Technical Note

Knotless, Retensionable Posterior Meniscal Root Repair With Anterior Cruciate Ligament Repair TightRope and FiberRing Sutures

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Abstract: Posterior meniscal root repair techniques continue to evolve, influenced by rapidly increasing clinical interest, surgical technology advances, and biomechanical insights. A posterior meniscal root repair technique is presented, utilizing a knotless, retensionable suspensory construct developed for anterior cruciate ligament repair but is also well suited for meniscal root repair. Benefits include built-in shuttling sutures, knotless technology, and poststressing retensioning capability to ensure maximal final repair security.

Posterior meniscal root tears are increasingly recognized as a relatively common tear pattern,[1] a consequential injury biomechanically equivalent to a total meniscectomy,[2] and associated with early and rapid joint degeneration.[3,4] Medial/lateral tear ratio is approximately 2/1.[5]

Posterior meniscal root repair has been associated with improved joint preservation and clinical outcome, decreased progression to arthritis, and lower overall socioeconomic costs.[6-9] The repair is commonly performed with transtibial pullout sutures secured to the anterior tibia with either knots over a button or with a suture anchor.[10]

The ACL Repair TightRope (Arthrex) is a retensionable suture construct, with one open loop for interlinkage to other structures and a cortical button for suspensory fixation (Fig 1A). The FiberRing with Shuttle Loop (Arthrex) is a suture construct with a thick suture ring (FiberRing) interlocked with a suture shuttling loop containing a collapsible suture eyelet (Shuttle Loop) (Fig 1B).

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The combination of ACL Repair TightRope and FiberRing, developed for arthroscopic anterior cruciate ligament (ACL) repair, is also well suited for meniscal root repair, as both treatments entail onlay, transosseous suspensory fixation of soft tissue to bone. Incorporation of the ACL Repair TightRope also adds the retensionable feature not available with the prevalent meniscal root repair techniques.

In this article, a technique of posterior meniscal root repair with ACL Repair TightRope and FiberRing sutures is presented.

Indications

Posterior meniscal root repair is indicated in symptomatic patients with an unstable tear and overall well-preserved articular surfaces. Contraindications include limb malalignment ($\geq 5°$), inability or unwillingness to comply with the necessary temporary postoperative activity restrictions, and notable degenerative pathology of the tibiofemoral compartments (Kellgren-Lawrence grade >2, substantial areas with Outerbridge grade >2 chondromalacia, etc).[10] Elevated body mass index (BMI) of ≥ 30 to 35 kg/m^2 has been associated with suboptimal repair outcomes.[11,12]

Patient Evaluation and Imaging

Patients may report an acute, painful onset, often during trivial stress such as standing from a crouched position, with a pop.[13] Medial tears are more often associated with articular cartilage degeneration.[14] Lateral tears are associated with acute ACL and multiligamentous injuries.[15]

