Technical Note

Rotator Cuff Repair Technique With Transosseous Knotless Anchor System

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Abstract: Various surgical techniques exist for rotator cuff repair that provide a suitable environment for tendon–bone healing. Arthroscopic recreation of transosseous repairs, which had previously been performed by open or miniopen techniques, can now be performed; however, arthroscopic, transosseous passage of suture material can be challenging technically. There are potential biologic and cost-saving advantages of arthroscopic transosseous rotator cuff repair that make an efficient and reproducible technique desirable for arthroscopists. The technique for arthroscopic transosseous rotator cuff repair using a knotless anchor-based system is demonstrated in the current Technical Note. Potential advantages of this construct include excellent biomechanics, enhanced footprint vascularization, and utility in poor bone quality while using minimal anchor numbers. Further studies will be needed to elucidate healing rates and clinical outcomes.

Arthroscopic rotator cuff repair techniques have been developed and modified to improve biomechanical properties of repair constructs and to restore an environment suitable for tendon–bone healing. Factors thought to contribute to a favorable healing environment include higher failure loads, reduced gap formation during cyclic loading, increased tendon–bone contact, and footprint coverage.[1,2] Various repair constructs have been used that achieve good clinical healing rates and functional outcomes, although re-tears, repair failures, and poor outcomes do occur. Recently, arthroscopic transosseous repair constructs have been described that may offer advantages to traditional arthroscopic constructs, including broad footprint coverage, fewer anchors, and decreased pain with similar functional outcomes.[3-5]

To further study biomechanical properties of arthroscopic transosseous repair, Tashjian et al.[2] compared biomechanical properties of a transosseous-equivalent (TOE) repair technique with a knotless anchor transosseous repair system (KATOR, Logan, UT). Results of this comparison demonstrated that there were no significant differences in cycling gapping, stiffness, and ultimate failure loads between techniques in cadaveric specimens despite using 4 anchors in the TOE technique and only 2 in the KATOR system. Additionally, TOE repair failures occurred by complete or partial construct-related failure, whereas transosseous knotless anchor failures occurred only via soft-tissue failure. Reduced anchor burden, allowing for an increased bony surface for healing, and potential reduction in implant-related cost were noted to be potential advantages of the knotless transosseous system.

Because transosseous repair, performed arthroscopically, requires passage of suture material through bone tunnels, the surgical technique may be technically challenging and less efficient than traditional repair for some surgeons.[6] This has been addressed by new instrumentation that facilitates transosseous passage and may improve ease and efficiency for surgeons using transosseous repair. The KATOR suture anchor system may offer a solution for knotless, arthroscopic, transosseous rotator cuff repair, with instrumentation designed for simple and fast transosseous suture passage and intuitive suture management. The following technique illustrates the use of an arthroscopic knotless transosseous repair system for rotator cuff tear.

Surgical Technique

The repair was performed as follows and is indicated for small to large rotator cuff tendon tears with mobility

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Table 1. Pearls and Pitfalls

Pearls	Pitfalls
Perform adequate subacromial/subdeltoid bursal debridement to allow visualization before tunnel placement.	Avoid suture unloading from anchor during suture passage.
After medial tunnel creation with fluted awl, clear residual debris from medial tunnel using arthroscopic shaver with suction.	Pass sutures appropriately in rotator cuff tissue to avoid tissue overtensioning, similar to conventional double-row suture passage.
If more than 1 anchor is to be used, drill an anterior lateral tunnel just posterior to biceps groove to allow space for posterior lateral tunnel.	Avoid tangling of suture within cannula by maintaining slight tension on suture ends during anchor passage through cannula.
Allow adequate spacing between transosseous tunnels to avoid tunnel convergence.	
Note arm position (i.e., rotation and abduction) at time of tunnel creation.	
Before anchor insertion, note that arm position adjustment may be required for collinear insertion of anchor. A small switching stick passed easily into lateral tunnel may be performed ensure trajectory is appropriate before anchor insertion.	

appropriate for reasonable footprint coverage. The patient is positioned in the beach chair position, and the operative arm is draped after sterile preparation. An arm holder of the surgeon's choice is used. A diagnostic arthroscopy is performed using a 30° arthroscope viewing from a standard posterior portal, and a

