Technical Note

Arthroscopic Medial Meniscus Posterior Horn Direct Anchor Root Repair: Transtibial Approach With Knotless Adjustable Aperture Fixation

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Abstract: The integrity of the posterior meniscus root attachment is vital for the preservation of knee joint biomechanics. Meniscus root tears treated nonoperatively or with meniscectomy lead to poor functional outcomes and progressive knee degeneration. Repair returns knee biomechanics back to the intact state and has an established record of positive mid-term to long-term results. Although transtibial pullout repair has been the gold standard, innovation is needed to overcome the limitations inherent to traditional approaches. The latest generation of transtibial pullout repair devices is adjustable, permits suture anchor placement directly into the root footprint, and has demonstrated encouraging early results in biomechanical analysis. This Technical Note describes an arthroscopic technique for medial meniscus posterior root repair that uses a knotless adjustable implant (SutureLoc; Arthrex) for aperture fixation via a transtibial approach with intratunnel soft anchor direct fixation and rip-stop suture configuration.

Meniscus tears have been identified as the most common knee injury, with tears of the meniscus root accounting for up to 20% of all meniscus tears.[1,2] The chondroprotective role of the meniscus relies on intact root attachments for the conversion of axial loading forces across the knee into circumferential hoop stresses.[3] Meniscus root tears (MRTs) disrupt tibiofemoral contact mechanics and have been reported to be functionally and biomechanically equivalent to complete meniscectomy.[4,5] When treated nonoperatively, MRTs result in significant functional limitations, progressive cartilage degeneration, and potential conversion to total knee arthroplasty.[2,6,7] Partial meniscectomy is another historical treatment intervention that has demonstrated similar outcomes to nonoperative management and identified as a risk factor for the progression of osteoarthritis.[5]

A growing body of evidence highlighting the importance of meniscus preservation and anatomic reduction has identified MRT repair as a viable option to return tibiofemoral contact mechanics back to the intact state.[8,9] Similarly, contemporary evidence shows MRT repair to have superior outcomes to both nonoperative management and meniscectomy and should be considered first-line treatment in select patient populations.[9,10] Although there is broad consensus on the rationale for MRT repair, many unanswered questions remain regarding the optimal repair technique. The ideal operative technique should be safe, possess limited technical barriers, provide anatomic reduction with high primary fixation strength resistant to subsequent cyclic loading forces, and facilitate a biologic environment that promotes healing of the meniscus to bone.

There have been several recent studies evaluating the biomechanics of various suture devices and configurations. The suture anchor technique is an all-arthroscopic approach that uses a posteromedial portal to achieve direct suture anchor placement into the root footprint. This approach maintains all tibial bone for concomitant procedures such as proximal tibia osteotomy or ligament reconstruction and has demonstrated enhanced stiffness and less cyclic displacement when compared to traditional transtibial

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Table 1. Pearls and Pitfalls of Arthroscopic Medial Meniscus Posterior Horn Direct Anchor Root Repair Using a Transtibial Approach With Knotless Adjustable Aperture Fixation

Pearls	Pitfalls
Curette the anatomic root attachment site on the tibia to facilitate soft tissue healing to bone.	Inadequate exposure
Transfer all the sutures to the anterolateral portal and pass first No. 2 repair suture independently from the anteromedial portal with the cannula in place, and then shuttle over the loop suture to create a knotless mechanism. Then repeat this process with the other No. 2 repair suture.	Ease of suture management and creating the 2 separate knotless mechanisms
Use a hemostat to secure the conversion sutures outside the tibia during suture passage.	Inadvertent loss of the critical conversion sutures, which complete the knotless fixation for the No. 2 blue and white repair sutures
Consider releasing the medial meniscus root peripheral attachment and the meniscotibial ligament if needed in cases of chronic extrusion to facilitate reducing the root back to the bony origin.	Less than adequate reduction
When shuttling the SutureLoc implant beneath the anatomic footprint, a suture grasper can be used to pull tension on the suture loop to create a smaller profile to facilitate passage through the 2.4-mm drill hole.	

approaches.[11,12] The transtibial pullout repair technique secures the meniscus root to the tibial plateau via meniscus suture passage through a tibial bone tunnel and has become the gold standard in MRT repair as optimal posterior portal creation for direct fixation is not always possible. The transtibial technique uses standard and familiar arthroscopy portals, restores biomechanical function, and has an established record of positive mid-term to long-term results. When choosing suture constructs, resistance to cyclic displacement and ultimate load to failure must be considered. Importantly, the meniscus-suture interface represents the weakest link in repair constructs.[13] Suture constructs employing a rip-stop function (Fig 1), such as the modified Mason-Allen technique, reduce suture lengthening effects at the meniscus-suture interface.[14,15] This Technical Note describes an arthroscopic technique for medial meniscus posterior root repair that uses a knotless adjustable implant (SutureLoc; Arthrex) for aperture fixation via transtibial approach with intratunnel soft anchor direct fixation and rip-stop suture configuration. This is the first root repair technique that allows direct anchor fixation without a need for posterior portals. The technique is demonstrated in a video (Video 1) along with a list of pearls and pitfalls that the authors have found to be helpful (Table 1).

