

Arthroscopic Transtibial Pull-Out Repair for Meniscal Posterior Root Tear: The Slip Knot Technique



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Abstract: A meniscal root tear can increase the tibiofemoral contact pressure to approximate that of total meniscectomy and eventually lead to degenerative change. An anatomic and stable meniscal root repair is essential in restoring the tibiofemoral contact pressure back to that of a normal knee. Suture anchor technique and pull-out suture technique are the 2 main arthroscopic root repair procedures with equivalent success; nonetheless, there remains a lack of an optimal technique with a biomechanical property matching that of the intact root. This article presents a technically simple, fast, and robust pull-out suture construct that incorporates 2 slip-knot locking loops at the meniscus-suture interface. This technique can be used for both medial and lateral posterior root repair, as well as concomitantly with cruciate ligament reconstruction.

The medial and lateral meniscus are a pair of semilunar fibrocartilage that function in load distribution, shock absorption, joint stability, and lubrication of the knee joint.¹ As high as 10% to 28% of all meniscal tears are at or near the attachment sites.^{2,3} Meniscal root tears are radial lesions, located within 9 mm from their insertion, or bony avulsions at this level,⁴ and they can increase the tibiofemoral contact pressure to approximate that of total meniscectomy, alter kinematics of the knee joint in causing instability, and eventually lead to degenerative change within a year.^{5,6} Posterior root tears of the medial meniscus are usually degenerative in nature, commonly seen in obese, middle-aged women with varus deformity,⁷ whereas those of the lateral meniscus are usually traumatic injuries, as seen in 8% of anterior cruciate ligament (ACL) tears.⁸ A successful meniscal root repair can restore

the tibiofemoral contact pressure to that of a normal knee,⁹ improve joint stability, provide good functional outcomes, and prevent further degenerative change.^{10,11}

Two main techniques for repairing the meniscal posterior root tear are the suture anchor technique and the pull-out suture technique through transtibial tunnel. A recent systematic review of laboratory studies showed that there is no consensus on biomechanical superiority between the 2 techniques if done anatomically.¹² A biomechanical study simulating the cyclic loading during postoperative rehabilitation revealed that the meniscus-suture interface contributed significantly more displacement than the button-bone interface or suture elongation in the transtibial pull-out repair construct.¹³ Therefore optimizing the stability of the meniscus-suture interface should be the main objective in such root repair technique. The aim of this Technical Note is to convey a fast, simple, yet robust arthroscopic transtibial pull-out suture technique that can be used to repair the posterior root of either medial or lateral meniscus.

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Indications for Surgery

Indications for surgical management of meniscal root tears are (1) symptomatic degenerative tears that are refractory to nonsurgical management with limitations of daily living activities and (2) acute tears that are concomitant with other knee injuries such as anterior cruciate ligament tear. Contraindications to meniscal root repair are (1) high-risk patients with medial comorbidities or advanced age,¹⁴ (2) diffuse International Cartilage Repair Society grade 3 or 4 chondral

Table 1. Special Instruments Required for Arthroscopic Meniscal Root Repair with the Slip Knot Technique

Arthroscopic cannula (8 mm × 3 mm PassPort Cannula, Arthrex)
Self-retrieving suture passing device (Knee Scorpion, Arthrex)
Retroreamer (6-mm FlipCutter, Arthrex)
UHMWPE suture (2-0 FiberWire, Arthrex)
4.75-mm Swivelock anchor with preloaded 2-mm FiberTape (Arthrex)
UHMWPE, ultra-high molecular weight polyethylene.

changes in the ipsilateral femoral condyle or tibial plateau articular cartilage,¹⁵ and (3) patients with significant asymmetric malalignment ($>5^\circ$) who should undergo a corrective osteotomy concurrently or before the root repair.¹⁶

Surgical Technique

A detailed step-by-step description of the surgical technique is demonstrated in [Video 1](#). In addition to standard arthroscopic instruments, some specialized devices are required for the presented slip knot technique ([Table 1](#)), of which pearls and pitfalls are listed in [Table 2](#).