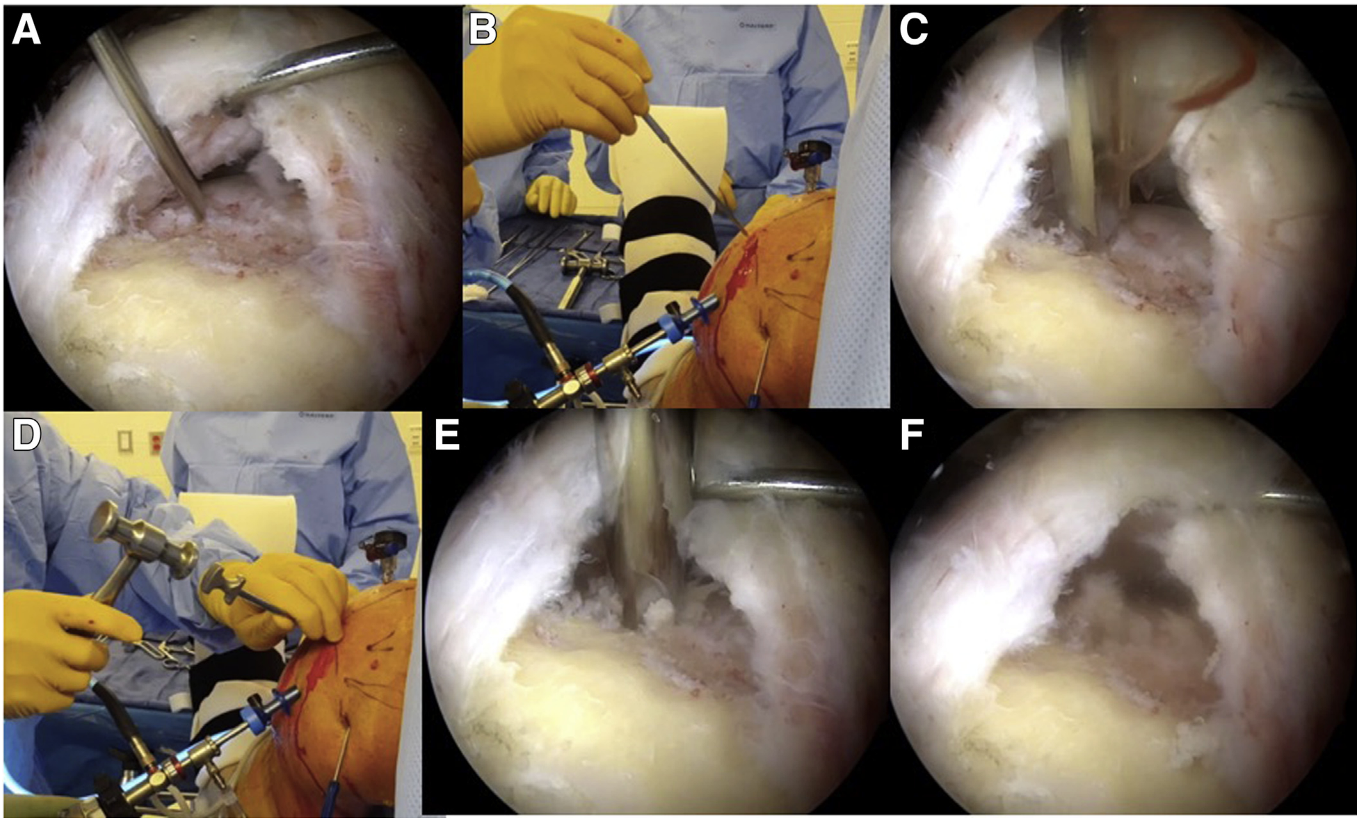

Fig 1. Arthroscopic and exterior views of medial tunnel creation. Arthroscopic view of a left shoulder rotator cuff tendon tear after footprint preparation viewed with a 30° arthroscope from a lateral viewing portal. (A) A probe from the posterior portal elevates the tendon while a spinal needle is inserted just off the lateral edge of the acromion for localization of medial tunnel placement for a transosseous rotator cuff repair. (B) Exterior view from posterior of a left shoulder in beach chair position, demonstrating position of lateral viewing portal and arthroscope, and the position and trajectory of the medial fluted awl inserted through a stab incision just off the lateral aspect of the acromion. (C) Arthroscopic view of fluted awl positioned on footprint, for creation of the anterior medial tunnel, just lateral to the articular surface at the anterior aspect of the rotator cuff tear. (D) Exterior view demonstrating position and trajectory of the fluted awl as it is malleted, creating the medial portion of the transosseous tunnel. (E) Bony debris is noted in the flute of the awl during creation of the tunnel. (F) Rotation and removal of the awl clears bony debris and completes the creation of the medial portion of a transosseous tunnel.

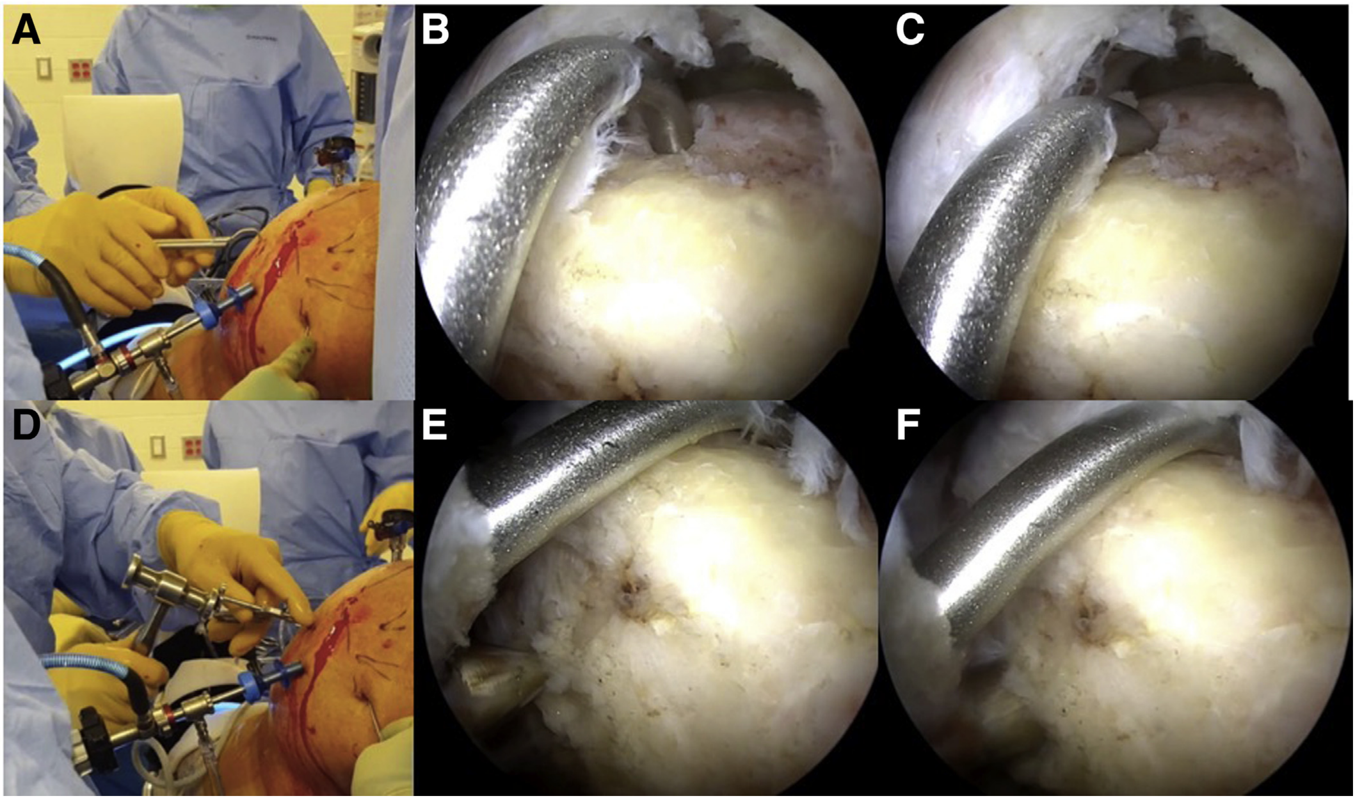

Fig 2. Exterior and arthroscopic views of lateral tunnel creation. (A) Exterior view from posterior of a left shoulder in beach chair position, demonstrating position of lateral viewing portal and arthroscope, and the position and trajectory for insertion of the BoneStitch tunnel guide through a lateral portal located at the anterior edge of the rotator cuff tear, about to be inserted percutaneously to facilitated lateral tunnel creation. (B) Arthroscopic view of a left shoulder rotator cuff tendon tear viewed with a 30° arthroscope from a lateral viewing portal, with insertion of the tunnel guide into a previously created medial tunnel, (C) followed by full seating of the guide flush with greater tuberosity laterally. (D) Exterior view after insertion of the lateral punch into the tunnel guide, and a mallet about to drive the lateral punch into bone to complete creation of transosseous tunnel. Arthroscopic view demonstrating entrance of the lateral punch on the lateral aspect of the greater tuberosity, in the same plane with the tunnel guide positioned within the previously created medial tunnel (E) before and (F) after malleting the lateral punch to complete transosseous tunnel creation.