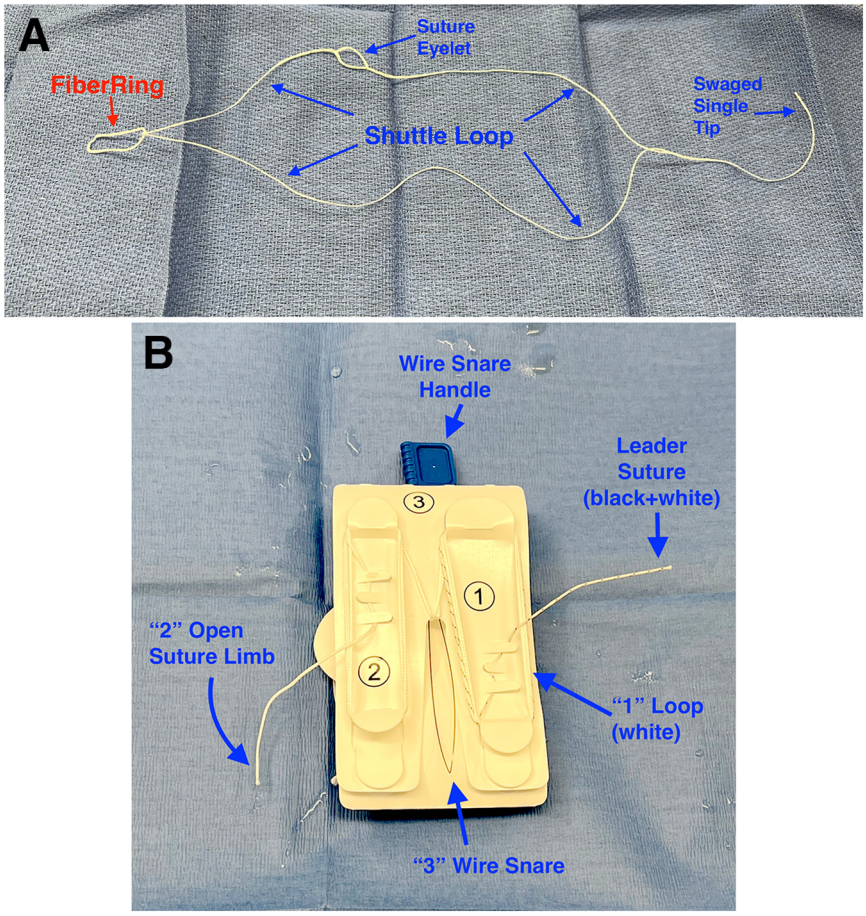

Fig 1. (A) FiberRing with Shuttle Loop (Arthrex). The specialty suture has 2 linked suture loops, FiberRing and Shuttle Loop. FiberRing is the shorter and thicker suture implant for tissue capture that comes in lengths from 25 to 55mm. Shuttle Loop is the longer, thinner, and teardrop-shaped loop that terminates in a swaged single tip for use with a suture passer through tissue and contains a suture eyelet that collapses when pulling through tissue yet self-expands for suture insertion. (B) ACL Repair TightRope (Arthrex), a retensionable suture complex with one side left open for linkage to another closed loop, which in this technique are the 2 FiberRings placed in the meniscus. The numbers on the packaging card for the components and the wire snare for open-strand passage facilitate the in situ TightRope assembly after the FiberRings are implanted in the meniscus. The cortical button and the rest of the TightRope are inside the container card to eliminate tangling.

Examination often demonstrates joint line tenderness, effusion, antalgic gait, and positive meniscal examination findings. Weightbearing plain radiographs and magnetic resonance imaging (MRI) are important to rule out significant degenerative changes, particularly in the tibiofemoral compartments. MRI typically reveals an abrupt meniscal discontinuity adjacent to the root location and a faint outline on sagittal view at the root (ghost sign). Midbody meniscal extrusion is consistent with compromised meniscal stability.

Surgical Technique

Setup and Initial Assessment

Patient is set up supine, for standard knee arthroscopy, with appropriate antibiotics, anesthesia, prepping, and draping.

Perform an arthroscopic examination, through anteromedial and anterolateral portals. Thoroughly evaluate the articular surface condition and meniscal tear type, severity, and tissue quality to confirm a root repair is indicated and feasible. Debride meniscal tear area to remove compromised tissue (Fig 2).

Tibial Footprint Debridement and Tunnel Placement

Debride the meniscal root and the tibial footprint (Fig 3A). Place the drill guide marking hook tip at the center of the footprint (Fig 3B). Through a small incision, set the drill sheath onto the anteromedial tibial cortex. Drill with a variable diameter retrograde reamer (FlipCutter III; Arthrex). Once the tip enters the joint (Fig 3C), expand the cutter to 8 mm and then carefully ream back to remove the articular cartilage, change the tip diameter to 6 mm, and then ream back another 10 mm (Fig 3D). Pass, retrieve, and secure a passing suture loop (FiberStick; Arthrex) through the tibial tunnel (Fig 3E).

Placement of FiberRings in the Meniscus

Suitable FiberRing length for meniscal root repair is typically 25 or 35 mm. Insert the tip of a self-retrieving suture passer (Knee Scorpion; Arthrex) through the FiberRing (Fig 4A), slide the FiberRing down the shaft away from the tip, and then engage the swaged single tip of the Shuttle Loop into the slot at the passer tip (Fig 4B).

Insert the suture passer through a portal, and take a thick bite of quality meniscal tissue, adjacent to the tear but sufficiently away from the edges to avoid

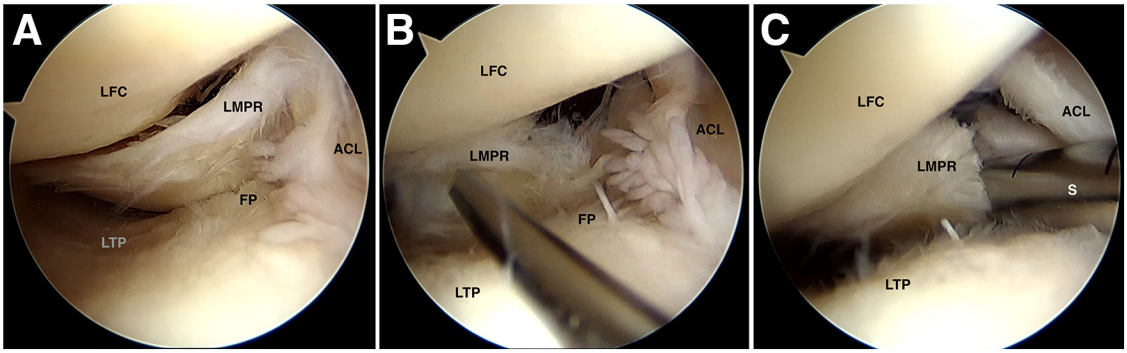

Fig 2. Right knee, supine position, view from anterolateral portal. (A) Lateral meniscus posterior root tear, showing separation of lateral meniscus posterior root (LMPR) from footprint (FP). (B) Torn LMPR, in a flap displaced away from FP. (C) Post-debridement appearance of LMPR, demonstrating a deep radial tear that destabilizes most of the posterior horn. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LTP, lateral tibial plateau; S, shaver.)

suture pullout. Pass the Shuttle Loop single tip through the meniscus (Fig 4C), retrieve, and pull it back out. Since the suture passer tip was first passed through the FiberRing, pulling the Shuttle Loop back automatically pulls it through the FiberRing, which then cinches around the meniscal tissue and through itself in a luggage-tag configuration (Fig 4D-F).

Repeat the process above to place and cinch another FiberRing of the same length around the meniscus, adjacent to the first FiberRing (Fig 4 G and H).