Surgical Technique (With Video Illustration)

Indications and Contraindications

The ideal candidate for meniscus root repair is a younger patient with an acute injury and otherwise healthy knee. Contraindications include varus malalignment >10°, Kellgren-Lawrence grade ≥3, subchondral bone collapse, or patients unable to adhere to postoperative rehabilitation protocols, particularly regarding the need for initial nonweightbearing status. Careful patient selection and preoperative counseling is necessary for patients with obesity or varus malalignment 5° to 10°.[16]

Patient Positioning and Diagnostic Arthroscopy

Prior to surgery, a meticulous review of preoperative imaging is vital to surgical planning, including long alignment films, as well as magnetic resonance imaging. Similarly, a thorough examination under anesthesia should be performed. Knee stability should be evaluated with varus and valgus stresses, including an assessment of the patient's Lachman, pivot shift, drawer test, and dial test. The patient is positioned

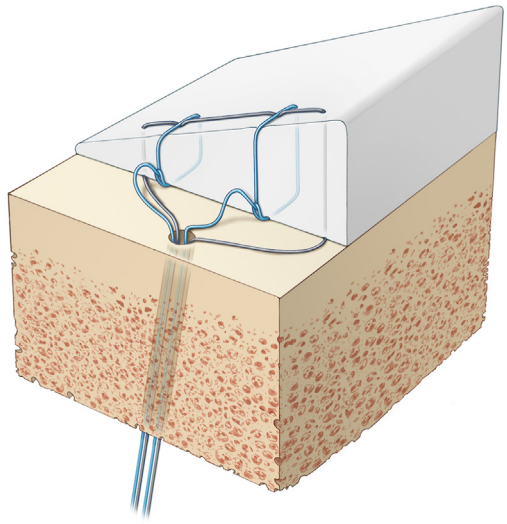

Fig 1. Rip-stop suture configuration. (*Permission provided by Mayo Clinic to publish Fig 1.)

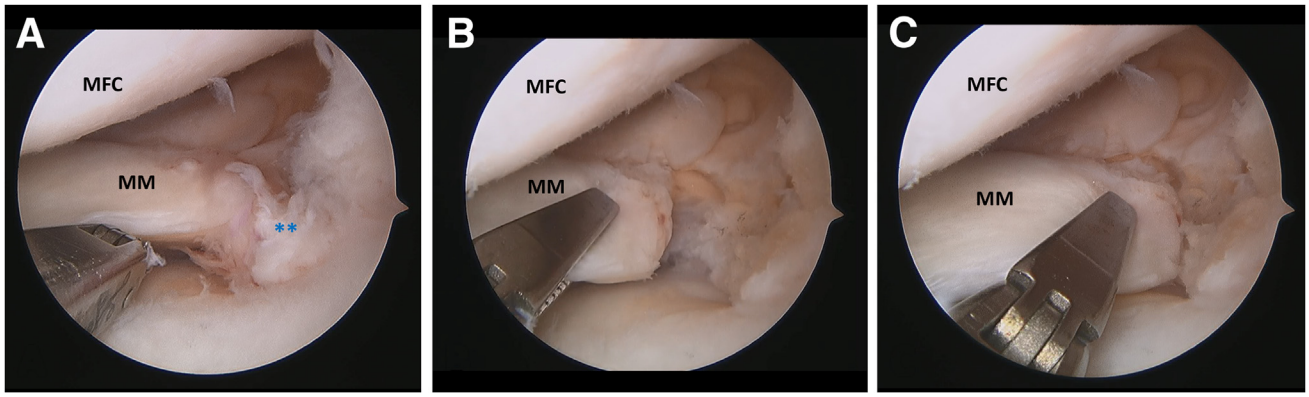

Fig 2. Medial meniscus posterior root tear preparation. Arthroscopic image of a left knee viewing from the AL portal demonstrating a chronic MMPR tear (**). (A) Before and (B) after posterior capsular attachment release via curved arthroscopic scissor through the AM portal. (C) Reduction of the root back to the bony origin. (AL, anterolateral; AM, anteromedial; MFC, medial femoral condyle; MM, medial meniscus; MMPR, medial meniscus posterior root.)

supine, and the operative extremity is prepared and draped in the standard sterile manner. Standard anterolateral (AL) and anteromedial (AM) portals are created for routine diagnostic arthroscopy, evaluating the integrity of the menisci and cruciate ligaments, as well as assessing for the presence of cartilage lesions and loose bodies.