Patient Positioning

After anesthesia, the patient is placed in the supine position on an operating table with a lateral bolster and a leg roll. No tourniquet is used as in all our other knee arthroscopic procedures. After prepping and draping the operated extremity in the usual sterile fashion, 3 standard (anterolateral [AL], anteromedial, and accessory anteromedial, which is added for concomitant ACL reconstruction) portals are made. Subsequent diagnostic arthroscopy with the knee in a figure-of-4 position reveals a completely torn ACL ([Fig 1A](#)) and a LaPrade⁴ type 4 tear of the lateral meniscus posterior root (LMPR) ([Fig 1B](#)). After determining the best perpendicular angle in suturing the root tear, which is from the anterolateral portal in this case, the arthroscope is reintroduced to the knee via the anteromedial portal.

Creation of the Tibial Bone Socket

To prevent an inadvertent injury to the meniscal suture, we prefer to create the tibial tunnel and bone socket before the passage of meniscal sutures. For this root the repair is being performed concomitantly with an ACL reconstruction, and a 2-cm tibial incision is made medial and just distal to the tibial tuberosity for graft harvesting and tunnel drilling. The bone socket is created at the posteromedial aspect of lateral tibial plateau by retroreaming with a 6.0-mm FlipCutter (Arthrex, Naples, FL), which is a 3.5-mm-diameter pin that converts to a 6.0-mm-diameter reamer. Through the AL portal, an ACL targeting guide (Arthrex) with its 3.5-mm inner sleeve, and an elbow aimer set at 60° is placed on the anteromedial cortex just medial to the

tibial tubercle. Care should be taken not to drill the FlipCutter too medial on the tibial cortex in risking a tunnel convergence with the ACL tibial tunnel. The FlipCutter is drilled through the targeting guide and advanced until the cutting portion is completely visible in the joint. The targeting guide is removed, and the inner sleeve is further tapped into the cortex 5 mm with a mallet. The FlipCutter blade is then flipped and retroreamed to create a 1-cm-deep, 6-mm-diameter socket. The FlipCutter is then flipped back straight and removed from the ACL guide while keeping its sleeve in place. The efficiency of the FlipCutter is 2-fold: (1) creating a bone socket in a single step by functioning as both a drill bit and a reamer; (2) bypassing the need of curetting the articular cartilage at the root repair site to enhance meniscal healing. A Beath pin (Arthrex) with a metal wire loop (Arthrex) placed into its eyelet is inserted through the sleeve into the joint. Through the AL portal, an arthroscopic grasper is inserted to retrieve the looped end of the metal wire, which will be used as a shuttling device in pulling out the meniscal root sutures transtibially. The sleeve is then removed from the tibia with the tail of the metal wire outside of the tibial tunnel.

Passage of Meniscal Root Sutures for Slip Knots

To prevent the formation of a soft-tissue bridge during the passage of sutures and instruments, an 8 mm × 3 cm PassPort Cannula (Arthrex) is inserted at the AL portal with the aid of a Kelly clamp. A half hitch is made at the midportion of a 2-0 FiberWire suture (Arthrex) on the

Table 2. Pearls and Pitfalls of Arthroscopic Meniscal Root Repair with the Slip Knot Technique

Pearls	
Pie-crusting of the medial collateral ligament (1cm below its medial epicondyle insertion) may be necessary if the medial compartment is deemed too tight	
In LMPR repair, use AL portal as the working portal for suture passage and knot creation, whereas in MMPR repair, use AM portal as the working portal	
Place the PassPort Canula at the working portal to avoid tissue-bridge formation during suture management	
Transtibial tunnel drilling before meniscal suturing to avoid inadvertent suture damage	
Pull suture knots into the bone socket to avoid chondral abrasion	
Tibial fixation of pullout suture is performed after fixation of cruciate ligament graft	
Pitfalls	
Transphyseal drilling may lead to growth arrest if done in patients with open physis	
Avoid tunnel coalition at the tibial cortex if concomitant cruciate ligament is performed	
Too deep a bite on the meniscal root by the Scorpion may impede needle piercing	
Fixation failure may occur if patient fails to comply with rehabilitation protocol	

AL, anterolateral; AM, anteromedial; LMPR, lateral meniscus posterior root; MMPR, medial meniscus posterior root.