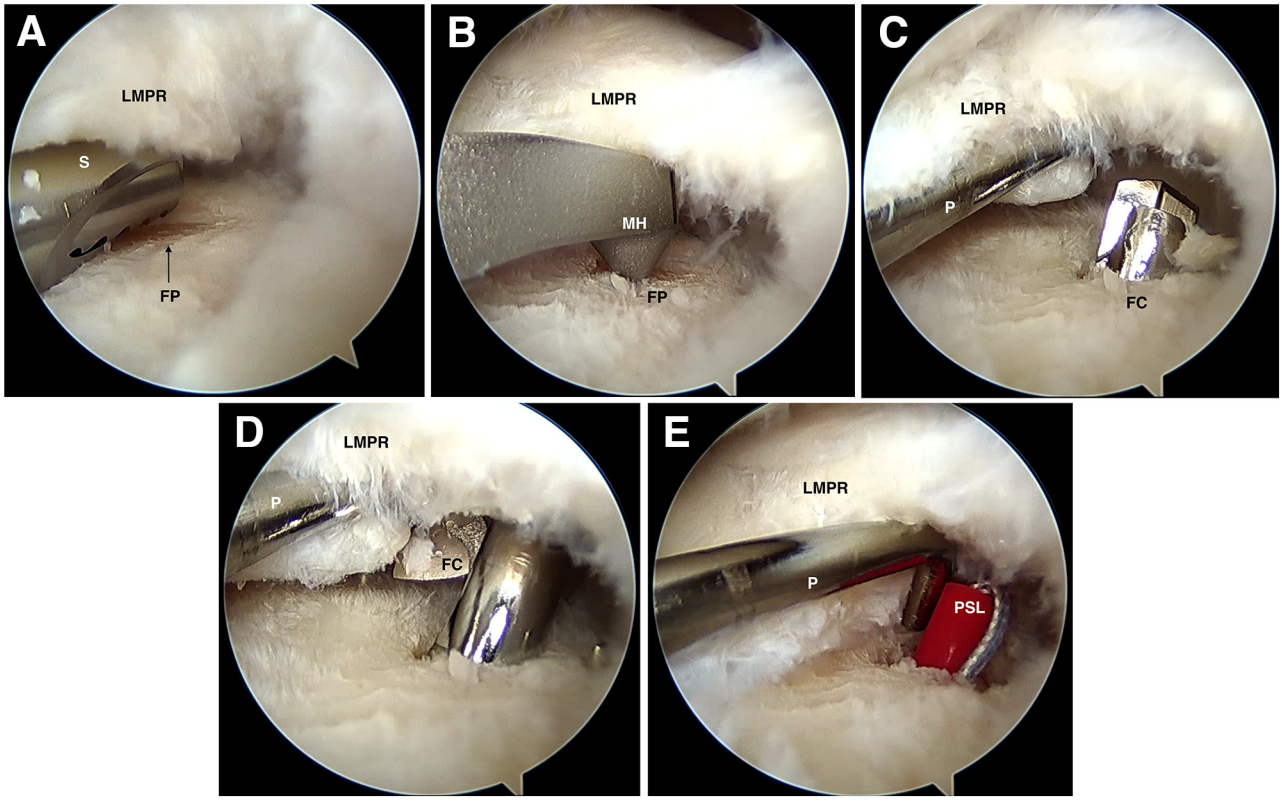

Fig 3. Right knee, supine position, view from anteromedial portal. (A) Footprint (FP) debridement with shaver (S). (B) The marking hook (MH) for the tibial tunnel drill guide is inserted through the anterolateral portal and placed at the FP on the tibia. (C) The variable-diameter retrograde reamer (FlipCutter III; Arthrex) (FC) is inserted under power through the tibial drill guide and enters the joint at the footprint. (D) The FC tip is expanded and retrograde reaming is done to debride the footprint area and to create a socket for fixation sutures. (E) A passing suture loop (FiberStick; Arthrex) (PSL) is advanced up the tibial tunnel once the FlipCutter is withdrawn. (LMPR, lateral meniscus posterior root; P, probe.)