Medial Meniscus Posterior Root Tear Preparation

The medial compartment is entered while applying a valgus force to the knee, and a percutaneous medial collateral ligament lengthening is completed using a spinal needle 1 cm above the joint line. Visualization of the posterior root footprint is further enhanced via a small resection of the medial tibial spine and posterior cruciate ligament synovium. In an effort to promote vascular infiltration and enhance healing, the edge of the posterior root tear is debrided and its bony origin is decorticated with a curette. In cases of chronic extrusion, release of the meniscus root peripheral attachment and meniscotibial ligament is considered to facilitate mobilizing the root attachment to its bony origin (Fig 2). Meniscus centralization can be performed at this time per surgeon discretion.

Transtibial Drilling

The Arthrex root guide is introduced through the AM portal, and the tip is positioned over the meniscus root footprint. The drill guide is rotated to the anteromedial face of the tibia, and a small stab incision is made to accommodate the 2.4-mm-diameter pin (Fig 3). The cannulated guide pin is advanced into the tibia, entering the joint at the anatomic footprint. The trocar is then removed from the cannulated pin.

Passage of SutureLoc Implant

A nitinol suture shuttle is advanced into the joint through the cannulated pin and retrieved through the AM portal. Next, the SutureLoc (Arthrex) implant is

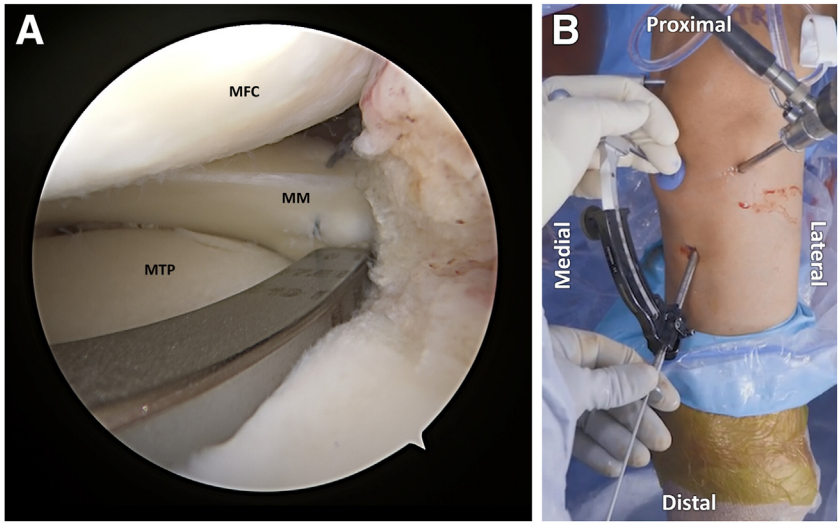

Fig 3. Transtibial drilling. (A) Arthroscopic and (B) gross images of transtibial drilling via a root guide (Arthrex) through the AM portal in position at the anatomic footprint of the MM posterior root (left knee, viewing from the AL portal). (AL, anterolateral; AM, anteromedial; MFC, medial femoral condyle; MM, medial meniscus; MTP, medial tibial plateau.)

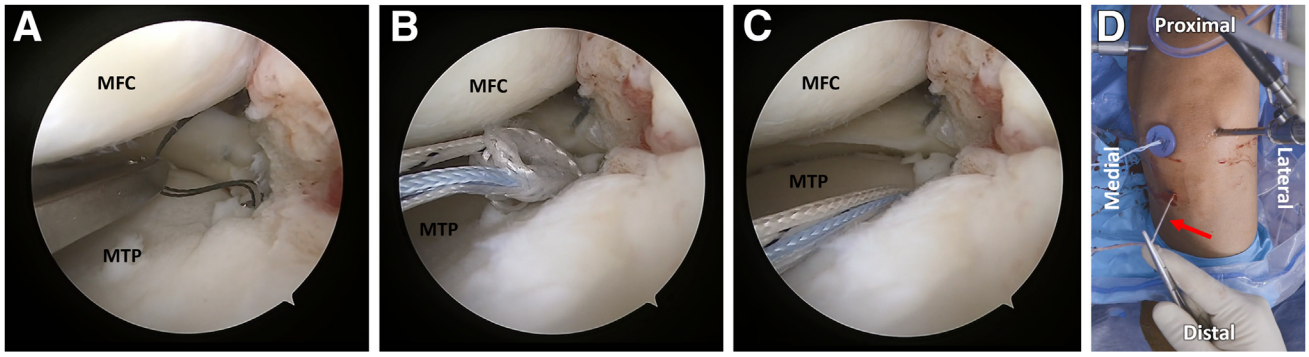

Fig 4. Passage of SutureLoc implant. (A) Nitinol suture shuttle being advanced through the cannulated pin and retrieved through the AM portal (left knee, viewing from AL portal). (B) Retrograde passage of SutureLoc (Arthrex) implant through the tibial tunnel and subsequent (C) deployment beneath the anatomic footprint for aperture fixation. (D) Gross image of retrograde passage of the implant as it exits the tibial tunnel (red arrow). (AL, anterolateral; AM, anteromedial; MFC, medial femoral condyle; MTP, medial tibial plateau.)