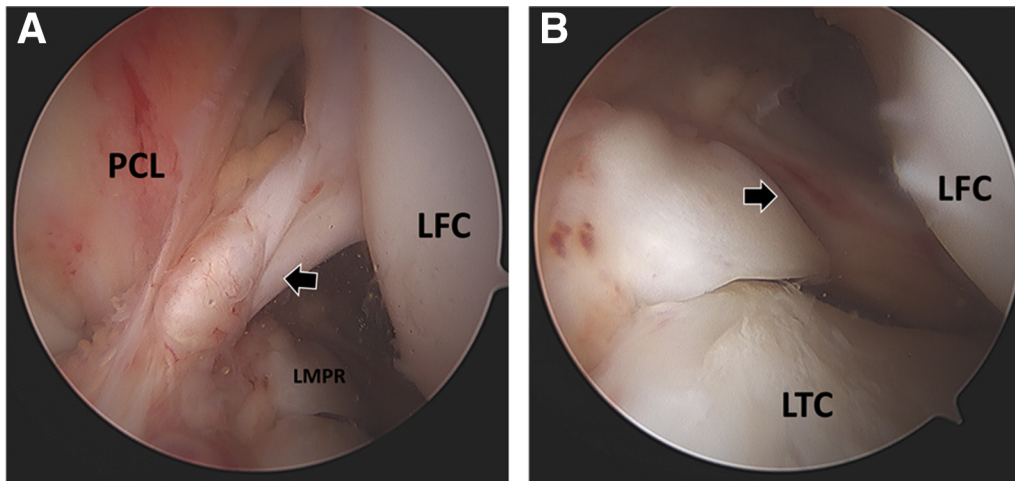


Fig 1. Left knee arthroscopy, viewing from the anterolateral portal with knee in 90° flexion (figure-of-4) position. **(A)** A torn ACL (*arrow*). **(B)** Viewing the posterior lateral compartment reveals an oblique radial tear (*arrow*) of LMPR about 7 mm from its insertion site. ACL, anterior cruciate ligament; LMPR, lateral meniscus posterior root; LFC, lateral femoral condyle; LTC, lateral tibial condyle; PCL, posterior cruciate ligament.

rigid post of a self-retrieving suture passing device (Knee Scorpion; Arthrex) (Fig 2), onto the lower jaw of which one free end of the suture, after being marked as the working limb, is then loaded and pierced through the torn meniscal root by the Scorpion needle (Fig 3). Upon its retrieval by the upper jaw of Scorpion through the PassPort cannula, the working limb is deliberately passed through the half-hitch loop (Fig 4) to make an overhand running knot that slides easily into the joint and forms a loop (noose) on the meniscus (Fig 5), thus creating a slip knot configuration. The knot tightens upon pulling on the working limb and can be loosened by pulling on the other (standing) limb. The 2-mm-width FiberTape preloaded on a 4.75-mm BioComposite SwiveLock (Arthrex) that is to be used for tibial fixation is then taken down and used to repeat the procedure 5 mm medial to the initial suture to provide 2 suture-loops spanning the posterior root of the meniscus (Fig 6).

Suture Passage Into Tibial Socket

The transtibial metal wires that parked earlier at the AL portal is now retrieved through the PassPort Cannula. The 4 limbs of meniscal sutures are then passed through the metal wire loop and shuttled through the tibial tunnel. By pulling on the working limbs of the 2 sutures, the meniscal root is securely reduced to the bone socket with the knots embedded within to avoid possible suture abrasion on the articular cartilage (Fig 7).