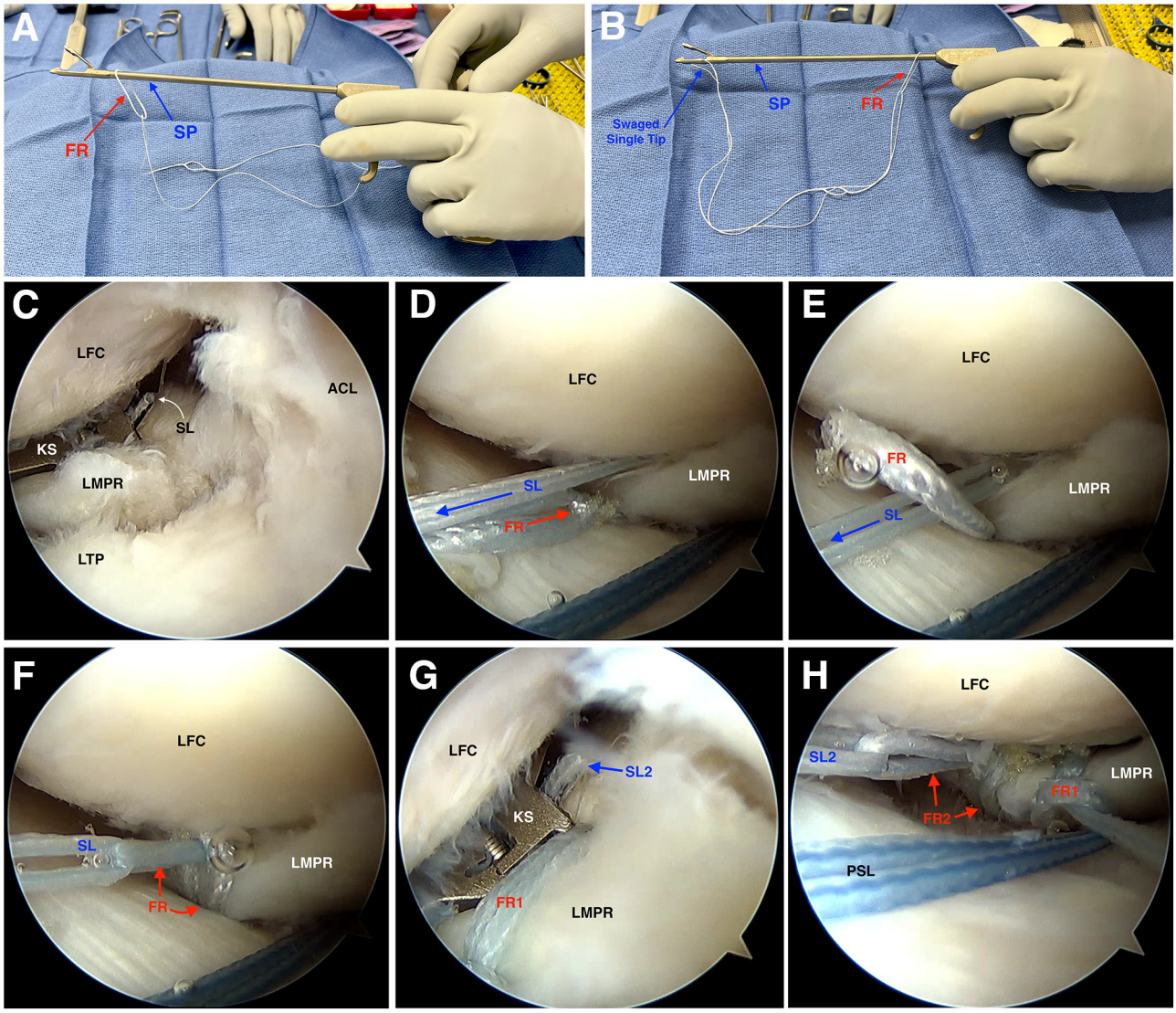

Fig 4. Right knee, supine position, arthroscopic views from anteromedial portal and exterior views of the suture and suture passer setup. (A) The tip of the suture passer is placed through the FiberRing. (B) The FiberRing is slid down the passer shaft, and then the swaged single tip of the Shuttle Loop is loaded at the tip of the suture passer. (C) The swaged single tip of the Shuttle Loop (SL) is passed through the lateral meniscus posterior root (LMPR) using the self-retrieving suture passer (Knee Scorpion; Arthrex) (KS). (D) As the SL is retrieved and pulled back, the FiberRing (FR) is pulled into the joint. (E) Pulling the SL back further, the FR is fully advanced into the joint. (F) When the SL is pulled back maximally, the FR forms a luggage-tag configuration and cinches around the meniscus tissue. (G) The single swaged-tip end of the second Shuttle Loop (SL2) is passed through the LMPR with a KS, adjacent to the first FiberRing (FR1). (H) The SL2 is fully retrieved, and the second FiberRing (FR2) is fully advanced and cinched, forming a second luggage-tag configuration next to FR1. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LTP, lateral tibial plateau; PSL, passing suture loop previously placed in the tibial tunnel in Fig 3E and saved for later use.)

Connecting the ACL Repair TightRope to the FiberRings

Place a cannula (PassPort; Arthrex) through the anteromedial portal (Fig 5A). Retrieve one of the FiberRing/Shuttle Loop constructs into the cannula.

Cut open the Shuttle Loop in the cannula, at the swaged tip. Unfurl fully the TightRope loop labeled "1" in the Arthrex ACL Repair TightRope card (Arthrex), feed its black-and-white leader suture into the Shuttle Loop's suture eyelet, and pull the strand of the Shuttle Loop without the suture eyelet to advance the black-and-white leader suture into the joint, through the first FiberRing, and back out of the cannula (Fig 5B-D).

Retrieve the Shuttle Loop for the second FiberRing into the cannula, and repeat the process above to pass the same black-and-white leader suture through the second FiberRing and out of the cannula. Pull on the leader suture to advance the "1" TightRope loop