shuttled retrograde down through the tibial tunnel and subsequently deployed beneath the anatomic footprint for aperture fixation (Fig 4). The device is set by pulling on the closed blue loop out the tibia (Fig 5). The security of the anchor deployment can then be checked as it should not be able to be pulled back out of the portal once deployed. A clamp is then placed over all the sutures exiting out the tibial incision.

Fixation of Posterior Root Sutures With Rip-Stop Configuration

First, a (PassPort; Arthrex) cannula is placed in the AM portal to prevent soft tissue bridging with suture passage. Next, both the repair and blue and white shuttle sutures for the SutureLoc are retrieved out the AL portal. Working from posterior to anterior, a self-retrieving suture passing device (Knee Scorpion;

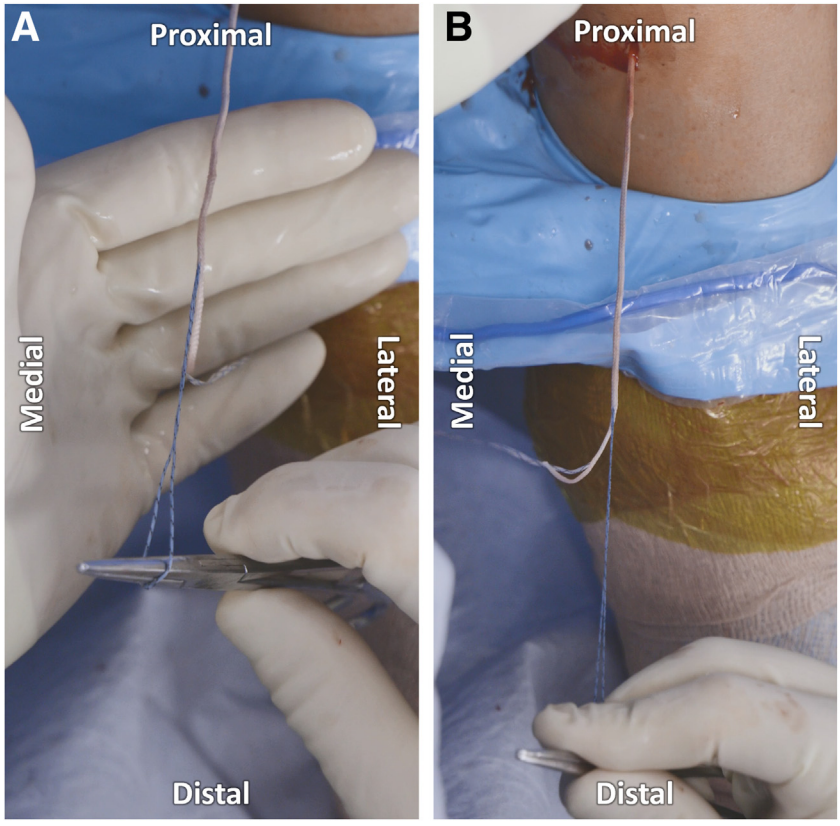

Fig 5. Deploying SutureLoc implant. The device is set (secured beneath the anatomic footprint) by (A) identifying and (B) pulling on the closed blue loop from the tibial tunnel.

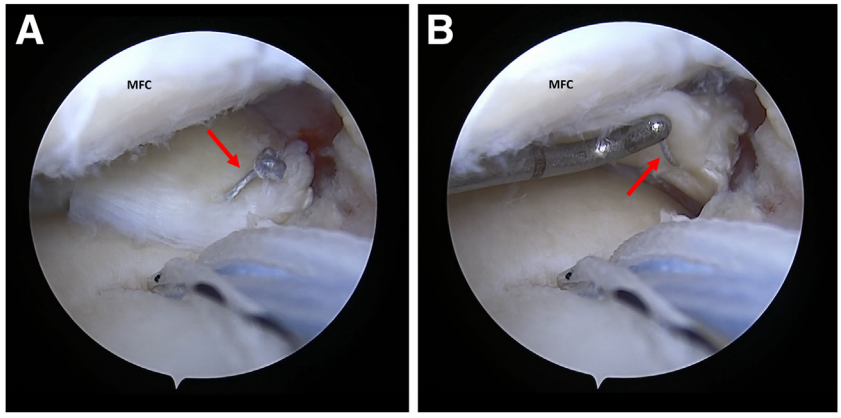

Fig 6. Dedicated rip-stop suture. (A) Arthroscopic image of a left knee viewing from the AL portal after a 2-0 FiberWire (Arthrex) suture (red arrow) is passed in a horizontal mattress fashion and tied for a rip stop in the posterior horn of the medial meniscus. (B) Probe through the AM portal showing the undersurface of the dedicated rip-stop suture (red arrow). (AL, anterolateral; AM, anteromedial; MFC, medial femoral condyle.)

