear correction. Second, we tie the posterior straight suture (blue in diagram/violet in video), tighten it over the cuff, place the knot onto the tuberosity, and cut it. The box suture (green in diagram/light blue in video) is tightened, further reducing and compressing the cuff onto the FP, and finally the X (red in diagram/tiger suture in video) suture is tied (Fig 7C), leaving all knots on the tuberosity side. The X-box repair is now completed (Fig 8B) and inspected from the bursal and the articular side.

There are 2 modifications of the standard technique: (1) A posterior dog ear can be easily corrected with left long white anterior suture before tying the X. (2) In case of further tear extension into ISP with typical delamination, we add a fourth suture when shuttling through the posterior channel. This suture will be passed through the cuff far posteriorly using a suture lasso and provides additional stability for the deep portion of ISP.

Discussion

Transosseous techniques have been the mainstay of open RC repairs. The approach is based on transosseous bone channels (tunneling) located at the footprint of the SSP and ISP tendon. In the wake of the advancement of arthroscopic routines, transosseous fixation procedures have been left behind, and arthroscopic suture anchor fixation is becoming the predominantly chosen therapy concept.[1] The foundation of any successful RC repair depends on specific mechanical key factors. Pressure, a maximized contact area, and reduction of motion at the tendon–bone interface have been shown to promote healing between tendon and footprint. In the continuing pursuit to improve tendon healing, RC repair techniques have evolved with the aim to design stronger biomechanical constructs. These efforts have led to the advent of transosseous equivalent (TOE) suture bridge fixation with anchors[8] and—recently again—arthroscopic anchorless transosseous techniques.[2,3]

Compared with single-row anchor fixation, the tendon constructs after repair with transosseous sutures have shown, in a classical article by Apreleva et al.,[5] a greater area of contact at the tuberosity and thus better potential for healing. More recent biomechanical studies show low tendon mobility at the tendon–bone interface for both anchored and anchorless repairs.[9,10] Although anchored fixation has shown superior results on cyclic loading[1,11] some other biomechanical studies have shown equivalent results concerning cuff edge displacement,

Table 2. Advantages and Disadvantages of Transosseous Rotator Cuff Repair as Compared With Anchor Fixation

Pros	Cons
Favorable pressure distribution on footprint like previous open gold standard	Operation time longer on beginning of learning curve
High blood flow provided by bone tunnels	Technically more challenging in complex tear configurations
Untouched footprint in revision surgery	Possible cut-through of sutures in osteoporotic bone (rarely observed)
Lower costs	Lower ultimate failure load according to some biomechanical studies
Equal operating time as anchored technique	
Easily mastered by experienced arthroscopist	
Anatomic footprint restoration as observed on magnetic resonance imaging	

pull-out force, and failure rates.[10] Biological tendon healing seems to be enhanced not only by the maximized contact area between tendon and bone at the humeral footprint, but also by the tunneling of the transosseous sutures at the greater tuberosity, acting like additional channeling at the footprint. In an ultrasound study, increased blood flow in the repaired RC could be shown in a transosseous approach as compared with TOE fixation.[6] Obviously, medial cuff failures are a concern of TOE techniques, because with the advent of double-row fixation, medial retears on the muscle—tendon junction have been observed more frequently.[9,12] They seem to represent a potentially severe drawback of these techniques but are not typically associated with anchorless transosseous techniques.

In regard to range of motion and subjective outcome scores, arthroscopic transosseous RC repair has shown significant midterm improvement. Studies have shown high healing rates and few complications.[3,7,13] Suture cut-thorough of bone was only exceptionally observed.[2,7] Randelli et al.[14] demonstrated for the first time in a randomized double blind clinical trial comparing arthroscopic anchorless transosseous versus anchored single-row repair similar results regarding magnetic resonance imaging—assessed tendon healing (87% vs 88% Sugaya type I-III 1 year after surgery) and shoulder function assessed by Constant score, QuickDASH, and pain score.

Owing to the high incidence of RC disease, treatment and material costs in shoulder surgery have become a socioeconomic challenge. To achieve a stable fixation and reconstruction of the RC, the number of suture anchors depends on the size and configuration of the tear. In a transosseous approach, the tunnels at the footprint can be simply adapted to the extent of any RC lesion, and furthermore, the same instrument (AT) can be used multiple times during 1 operation, limiting hardware usage. Thus, in transosseous approaches, material costs were significantly lower, while surgical time was identical.[4]

Our technique complies with all advantages of a fully arthroscopic technique including less postoperative pain, better cosmetics, and a favorable patient acceptance. Following systematic step-by-step management, transosseous RC repair is a safe and reproducible technique (Table 1). Using different colors is of great help for suture management and contributes to avoiding accidental suture pull-out. The learning curve is steep but can be mastered by the experienced arthroscopist, such that after the first 20 to 30 cases, no extra operating time has to be calculated. Cortical reinforcement was routinely used for the posterior tunnel where bone might be weaker than anteriorly close to the bicipital groove. Figure 9 shows an example of a magnetic resonance imaging follow-up 2 years postoperatively with excellent footprint restoration. The 15-mm bone bridge created by the AT device is still clearly appreciated on this coronal image (Table 2).

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