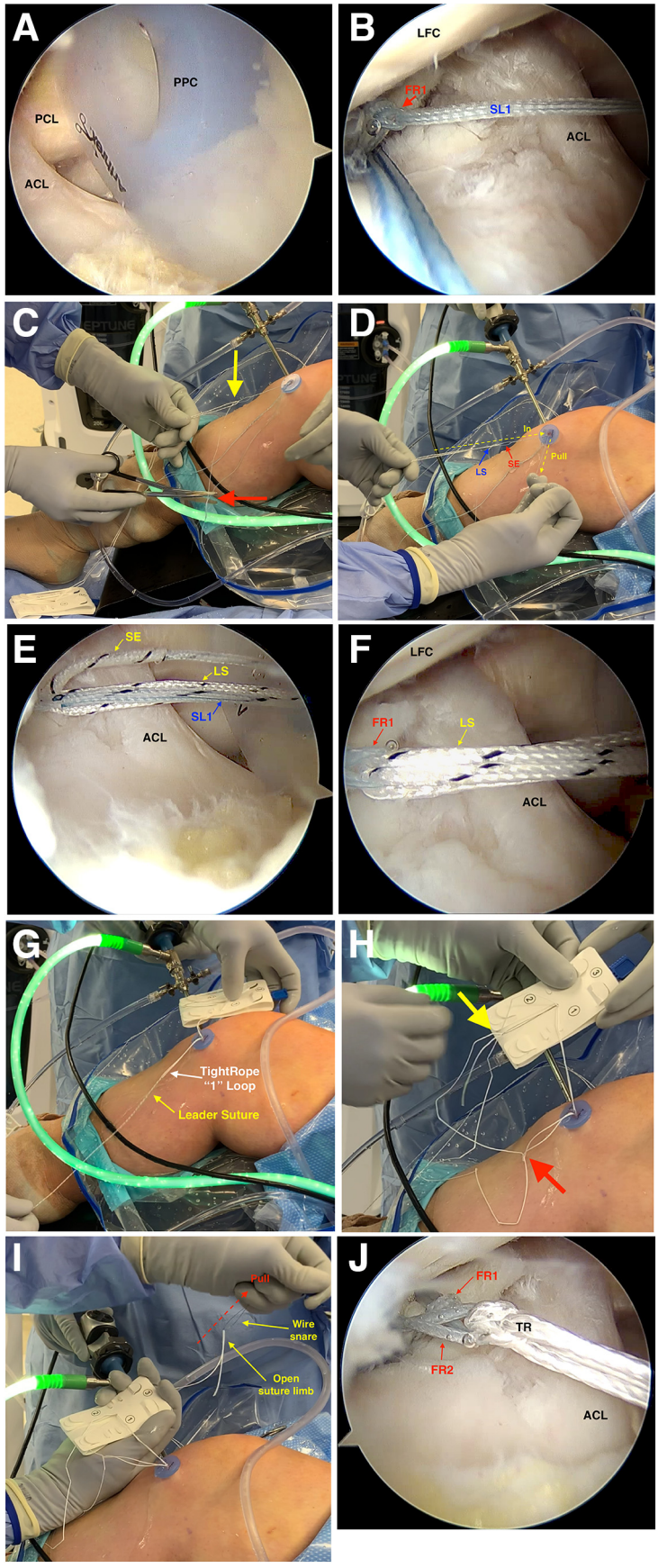

Fig 5. Right knee, supine position: arthroscopic views from anterolateral portal and exterior views from patient's left side viewing toward the right. (A) A flexible cannula is placed in the anteromedial portal. (B) The first Shuttle Loop (SL1) is brought into the cannula. Note the first FiberRing (FR1). (C) Outside the joint, SL1 is cut at the swaged tip (red arrow), and the black-and-white leader suture (LS) for the ACL Repair TightRope labeled "1" is fed into the suture eyelet of the Shuttle Loop (yellow arrow). (D) Pulling on the free strand without the suture eyelet shuttles the black-and-white leader suture eyelet (SE) into the joint. (E) Further pulling of the SL1 free strand advances the SE along with the black-and-white TightRope leader suture (LS). (F) SL1 is pulled out completely, passing the black-and-white TightRope loop LS through FR1 and out of the joint. (G) The steps above are repeated to pass the black-and-white leader suture and the "1" loop of the ACL Repair TightRope through both FiberRings and then out through the cannula. (H) The open suture limb of the TightRope is fed through the "1" loop (red arrow) and then fed through with the "3" wire snare (yellow arrow). (I) The open suture limb is pulled through the TightRope card with the wire snare, completing the TightRope construct. (J) The TightRope (TR) is now completed, closed, and also looped through both FiberRings (FR1, FR2). (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LMPR, lateral meniscus posterior root; LTP, lateral tibial plateau; PCL, posterior cruciate ligament; PPC, PassPort Cannula (Arthrex).)

through both of the FiberRings and then back out of the cannula. Cut and discard the leader suture.

Unfurl the "2" free strand of the TightRope. Feed it through the "1" TightRope loop, then through the "3" wire snare. Hold the card firmly, and pull the wire handle to pass the strand through. This closes the previously open loop and links the TightRope to the FiberRings.

Open the card completely. Remove the tape suture, but leave the blue traction suture in the button. With back traction on the button, adjust to equalize the lengths of the 2 tensioning strands (Fig 5E), but make