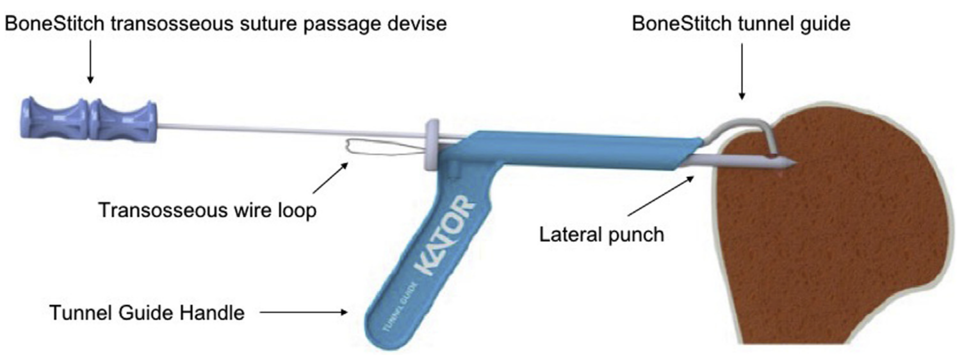

Fig 3. Schematic representation of the BoneStitch transosseous suture passage device system after insertion and deployment through the KATOR tunnel guide. After insertion of the device into the upper aperture of the tunnel guide, a wire is advanced, passing within the tunnel guide to traverse the medial and lateral tunnels within the greater tuberosity. The wire loop exits the aperture of the lateral punch. Four strands of No. 2 suture, or 2 strands of high-strength suture tape are placed within the wire loop and passed transosseously with withdrawal of the device.

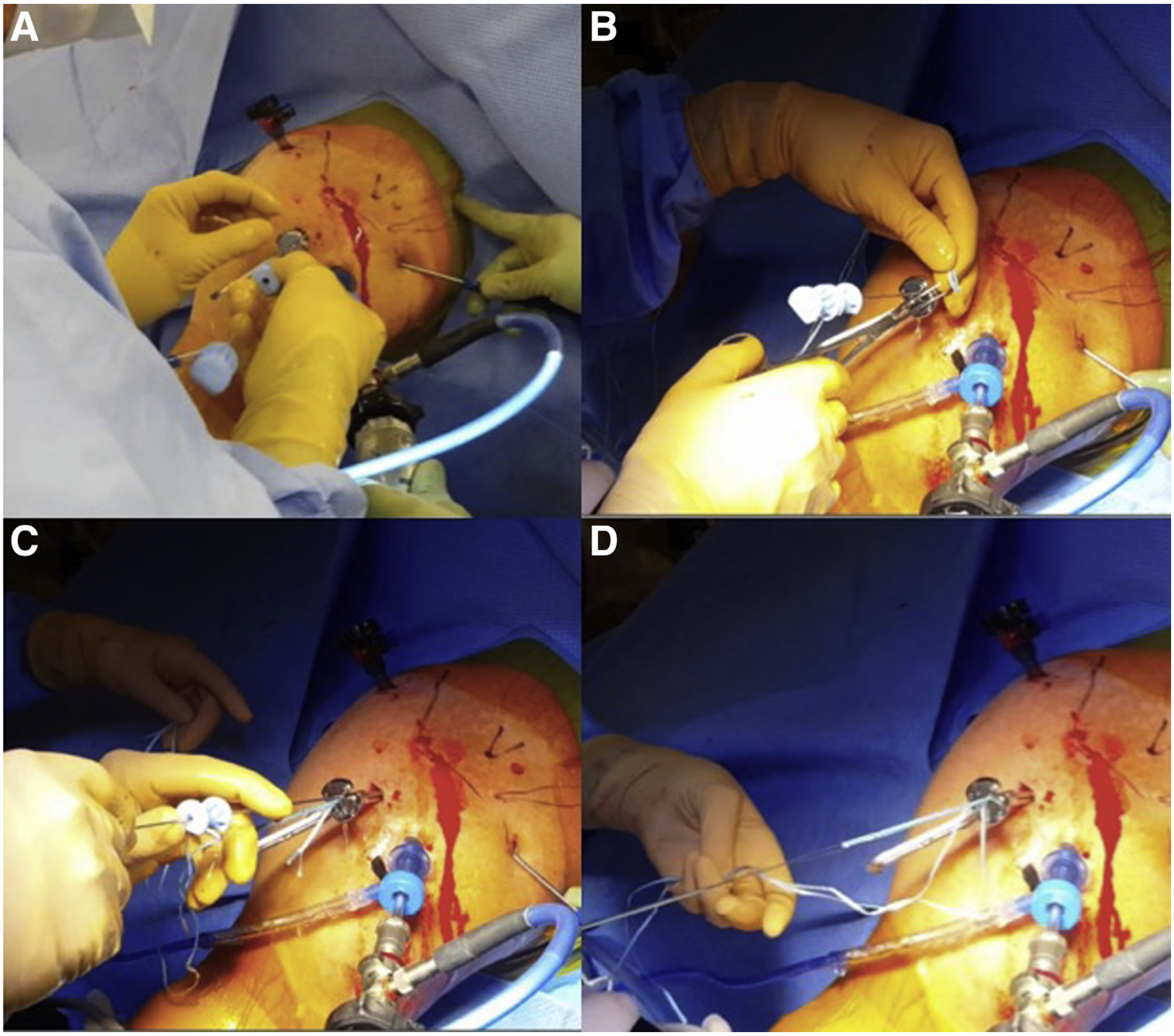

Fig 4. Exterior view from posterior of a left shoulder in beach chair position demonstrating insertion of BoneStitch transosseous suture passage device and passage of high-strength suture limbs. A 30° arthroscope is present in a lateral viewing portal and a tunnel guide in the lateral working portal. An arthroscopic probe in the posterior portal assists with retraction; a black crystal cannula is present in the anterior portal. (A) The transosseous suture passage device (light blue handle) is inserted through the tunnel guide in the lateral working portal. A curved Kelly clamp is used to pass 2 strands of high-strength suture tape through the wire loop of the transosseous suture passage device. (B) The wire loop exits the lateral punch of the lateral tunnel guide. (C and D) The transosseous suture passage device is being withdrawn from the tunnel guide, facilitating passage of 2 strands of high-strength suture material through a previously created transosseous tunnel within the proximal humerus.

standard anterior working portal is established. After glenohumeral arthroscopy, the subacromial space is accessed and debrided of inflammatory subacromial bursa, facilitating visualization of the rotator cuff tear (Table 1). Using spinal needle localization, a lateral viewing portal is established, as is a lateral working portal near the anterior edge of the rotator cuff tear, which is typical for rotator cuff repair. Next, with visualization through the lateral portal, preparation of the tendon edge and footprint is performed. Thorough preparation of the lateral subdeltoid bursal space is performed to allow adequate visualization for later lateral tunnel creation. At this point, a large Passport cannula (Arthrex, Inc., Naples, FL) may be used to facilitate passage of instrumentation laterally, but percutaneous placement can be performed, as demonstrated in Video 1.