Arthrex) is used to place a separate 2-0 FiberWire (Arthrex) suture in a horizontal mattress that is tied for a rip stop in the posterior horn of the medial meniscus (Fig 6). The solid white color repair No. 2 suture is retrieved with a looped grasper out the AM portal and passed through the meniscus root in a simple fashion just posterior and medial to the dedicated rip-stop suture. The black and white looped shuttle suture is retrieved out the AM portal, and the repair is passed through this looped suture folded at the marked blue line, and the clamp removed off all the sutures at the tibial incision and the black and white pull suture is used to shuttle the repair suture back through the tibial tunnel and into the knotless mechanism using this conversion suture of the corresponding color (Figs 7-8). The tibial clamp is reapplied, and the same steps are followed with the remaining No. 2 blue repair suture passed anterior and medial to the tied horizontal mattress suture. This suture is then shuttled with the blue and white shuttle suture, and after tibial clamp removal, the knotless mechanism is made with the tibial blue and white conversion suture. Next, the repair sutures are sequentially tensioned under direct visualization (Fig 9). Final tensioning of centralization sutures can be completed at this time as well. After confirming the meniscus root is well reduced, the suture tails are cut as they exit the proximal tibia (Fig 10).

Alternative Rip-Stop Technique

Alternatively, a rip-stop suture configuration can be achieved exclusively with the 2 No. 2 repair sutures from the SutureLoc implant. Working from posterior to anterior, the first repair suture is placed in a horizontal mattress fashion with the Knee Scorpion and passed using a 2-0 FiberLink (Arthrex) shuttle. The second repair stitch is placed in simple fashion just medial to the horizontal mattress suture (Fig 11). Once the repair sutures are passed, they are converted into their respective knotless mechanisms through the tibial plateau as described in detail above.

Postoperative Rehabilitation

Rehabilitation protocols often differ between patients in the setting of concomitant injuries and surgery, such

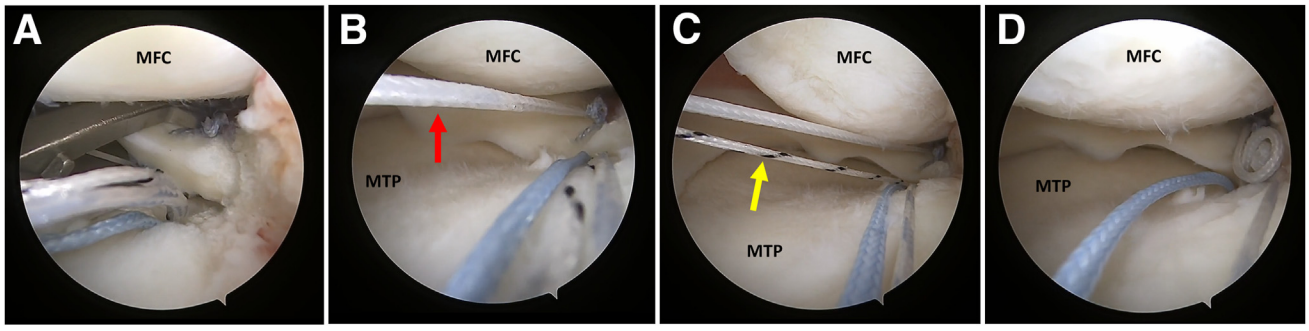

Fig 7. Arthroscopic suture passage and shuttling. (A) Knee Scorpion (Arthrex) from the AM portal piercing the meniscus just posterior and medial to the dedicated rip-stop stitch to pass the solid white-colored repair suture. (B) Solid white repair suture (red arrow) retrieved through the AM portal. (C) The black and white looped shuttle suture (yellow arrow) is retrieved out the AM portal, and the repair suture is passed through the looped shuttle suture for (D) retrograde passage through the tibial tunnel and conversion into the knotless mechanism. (AL, anterolateral; AM, anteromedial; MFC, medial femoral condyle; MTP, medial tibial plateau.)