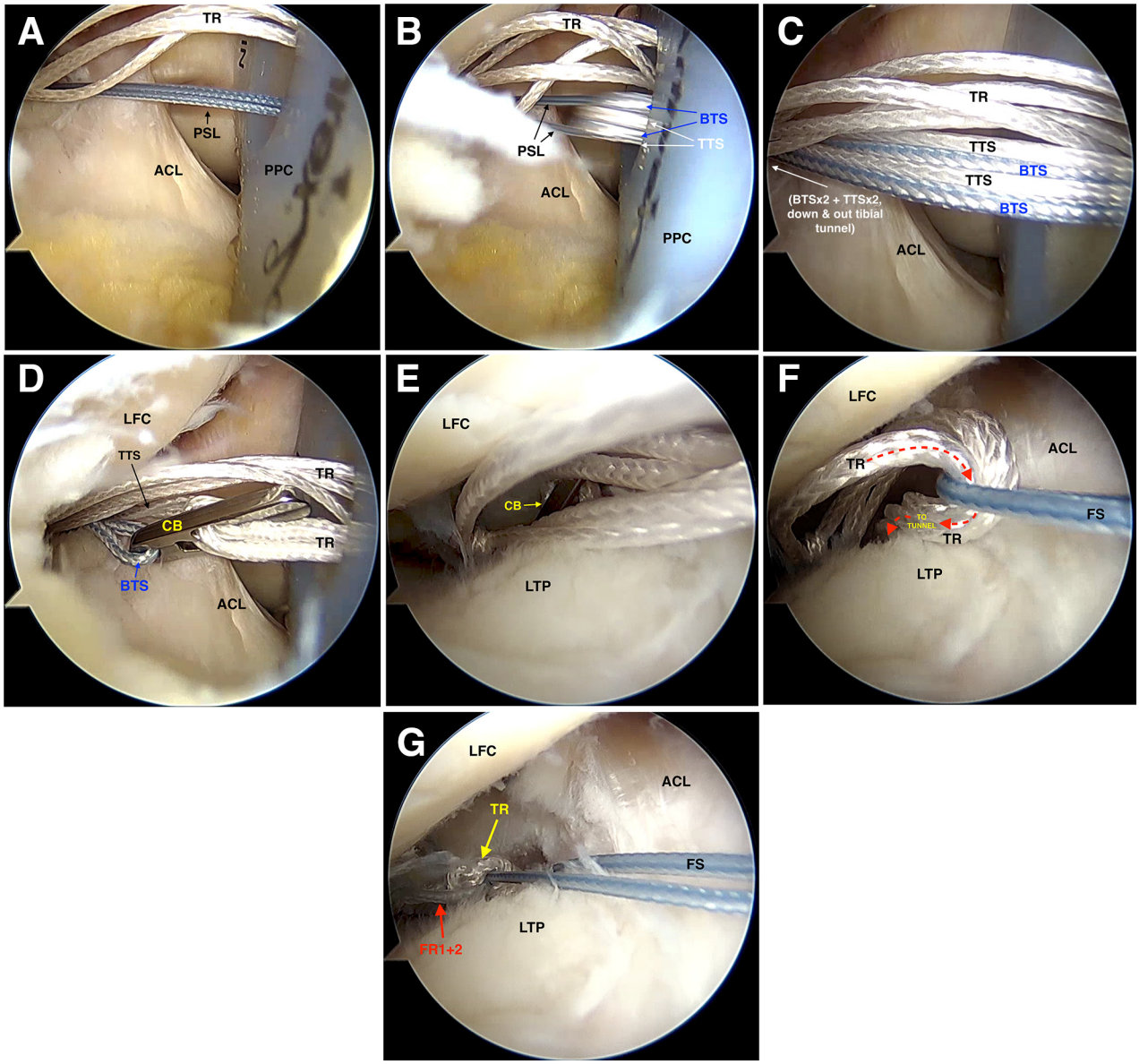

Fig 6. Right knee, supine position, view from anterolateral portal. (A) The passing suture loop (PSL) in the tibial tunnel is now retrieved into the cannula. Ensure there are no tangles with the white TightRope (TR) loops. (B, C) All 4 strands distal to the cortical button—the 2 blue button traction strands (BTSx2) and the 2 white TightRope tensioning strands (TTSx2)—are fed through the PSL, then passed down and out the tibial tunnel. (D) The cortical button (CB) is pulled toward the tibial tunnel by the blue button traction strands (BTS). The 2 TightRope tensioning strands (TTS) are also in the tibial tunnel, but pull on them just enough to remove slack without shortening the TR. (E) The CB is making the turn into the tibial tunnel. (F) The button has entered the tibial tunnel. TR strands follow the button down the tunnel. The arrows show the direction of movement of the TightRope strands. A free suture (FS) looped around the TightRope helps maintain control and prevent TightRope bunching during button passage. (G) The TightRope has exited the joint down the tibial tunnel, and only the very end portion is seen (TR, white), linked to the 2 FiberRings (FR1+2, blue). The FS is removed once the button has safely exited the tibial tunnel distally and the risk of tangling has subsided. (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LMPR, lateral meniscus posterior root; LTP, lateral tibial plateau; PCL, posterior cruciate ligament; PPC, PassPort cannula.)

sure to leave enough overall TightRope length so the button can exit the tunnel.

Cortical Button and TightRope Passage Through the Tibial Tunnel

Retrieve the tibial tunnel passing suture loop into the cannula (Fig 6A). Ensure the loop is not intertwined with the TightRope complex. Use the suture loop to pass the button traction suture strands and the TightRope tensioning strands down and out the tunnel distally (Fig 6 B and C). Pull on both blue suture strands to pull the button down the tibial tunnel (Fig 6D), periodically pulling the white tensioning strands just enough to advance them but without shortening the TightRope, until the button is out of the distal tibial tunnel (Fig 6E-G).

Suspensory Fixation Stressing and Retensioning of Meniscal Root

Pull alternatingly on the tensioning strands to seat the button on the cortex, fully tighten the TightRope, and secure the meniscus down on bone (Fig 7A).

Stress test the repair, and retension the TightRope as needed, to ensure full fixation security (Fig 7 B and C).

For healing enhancement, debride the lateral notch wall to expose nonarticular bone, and puncture several spots with a microfracture pick to produce osseous bleeding (Fig 7 D and E).

Please see Video 1 for surgical technique demonstration and Table 1 for pearls and pitfalls.