Video 1 demonstrates the creation of transosseous tunnels, viewing from an accessory lateral portal. First, a medial bone tunnel is created. After approximation of the medial tunnel using spinal needle localization just off of the lateral aspect of the acromion (Fig 1A), the entrance of the medial tunnel is selected. Here the medial tunnel is placed on the most medial aspect of the

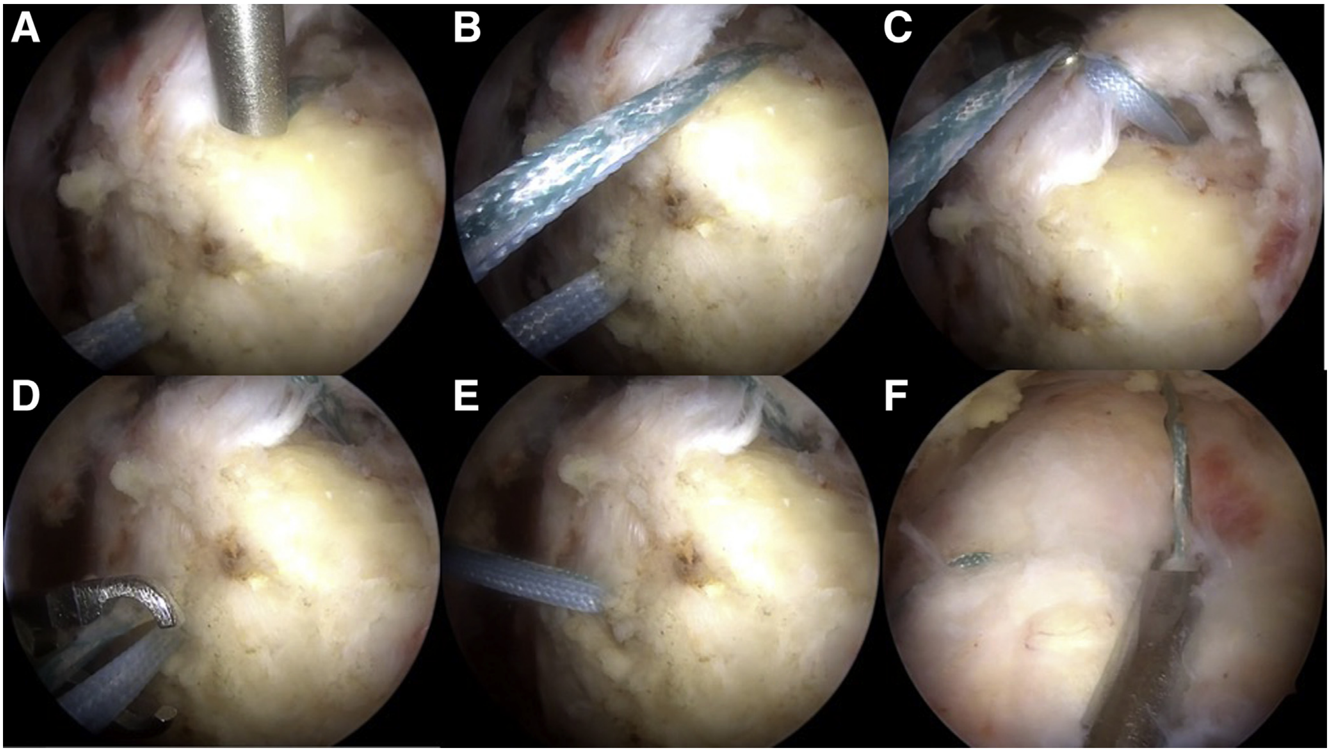

Fig 5. Arthroscopic view after transosseous suture tape passage, suture shuttling, and passage through rotator cuff tendon. Arthroscopic view of a left shoulder viewed with a 30° arthroscope from a lateral viewing portal. (A) The BoneStitch tunnel guide is being withdrawn from the previously created medial tunnel, leaving 2strands of high-strength suture tape, which has been passed through a transosseous tunnel. (B) Medial limbs exit the medial portion of the transosseous tunnel and lateral limbs exit the lateral portion of the tunnel. The medial limbs can be retrieved from the (C and E) anterior portal and lateral limbs retrieved (D and E) from an anterolateral stab incision to facilitate suture management during passage into rotator cuff tendon tissue. An arthroscopic suture passer is used to sequentially pass the medial limbs of high-strength suture tape through rotator cuff tendon, similar to the process used if medial suture bridge anchors had been placed. (F) In this example, medial limbs are passed approximately 5 mm lateral to the musculotendinous junction, separated by 5 mm anterior to posterior.

greater tuberosity. The fluted awl is introduced through a stab incision made after spinal needle localization (Fig 1B) and positioned onto bone (Fig 1C). The awl is malleted (Fig 1D) to a depth denoted by a line on the awl and rotated during removal from bone, clearing bony debris from the tunnel (Fig 1E and F). The BoneStitch tunnel guide is introduced through the working lateral portal (Fig 2A) and the tip positioned within the medial tunnel, using a bend that accommodates the profile of the greater tuberosity to fully seat the guide (Fig 2A and B). Next, the lateral punch is introduced into the BoneStitch guide and the location of the first lateral tunnel is confirmed visually, allowing for appropriate tunnel spread between tunnels, if 2 or more are to be placed (Fig 2D and E). Typically, the lateral tunnel for an anterior anchor is placed just posterior to the biceps at the anterior humeral edge. The lateral tunnel is punched using a mallet, thereby completing the transosseous path for suture placement (Fig 2D and F).

At this point, transosseous suture passage is performed. The BoneStitch guide remains in place, and the transosseous suture passage device is introduced into the cannulated guide (Fig 3 and 4A), best demonstrated in Video 1. Depending on surgeon preference and tear morphology, 4 strands of No. 2 suture, or 2 strands of high-strength suture tape can be passed in each transosseous tunnel. Two strands of 2-mm high-strength suture tape, as demonstrated in this case, is introduced into the BoneStitch wire loop (Fig 3 and 4B) and passed transosseously by removing the suture passage device from the guide (Fig 4C and D). The lateral and medial punches are removed (Fig 5A and B); transosseously positioned suture tape is now available for passage into tissue (Fig 5B). If more than 1 anchor is to be used, as in this example, the medial and lateral suture tape strands can be retrieved and stored in the anterior portal and an accessory anterolateral portal, respectively, while an additional transosseous tunnel is created (Fig 5C-E).