Tibial Fixation of Meniscal Root Sutures

This step is performed after the standard single-bundle ACL reconstruction with hamstring autograft has been done. The aforementioned 4.75-mm Bio-Composite SwiveLock anchor (Arthrex) is used for the

tibial cortical fixation of meniscal sutures. A pilot hole is drilled 1.5 cm distal to the FlipCutter tibial hole, followed by a tapping of the cortex by a 4.5-mm tap. With the knee flexed to 30°, the 4 suture limbs of meniscal sutures are passed through the eyelet of the SwiveLock; under moderate tension to the suture, the anchor is screwed into the tibial hole until it is flush with the cortex (Fig 8). The arthroscope and probe are then



Fig 2. A half hitch (*arrow*) is made at the midportion of a 2-0 FiberWire suture (Arthrex, Naples, FL) on the post of Knee Scorpion (Arthrex).

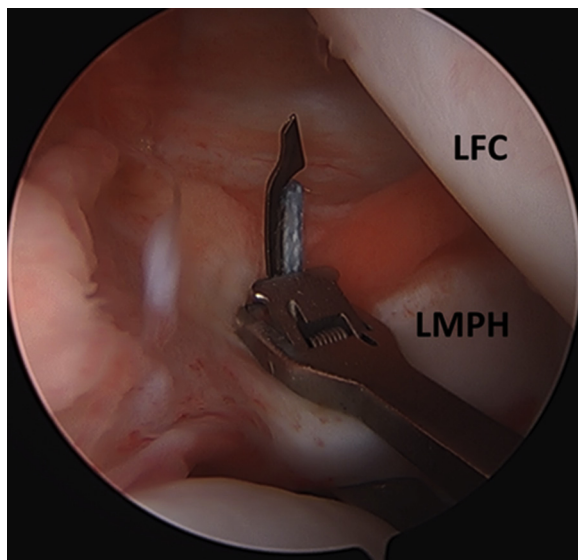


Fig 3. Left knee arthroscopy of posterior lateral compartment, viewing from the anteromedial portal with knee in 90° flexion (figure-of-4) position. A Knee Scorpion is inserted from the anterolateral portal via the PassPort Cannula to pass the working limb of the 2-0 FiberWire through the torn end of lateral meniscus. LFC, lateral femoral condyle; LMPH, lateral meniscus posterior horn.

reintroduced into the joint to confirm that anatomic stable fixation has been obtained.

Postoperative Care

The operated knee is placed in a knee extension brace for 4 weeks and remains non-weightbearing for 6 weeks. Passive range of motion is allowed from 0° to 90° for 6 weeks starting on day 1, followed by full range of motion and a graded return to weightbearing from weeks 6 to 8 after operation. Deep squats are allowed at 4 months with running at 6 months after operation.

Discussion

Increasing numbers of biomechanical and clinical studies have shown that anatomic repairs of the meniscal posterior root tear can significantly improve knee functional score, normalize joint kinematics, and delay the degenerative changes.^{5,17-19} However, despite the significantly improved clinical outcomes, the healing status of the root repair has been suboptimal.^{10,11} In a systematic review on transtibial pullout for medial meniscus posterior root tears, Feucht et al.¹⁰ showed that based on magnetic resonance imaging and second-look arthroscopy, 62% of patients had complete healing, 34% had partial healing, and 10% had re-tear. Likewise, in a case series of 56 patients undergone pullout repairs for medial meniscus posterior root tears, Lee et al.¹¹ showed that only 69.7% had successful healing upon second-look arthroscopy. LaPrade et al.²⁰ reported failure and the subsequent need

for revision surgery in 9.7% of the patients in their study. In pursuit of better healing potential, several surgical techniques have been proposed in the literature, yet the optimal method, which should have high stiffness with minimal displacement, has not been determined.²¹ In a systematic review evaluating the biomechanical properties of meniscal posterior root repair, Jiang et al.¹² ratified the lack of consensus on the optimal suture material and configuration, 2 factors of the meniscus-suture interface that are biomechanically proven to be the weakest link in the pullout suture construct.^{22,23} They further stated that more complex sutures would theoretically exhibit higher maximum loads but might not be technically feasible in vivo. Anz et al.²⁴ illustrated in their laboratory study that repair configuration of 2 double-locking loop sutures has significantly higher failure loads compares with that of 1 double-locking loop suture, 1 inverted mattress suture, or 2 simple sutures. Likewise, Mitchell et al.²⁵ in a biomechanical study comparing the pullout strength of 4 different repair constructs using No. 0 FiberWire (Arthrex), including a single suture, a double suture, a loop stitch, and a locking loop stitch, and found the locking loop stitch to be closest to the native load-to-failure strength of the meniscal root. Furthermore,



Fig 4. After being passed through the meniscus upon piercing of Scorpion needle, the working limb is captured by the upper jaw of Scorpion, retrieved out the joint from the anterolateral portal, and conveniently brought passed through the half hitch made earlier on the post of Scorpion (Fig 2) to form a slip knot.