Rehabilitation

Restrict weigh bearing to toe-touch for 4 weeks, and then transition to full over the subsequent 2 weeks. Motion, static, and open-chain strengthening can start immediately. Knee immobilizer is worn during mobilization for 4 weeks to prevent inadvertent crouching. Once fully weightbearing, gradually introduce closed-chain strengthening, but avoid squatting or leg presses at $\geq 90^{\circ}$ of flexion for 6 more weeks. Dynamic activities are initiated around 3 to 4 months. Transition back to activities occurs around 4 to 6 months depending on nature and intensity.

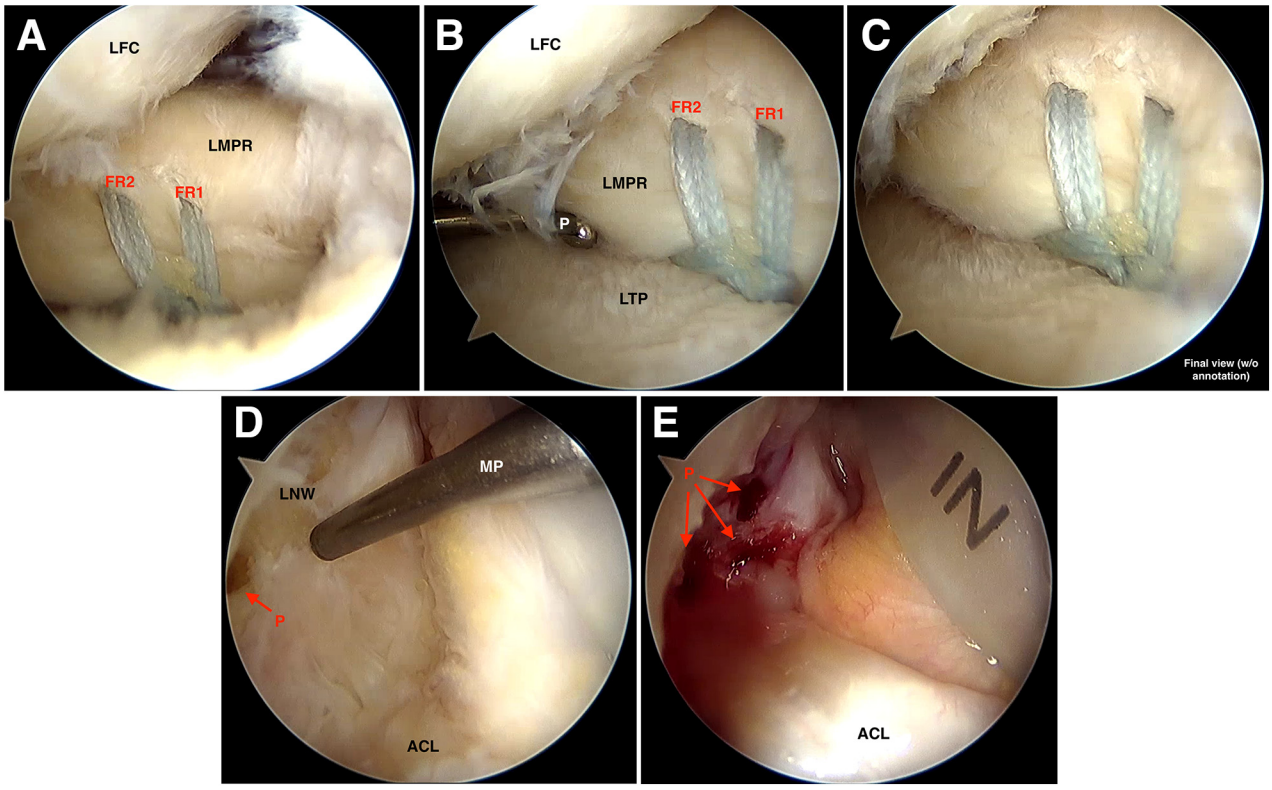

Fig 7. Right knee, supine position. (A) Arthroscopic view from anterolateral portal. After tensioning of the TightRope with the button on the tibial cortex, the lateral meniscus posterior root (LMPR) is secured to the tibial footprint by the 2 FiberRings (FR1, FR2) cinched through the meniscus and pulled down by the TightRope. (B) Arthroscopic view from anteromedial portal. The meniscal root repair is probed (P) and stressed, and TightRope retensioning ensures the final fixation stability is maximized. (C) Arthroscopic view from anteromedial portal. A final view of the repair, without annotation markings. (D) Arthroscopic view from anterolateral portal. For healing enhancement, the lateral notch wall (LNW) is debrided, and then a microfracture pick (MP) is used to make several bony punctures (P), mindful to stay away from ACL attachment. (E) View from anterolateral portal. Insufflation is shut off and abundant bony bleeding is confirmed from the puncture sites (P). (ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LMPR, lateral meniscus posterior root; LTP, lateral tibial plateau.)

Table 1. Pitfalls and Pearls

Pitfall: The starting point for drilling the tibial tunnel on the tibial cortex is on a slanted surface, which can alter the trajectory and adversely affect drilling accuracy.

Pearl: Consider predrilling with a smaller guidewire to confirm a satisfactory trajectory, adjust as needed, and then drill with the variable-diameter retrograde reamer.

Pitfall: Space can be tight in the posterior aspect of the knee, especially in the medial compartment. This can compromise every step of the procedure, including tunnel placement and suture management, and can result in articular cartilage damage.

Pearl: Perform a partial percutaneous medial collateral ligament release as needed to improve access.