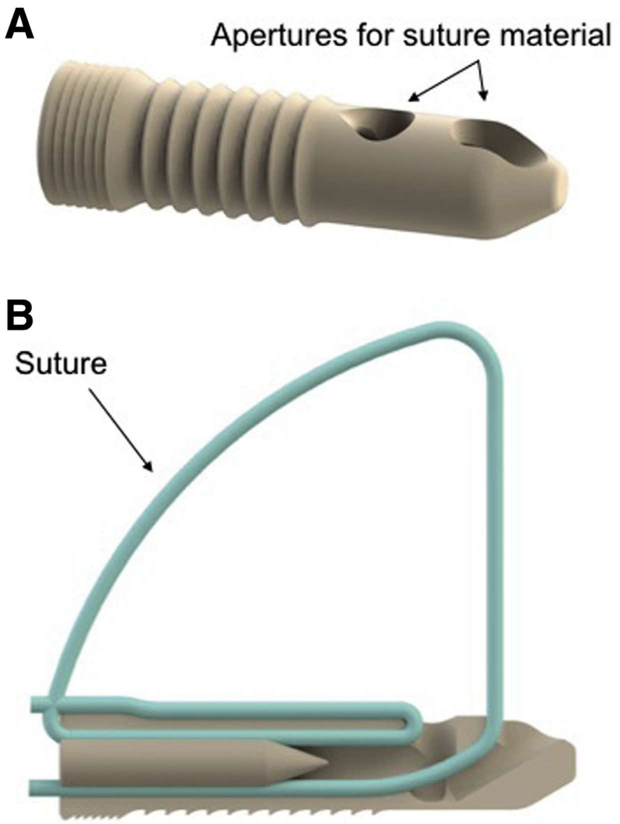

Fig 6. (A) Exterior depiction of polyetheretherketone knotless suture anchor and (B) cross-sectional image depicting suture arrangement after suture passage and locking member deployment within the anchor. The anchor body dimensions are 4 mm in diameter and 20 mm in length. The anchor provides an interference fit within bony tunnels. Two openings allow for entrance of medial and lateral tunnel suture or tape strands within the longitudinal passageway of the anchor. Within the anchor, a locking member compresses the suture against the anchor body, allowing knotless fixation.

A second tunnel, if needed, is created in a similar fashion approximately 10 to 12 mm posterior to the anterior tunnel by again using a medial punch and lateral punch through the BoneStitch guide. Again, 2 strands of suture tape, or alternatively, 4 strands of suture, are passed using the suture retriever. These are retrieved and stored in the posterior cannula for eventual passage through tissue.

At this point, a cannula is placed in the lateral working portal to facilitate suture management and sequential retrieval and passage of suture tape through rotator cuff tissue using an arthroscopic suture passer is performed (Fig 5F), identical to the process used if medial suture-bridge anchors had been placed. In the current example, the 4 suture tape limbs exiting from the medial tunnels are passed approximately 5 mm lateral to the musculotendinous junction, separated by 5 mm anterior to posterior.

After medial suture limbs have been passed through rotator cuff tendon, the anchor is loaded for eventual knotless fixation (Fig 6). Suture limbs exiting the lateral tunnels are loaded first. In this example, the 2 lateral strands from the anterior tunnel are first retrieved from the lateral working portal. These limbs are passed into the anchor using the labeled wire loop 1 (Fig 7, 8A and B). Keeping tension on the lateral suture tape (Fig 8C), the splittable plastic sheath is inserted under direct visualization (Fig 9). If this does not glide easily into the tunnel, adjustment of the arm may be necessary to improve ease of passage. Before loading and inserting the anchor, proper cannula/tunnel alignment can be confirmed by passing a metal rod or small switching stick through the lateral working cannula into the tunnel, checking for collinearity. After the splittable sheath is successfully inserted within the lateral tunnel, 2 strands of medial suture are then retrieved for placement into the anchor via wire loop 2 (Fig 7 and 10A-D). In this example, the most anterior limb and third-most anterior limb are retrieved and passed into the anchor using the labeled wire loop. The splittable sheath (Fig 7) is removed and discarded, and the anchor is attached to the Reusable Anchor Inserter via a screw-on mechanism (Fig 11A). Keeping tension on both the medial and lateral suture limbs, the anchor is introduced into the cannula to the aperture to the anterior tunnel (Fig 11B). Initial tension is applied to the medial sutures. The anchor is

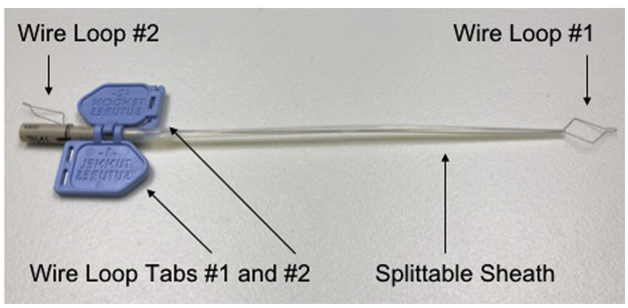

Fig 7. Suture anchor with splittable sheath and wire loops with tabs. Two strands of high-strength No. 2 suture tape or 4 strands of high-strength suture tape can be passed through each wire loop. Suture ends from the lateral bone tunnel are retrieved and passed through the anchor using wire loop 1. The splittable sheath allows easy transfer through a cannula and guides the anchor system into the lateral tunnel. Suture ends from medial bone tunnel, having been passed through rotator cuff tissue, are retrieved and passed through the anchor using wire loop 2. Care is taken to avoid unloading of the anchor during suture retrieval.

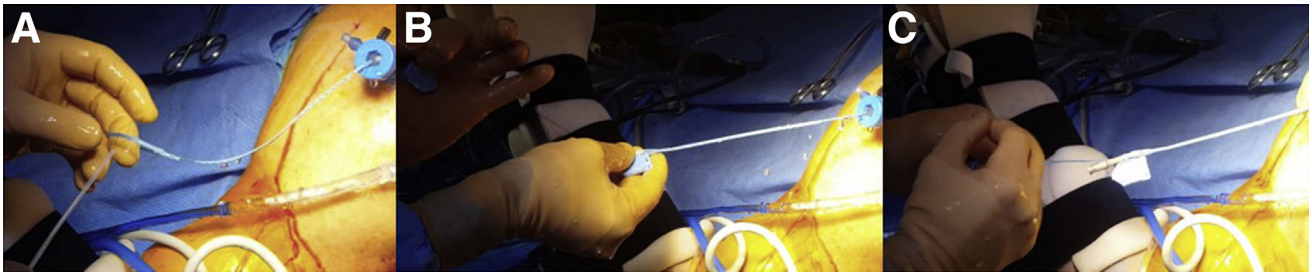

Fig 8. Exterior view from posterior of a left shoulder in beach chair position demonstrating loading of lateral suture limbs onto the anchor and positioning of the anchor before insertion through a lateral cannula. (A) Two high-strength suture limbs retrieved from the lateral portion of the transosseous tunnels through a lateral working portal of a left shoulder are passed through wire loop 1 of the anchor. The labeled wire tab 1 is pulled and the suture limbs are loaded through the splittable sheath and into the anchor. (B) Care is taken not to dislodge labeled wire tab 2 in this process. (C) The anchor and splittable sheath are advanced toward the lateral cannula, keeping slight tension on the suture limbs during advancement into the cannula.

inserted into the tunnel by malleting the reusable anchor inserter (Fig 11C). Tension is applied to the suture ends, which are then secured to the Reusable Anchor Inserter pegs (Fig 11D). Tension can be checked with an arthroscopic probe (Fig 12A) and adjusted, if necessary. If 2 anchors are used and tape or suture material is crossed between anchors, the crossing sutures can only be fully tightened after the second anchor is placed. Using the trigger mechanism, the anchor is deployed and suture is locked within the anchor (Fig 12B). Excess suture is trimmed.