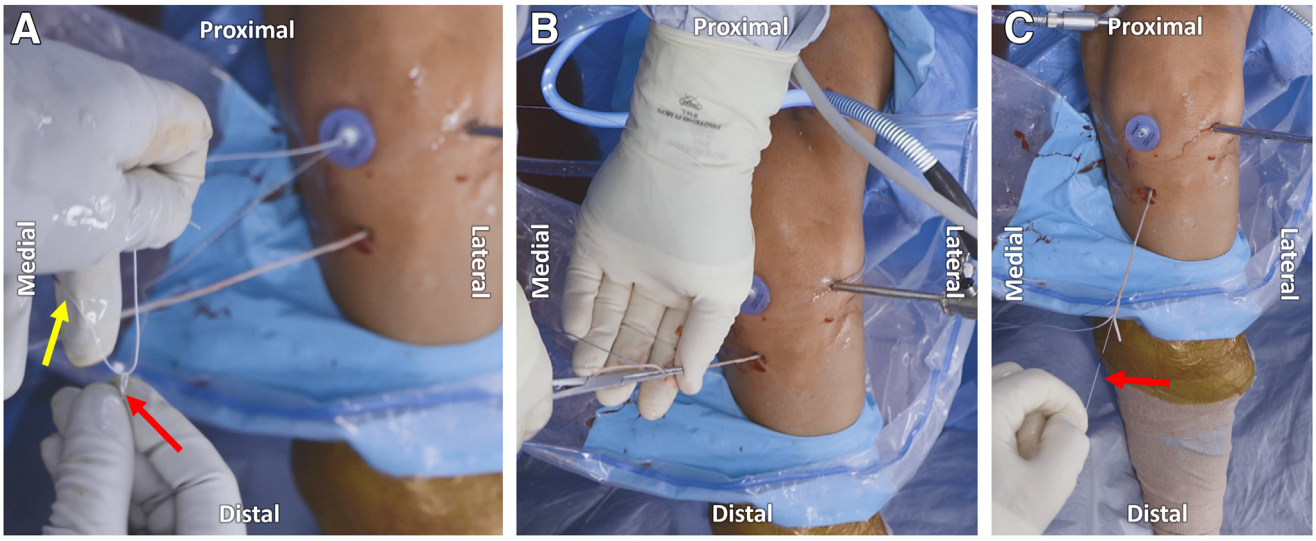

Fig 8. Suture management. (A) Solid white repair suture (yellow arrow) being passed through the loop of the black and white shuttle suture (red arrow). (B) The clamp is removed off all the sutures exiting the tibial tunnel, and (C) the black and white pull suture exiting the tibial tunnel (corresponding color to the black and white looped shuttle suture) is used to shuttle the repair suture back through the tibial tunnel (red arrow) for conversion into the knotless mechanism.

as anterior cruciate ligament (ACL) reconstruction. For the initial 6 weeks, we typically recommend a complex meniscus protocol consisting of toe-touch weightbearing in a long leg brace and activity limited to quad sets and straight-leg raises. Range of motion is limited to 90° for the first 4 weeks and advanced as tolerated thereafter. At 6 weeks, the patient transitions to a more traditional ACL rehabilitation protocol. However, impact activities such as jogging are not advised until 5 to 6 months after surgery.

Discussion

The role of the meniscus in knee joint preservation is dependent on the integrity of the meniscus root attachements.[4,17] MRTs lead to significant functional limitations and progressive cartilage degeneration. Root repair is accepted to be better than both nonoperative management and meniscectomy and has been shown to restore knee biomechanics to the intact state.[8,9,18] As authors have begun to agree on the necessity of meniscus preservation, the debate has shifted to