Pitfall: If the 2 FiberRings (Arthrex) are of significantly different lengths, the TightRope (Arthrex) will pull only on the shorter FiberRing, and the longer FiberRing will not exert a reduction force on the meniscus.

Pitfall: Suture tangles and soft tissue bridges can occur, leading to extra time spent untangling and re-retrieving the sutures before continuing, and can lead to lost components and extra time spent repeating steps of the repair. Keeping the sutures separated can take extra time, as they are repeatedly shuttled between the portals.

Pearl: Use the cannula to help with suture management and save time. The PassPort cannula (Arthrex) is flexible, and a suture retriever can be inserted between the soft cannula and soft tissue to directly retrieve the sutures out between the portal soft tissue and the cannula, allowing for safekeeping of multiple sutures not in immediate use in and around the cannula. When the sutures pulled out adjacent to the cannula are needed, they can also be directly retrieved into the cannula without having to first be shuttled to the other portal.

Pitfall: When advancing the button traction sutures and then advancing the button into the tunnel (Fig 6D-G), all the sutures including the TightRope strands are lax and can go into the joint as a bunch, which can create tangles that compromise button and suture passage and take extra time and effort to arthroscopically untangle.

Pearl: Loop a suture across the bundle, and have an assistant hold that suture "leash" back during suture and button advancement, not to impede movement but to keep control of the bunch, and straighten the sutures to avoid bunching and tangling. Clamping the suture and having the weight of the clamp hold the "leash" back also works. This ensures the components are advanced in the proper sequence: cortical button traction suture and the TightRope tensioning strands first, followed by the button, then the TightRope. (Note: in Video 1, this suture "leash" is the blue suture looped around the white TightRope strands and holding slight back tension during cortical button and TightRope passage down the tibial tunnel, starting at the 3:31 time point and removed after the 3:48 time point.)

Pitfall: The TightRope is too short, and when attempting to pass the button down the tunnel, it does not fully exit the tunnel and cannot be seated on the tibial cortex for suspensory fixation.

Pearl: The above pitfall is best avoided by doing the following: (1) note the approximate length of the tibial tunnel during drilling (drill sheath of most guides have markings to help with this), and generously overlengthen the TightRope portion of the construct between the button and the FiberRings (tunnel length plus another 50-60 mm, for example) before passing the button down; (2) advance the button and associated sutures and strands down the tunnel by primarily pulling on the blue cortical button traction suture, and pull the 2 white tensioning strands only enough to remove slack, to avoid inadvertently shortening the TightRope.

Pearl: To further counteract against meniscal extrusion, consider additional stabilization techniques to centralize the meniscus midbody in medial meniscus posterior root repairs.

Discussion

Meniscal root repair technique options are still expanding, owing to the accumulation of clinical experience, implant technology advances, and increasing pathology recognition leading to expanding surgeon participation in technique development. Nevertheless, the principal features of a successful repair technique are clear: proper patient and knee condition selection, anatomic meniscal position through accurate tunnel replacement, and secure onlay fixation to resist displacement during rehabilitation.

The FiberRing is more robust and thicker than other sutures commonly used for meniscal root repair, potentially improving tissue capture security. The Shuttle Loop threaded through each FiberRing significantly eases the tedious step of linking the TightRope to the 2 FiberRings already cinched through the meniscus.

Table 2. Advantages and Disadvantages

Advantages

- Retensionable fixation, allowing repeat tightening after stressing to ensure final fixation is maximally stabilized
- FiberRing (Arthrex) is more robust than the suture materials typically used for meniscal root repair and potentially holds tissue better
- Shuttle Loop (Arthrex) facilitates suture shuttling and the connection of ACL Repair TightRope (Arthrex) to the FiberRings
- Knotless construct, eliminating a possible fixation weak link
- Ease of use: the ACL Repair TightRope comes in a packaging with components clearly labeled for simple, by-the-numbers use and includes a wire snare that facilitates passage of the free strand to complete the construct

Disadvantages

- Increased demand on arthroscopic proficiency, especially familiarity with knotless retensionable suture technology and principles, and suture management skills to avoid complex, potentially irreversible suture tangles
- Potential difficulty passing the button into and through the tibial tunnel, requiring additional effort and implants to continue fixation
- Possible increased implant costs
- Needs clinical longitudinal studies to validate efficacy

The ACL Repair TightRope eliminates knots as a potential weak spot[16] and permits repeated stressing and retensioning to ensure the final fixation is maximally secure. Compared to the author's prior experience utilizing other retensionable constructs (TightRope BTB and Open TightRope ABS; Arthrex) for meniscal root repair, the ACL Repair TightRope, with its components numbered according to use sequence and with a built-in wire snare for free strand passage, simplifies the otherwise tedious and tangle-prone in situ TightRope assembly involving multiple suture loop passages in and out of the joint that can result in unusable implants and increased surgical time.

Disadvantages include increased demand of arthroscopic proficiency and familiarity with retensionable sutures, especially in suture management to avoid complex and possible irreversible suture tangles; potential difficulty passing the button into and through the tibial tunnel, requiring additional time, effort, and implants to continue the fixation; possible increased implant costs; and, as with any new technique, the need to validate efficacy through clinical studies.

Please see Table 2 for advantages and disadvantages.

Summary

A posterior meniscal root tear repair technique is presented, utilizing a suture implant and suspensory fixation system developed for ACL repair that is also well suited for root repair, with improved tissue capture, ease of suture shuttling and construct assembly, and knotless, retensionable fixation as its potential unique benefits.

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