A similar process is repeated for placement of a second anchor. Two lateral suture limbs are retrieved from the posterior lateral bone tunnel and passed into the anchor using wire loop 1, as described previously. The remaining medial suture limbs are retrieved and passed into the anchor via wire loop 2, as before. The anchor is secured to the reusable anchor inserter and introduced through the cannula to the aperture of the anterior tunnel, keeping slight tension on all sutures to facilitate easy gliding within the anchor. After provisional tensioning of the suture, the anchor is malleted into place, and final tensioning of the suture is completed, noting further reduction and compression of rotator cuff tissue onto the footprint. The anchor is then deployed, locking the suture tape within the anchor, and excess suture is trimmed. The final construct is inspected, demonstrating a transosseous, knotless, double-row rotator cuff repair with excellent compression and footprint coverage, using 2 anchors (Fig 12). Final suture configuration within the anchor is demonstrated in Fig 6B.

Discussion

Arthroscopic techniques for transosseous rotator cuff repair, which attempt to recreate the biomechanical environment and success rates of traditional open transosseous approaches, have been be more technically challenging than other anchor-based arthroscopic techniques and have an associated learning curve for

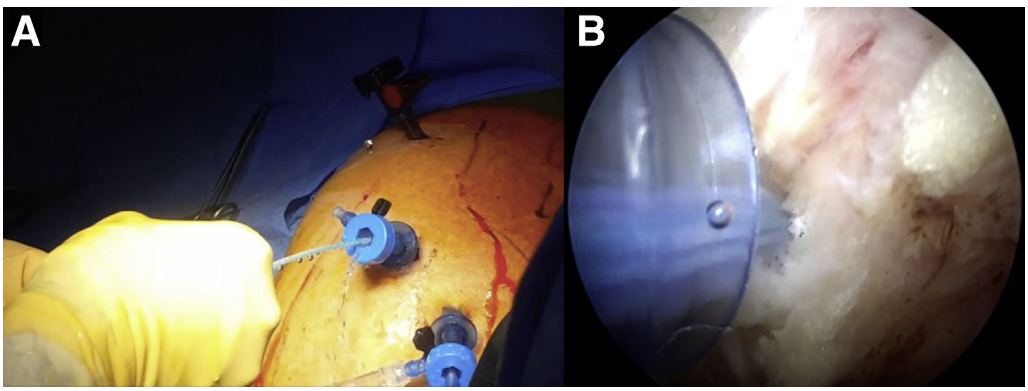

Fig 9. Exterior and arthroscopic exterior views of anchor advancement into cannula and lateral bone tunnel. (A) Exterior view from posterior of a left shoulder in beach chair position, demonstrating high-strength suture tape limbs within the splittable sheath of the anchor system, which facilitates smooth advancement of the anchor toward the lateral working cannula. (B) Arthroscopic view from a lateral viewing portal of a left shoulder, demonstrating high-strength suture tape limbs within the splittable sheath of the anchor system, which is advanced to the aperture of the lateral portion of a transosseous bone tunnel.