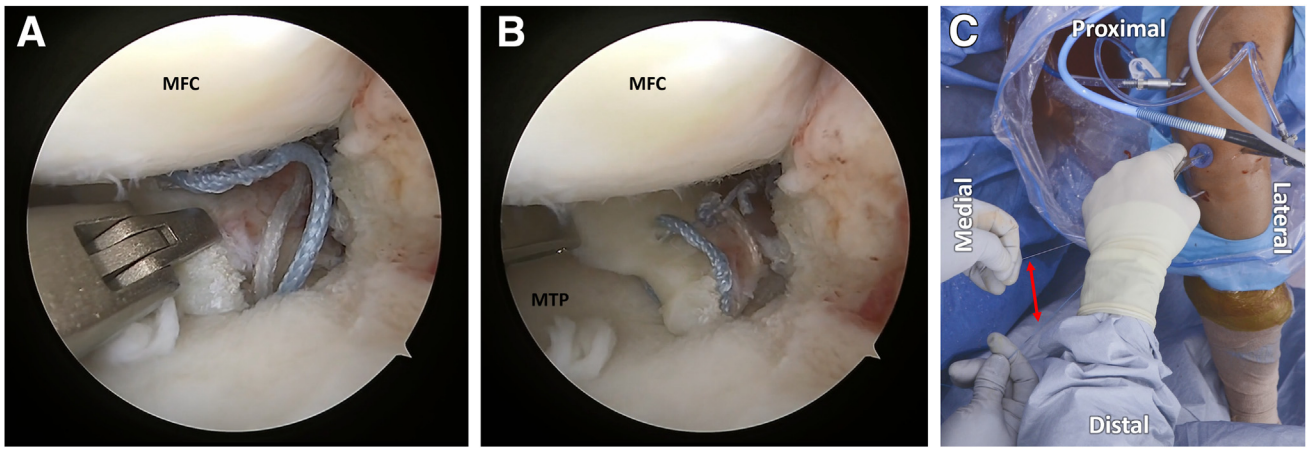

Fig 9. Meniscus root reduction via sequential tensioning. (A) Reducing the meniscus root to its anatomic footprint while (B) the solid blue and white repair sutures are sequentially tensioned under direct visualization. (C) The 2 striped pull sutures (corresponding to the colors of their respective repair sutures) exiting the tibia are sequentially pulled (double red arrow) to reduce the meniscus to its anatomic footprint (left knee, viewing from the AL portal). (AL, anterolateral; MFC, medial femoral condyle; MTP, medial tibial plateau.)

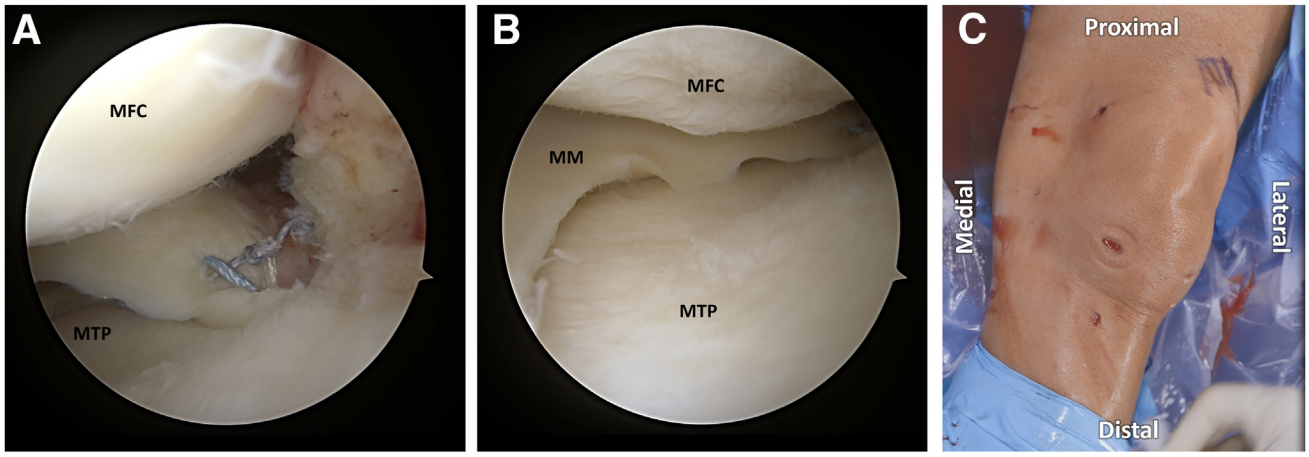

Fig 10. Final construct. (A) Left knee medial meniscus posterior root repair after final tensioning. (B) After confirming the meniscus is well reduced, (C) the suture tails are cut as they exit the proximal tibia. (AL, anterolateral; MFC, medial femoral condyle; MM, medial meniscus; MTP, medial tibial plateau.)

determining the optimal MRT repair strategy. Various repair techniques have been developed with the common goals of minimizing technical barriers while maximizing meniscus to bone healing through the enhancement of initial fixation strength and resistance against subsequent cyclic displacement during postoperative rehabilitation.

Given the decreased intrinsic healing capability of the meniscus and high stress placed on the root with normal cyclic loading, methods to improve its healing potential should be considered. Accordingly, securing the meniscus to an area of decorticated bone after introducing marrow contents to the repair site via transtibial drilling demonstrates a method that may enhance healing.[19] Transtibial techniques limit the technical barriers associated with suture anchor methods such as posterior portal placement near neurovascular structures and constrained suture passing within the knee. Although transtibial techniques have become the gold standard in MRT repair, innovation is needed to overcome the limitations inherent to traditional approaches.[12] Traditional transtibial pullout repair techniques secure the meniscus root to the tibial plateau with manual knot tying over a tibial suture-button or suture-anchor fixation via meniscus suture passage through a tibial bone tunnel. Consequently, the increased distance between the suture and anchor associated with transtibial designs may inherently prohibit concomitant procedures or cause suture abrasion and introduce creep into the construct. Contemporary transtibial pullout repair designs aim to overcome these intrinsic drawbacks and offer a knotless adjustable construct with direct fixation at the anatomic footprint via aperture intratunnel soft anchor fixation. A recent biomechanical study compared various suture configurations (2 cinch sutures, 2 cinch loops, 2 simple sutures, 1 horizontal suture, and Mason-Allen suture) using traditional fixed transtibial pullout repair techniques for posterior medial meniscus root repair versus a new knotless, adjustable device (SutureLoc; Arthrex) with intratunnel soft anchor fixation and rip-stop suture repair. The authors reported the adjustable transtibial pullout repair led to considerably higher initial repair load and relief displacement compared to all fixed repairs and restricted cyclic displacement to match with the native meniscus function.[12]