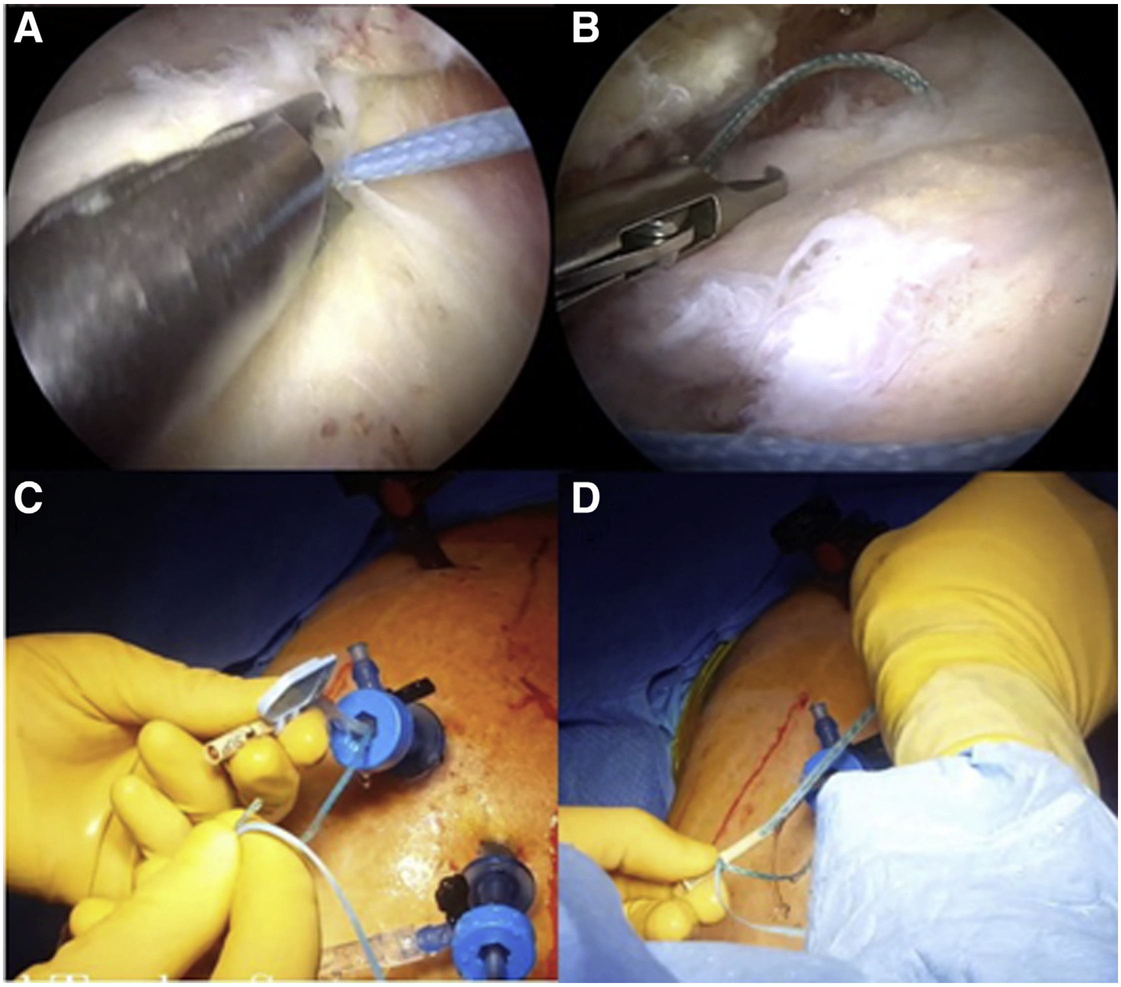

Fig 10. (A and B) Arthroscopic and exterior view of medial suture limb retrieval and loading onto the anchor. Arthroscopic view from a lateral viewing portal of a left shoulder, demonstrating retrieval using an arthroscopic instrument of medial suture limbs, which have previously been passed through rotator cuff tissue, similar to that of medial suture bridge anchor repair. Exterior view from posterior of a left shoulder in beach chair position after retrieval of medial suture limbs. The limbs are passed into wire loop 2 and through the anchor by withdrawing wire loop tab 2 from the anchor. (C and D) Excess slack is pulled from the suture, taking care not to unload any suture from the anchor during later anchor advancement through the cannula. The splittable sheath is then removed and discarded.

surgeons adopting a new technique.[6] Additionally, anchorless transosseous technique have shown potential for failure resulting from suture cut out from bone.[7] The KATOR system aims to simplify the passing technique and eliminate both knot tying and suture cut out from bone. Additionally, the potential to reduce the number of anchors while still attaining the benefits of double-row repair, such as broad footprint coverage and increased contact pressure, makes the previously described technique an attractive repair option. As shown in Video 1, the suture anchor system provides a reproducible and efficient method for transosseous suture passage and has several advantages over TOE repair (Table 2).

Reduced anchor burden is attractive for several reasons. Anchor number remains an important factor in surgical cost.[8] The previously described technique achieves a similar biomechanical construct with one-half the number of anchors, potentially decreasing direct costs of surgery.[2] Additionally, because no anchors are placed in medial row tunnels, footprint vascularization may be improved by allowing access of marrow elements to the bone tendon interface. Enhanced blood flow is thought to facilitate an improved biologic environment for repair.[9] Urita et al.[10] demonstrated that blood flow was significantly higher at 1 and 2 months postoperatively in transosseous repair compared with anchor-based repair. Finally, fewer anchors may be of benefit in the setting of healing failure because less of the footprint is affected by residual anchor material.

Transosseous repair may have benefits beyond reduced anchor burden. Randelli et al.[4] found that

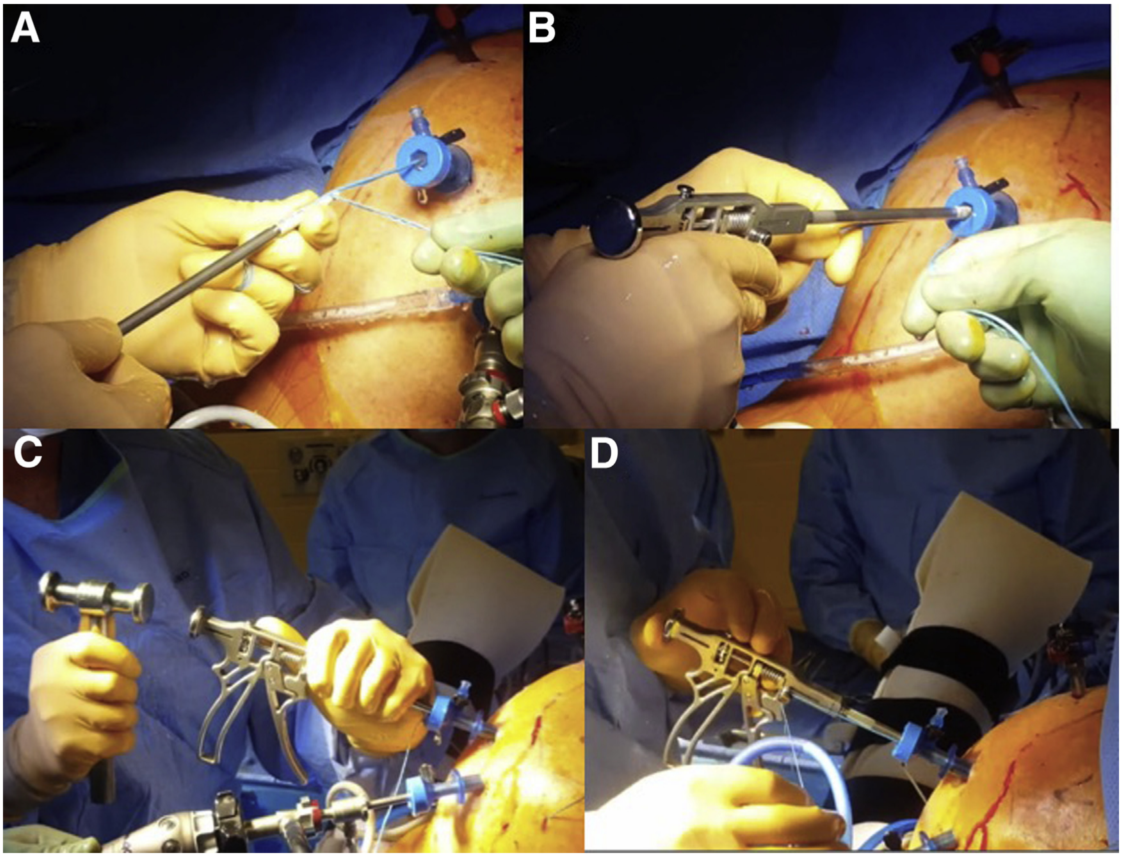

Fig 11. Exterior view from posterior of a left shoulder, demonstrating attachment of the anchor to the reusable anchor inserter and insertion of the anchor through the lateral working cannula. (A) The loaded anchor is now attached to the reusable anchor inserter via a screw on mechanism. (B) Keeping slight tension on suture ends helps them glide within the anchor; the inserter and anchor are advanced into the cannula into the aperture of the lateral tunnel. (C) A mallet is then used on the inserter to advance the anchor to an appropriate depth, denoted by a black line on the anchor when viewed arthroscopically. (D) Final tensioning is then applied individually to suture limbs, which are secured to pegs located on the inserter to maintain tension during anchor deployment. (C) The trigger of the inserter is then squeezed until the central locking member anchor is deployed within the anchor, completing knotless fixation.

postoperative pain levels decreased more quickly in patients treated with transosseous repair compared with metal anchor constructs in a randomized, controlled trial. Additionally, the orientation of the KATOR anchor within the lateral tunnel produces a high resistance to pull-out and may be of benefit in

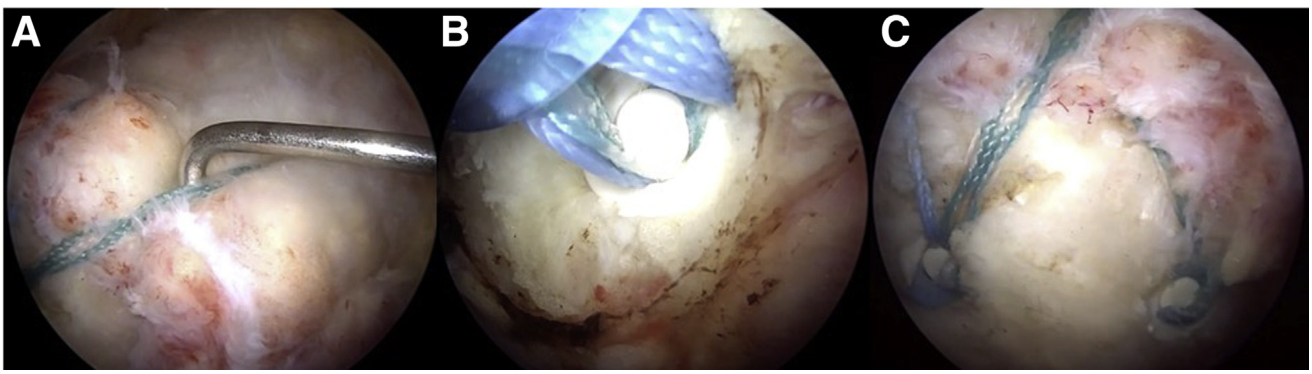

Fig 12. Arthroscopic views of the final anchor system construct. Arthroscopic view from a lateral viewing portal of a left shoulder. (A) A probe is introduced from the posterior portal to assess final tensioning of the suture limbs. (B) The central locking member is noted within the anchor, locking suture material in place, allowing for knotless fixation. Final images of the rotator cuff repair construct demonstrate double-row equivalent, knotless fixation, using 4 strands of high-strength suture tape and 2 anchors (C).

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
Reduced anchor burden	Surgical learning curve for new instrumentation
Enhanced vascularity at footprint	Clinical outcomes currently limited
High-strength construct in osteoporotic bone	Potential of failure by greater tuberosity fracture
Equivalent biomechanics to transosseous equivalent repair	Medial anchor placement may be challenging in patients with large lateral acromial overhang
Anchor compatible with suture and tape material (4 suture and 2 tapes per anchor)	
No implant in rotator cuff footprint in revision settings	

instances of poor bone quality. In comparative biomechanical testing, all failures using the anchor occurred through soft tissue, whereas failures using traditional anchors were due to anchors cutting or migrating out of bone.[2] Finally, each anchor is compatible with 2 strands of high-strength suture tape, as shown in Figure 12 C. Alternatively, 4 strands of No. 2 suture may be used in each anchor; thus, a variety of repair constructs can be devised depending on surgeon preference, tissue quality, and tear morphology. Figure 13 demonstrates repair of a large rotator cuff tear using 8 strands of No. 2 suture crossed between 2 anchors, providing robust compression of tendon against a broad, vascular footprint.

Risks of this technique include those related generally to arthroscopic surgery, such as infection-, neurovascular-, thromboembolic-, and anesthesia-related complications. The most common complications specific to arthroscopic rotator cuff repair are hardware complications, repair failure or rerupture, and stiffness.[11] Further study is needed to evaluate the rate of these complications using the described technique. Although prior transosseous anchorless repair may be of limited use in osteoporotic bone,[12] the current construct is well suited for osteoporotic bone because of the presence and orientation of the anchor, making suture cut out unlikely. One potential risk specific to the described construct may be migration superiorly or fracture of the entire greater tuberosity, although this was not observed in biomechanical testing.[2] Although no clinical failures related to anchor migration or fracture have been noted in our patients to date, further clinical study is needed to determine the rates of these complications using the described technique.

Arthroscopic transosseous technique is not without limitation. As mentioned, there is likely to be an associated learning curve for surgeons with adoption of new instrumentation and technique.[6] Our experience, however, given the reliability of instrumentation, suggests the described technique would be feasible for most surgeons with experience in arthroscopy. Although transosseous and double-row repair have well-established track records in rotator cuff repair,[4,10,13] further studies of healing rates and clinical outcomes will be helpful to validate the current implants and techniques in vivo. Transosseous techniques may not be appropriate for all tendon tears,

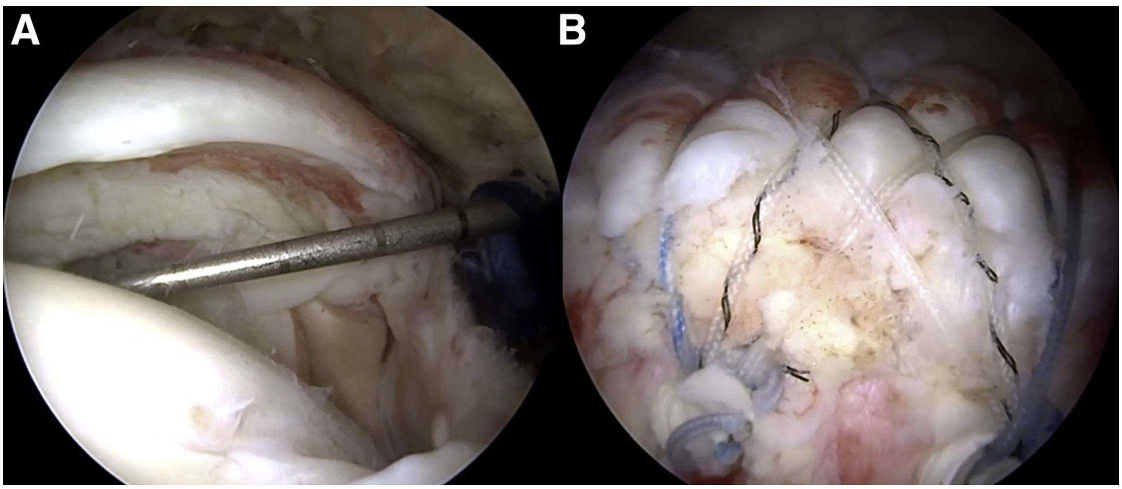

Fig 13. Arthroscopic views of large rotator cuff tear and repair using suture anchors with 8 strands of No. 2 suture. (A) Arthroscopic view of a large rotator cuff tear of a right shoulder from a lateral viewing portal, with a probe noted from the anterior portal during diagnostic arthroscopy. The anchor system was used for repair, allowing for robust compression against the rotator cuff footprint by 8 strands of No. 2 suture crossing between 2 anchors, which provide knotless fixation (B).

including massive or complex tears, and may not be well suited for repair of subscapularis tendon tears. In the case of complex tears, however, supplementing transosseous fixation with traditional anchor fixation, depending on specific tear pattern, is reasonable. It is believed that arthroscopic rotator cuff repair using the described knotless, transosseous technique creates a favorable biomechanical and biological environment for rotator cuff tendon healing.

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