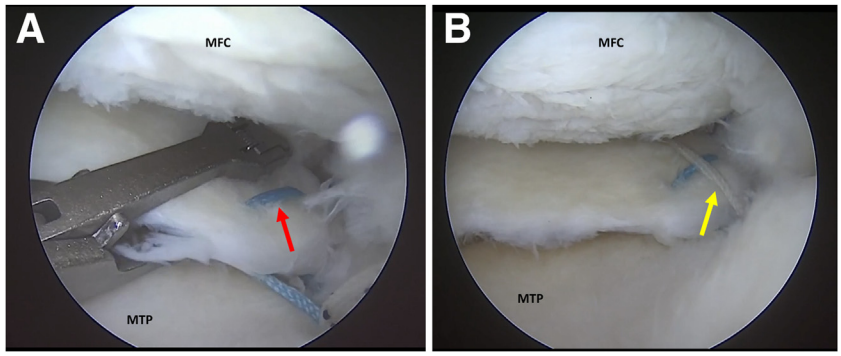

Fig 11. Alternative rip-stop technique. Left knee medial meniscus posterior root repair using a rip-stop suture configuration without a dedicated rip-stop stitch (viewed from the AL portal). (A) The first repair suture (red arrow) is placed in a horizontal mattress fashion followed by (B) the second repair suture (yellow arrow) placed in simple fashion just medial to the horizontal mattress suture. (AL, anterolateral; MFC, medial femoral condyle; MTP, medial tibial plateau.)

Table 2. Advantages and Disadvantages, Including Risks and Limitations, of Arthroscopic Medial Meniscus Posterior Horn Direct Anchor Root Repair Using a Transtibial Approach With Knotless Adjustable Aperture Fixation

Advantages	Disadvantages, Risks, and Limitations
No need for posterior medial portal, only 2 standard anterior portals used.	Learning curve for knotless suture management with the fixation device.
Biomechanical advantage with aperture direct anchor fixation adjacent to anatomic footprint.	Need to reassess at the end of the procedure to be sure optimal tension in repair is being maintained.
No fixation extending beyond the direct knotless suture anchor maintains all tibial bone for concomitant procedures like HTO, ACL, PCL, and so on.	Patient still needs to be protected weightbearing for 6 weeks postoperatively to avoid loss of fixation/root reduction.
Suture tension can be adjusted and readjusted under direct visualization.	
Aperture fixation with implant and rip-stop sutures provides excellent root repair stability.	

ACL, anterior cruciate ligament; HTO, high tibial osteotomy; PCL, posterior cruciate ligament.

The meniscus-suture interface has been identified as the weakest interface, and medial MRTs are often associated with degenerative tissue. Accordingly, the next generation of repair techniques requires special attention to optimize suture configuration strategies. Given the propensity of cinch sutures to pull through degenerative tissue, suture configurations with a rip stop represent an appealing alternative to limit suture cutout. Importantly, biomechanical analyses have identified suture configurations with a rip stop to demonstrate the lowest displacement during cyclic loading and the highest ultimate failure load.[14,15] We present 2 options for achieving a rip-stop suture configuration. The 2 SutureLoc repair sutures can be either passed in simple fashion behind a dedicated tied 2-0 rip-stop suture or exclusively tied in a rip-stop configuration via modified Mason-Allen technique or with a Mac stitch.[20]

This technique is not without limitations. Initial repair strategies focused solely on anatomic root repair have been unable to completely correct meniscus extrusion. Consequently, additional procedures such as meniscus centralization may be necessary to optimize the chondroprotective benefits of MRT repair.[21-23] Our technique uses standard and familiar anterior portals, optimizes suture configuration with the application of a rip stop, and aims to overcome the inherent limitations of traditional transtibial approaches with the utilization of a knotless adjustable implant that permits direct fixation at the anatomic footprint while preserving tibial bone for concomitant procedures (Table 2).

Disclosures

The authors report the following potential conflicts of interest or sources of funding: A.J.K. receives research support from Aesculap/B.Braun, receives royalties from Arthrex, and is a paid consultant for Arthrex. P.A.S. receives royalties from Arthrex; is a paid consultant, paid presenter, or speaker for Arthrex; receives research support for Arthrex; and has stock/stock options with Spinal Simplicity. All other authors (D.R.L., S.C.C., A.V.D.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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