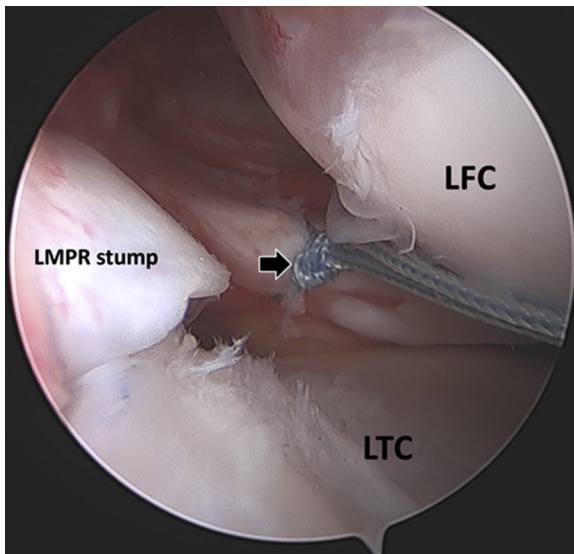


Fig 5. Left knee arthroscopy of posterior lateral compartment, viewing from the anteromedial portal with knee in 90° flexion (figure-of-4) position. The knot proceeds to slide into the joint through the PassPort Cannula and creates a locking loop at the meniscus (arrow). LFC, lateral femoral condyle; LMPR, lateral meniscus posterior root; LTC, lateral tibial condyle.

several biomechanical studies have shown that suture tape offers higher maximum load with less displacement than standard sutures.^{22,23,26} Although the slip knot technique described in this Technical Note has not

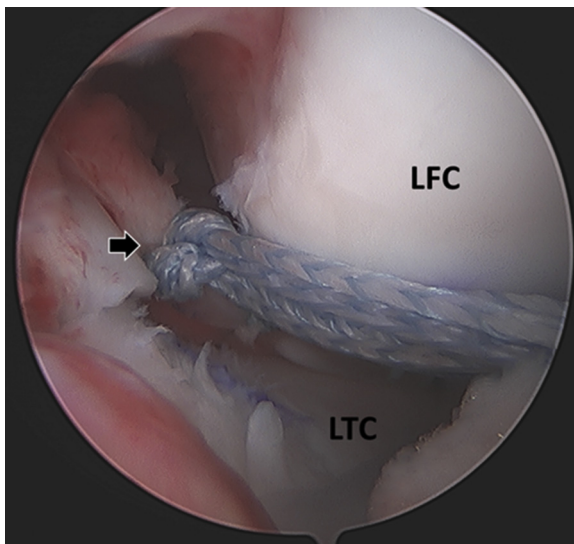


Fig 6. Left knee arthroscopy of posterior lateral compartment, viewing from the anteromedial portal with knee in 90° flexion (figure-of-4) position. A second slip knot (arrow), using the preloaded 2-mm-width FiberTape (Arthrex) on a 4.75 mm Swivelock (Arthrex), is made looping the meniscus 5 mm medial to the first knot for a 2-locking-loop meniscus-suture configuration. LFC, lateral femoral condyle; LTC, lateral tibial condyle.

been biomechanically attested, it does follow the same principles of previous studies in suture material, suture configuration, and anatomic repair.

Our technique for meniscus posterior root repair has several advantages (Table 3). First, the procedure can be done for either medial or lateral meniscus using standard anterior portals, no additional posterior portal required. Second, a 1-step creation of a locking loop at the meniscus-suture interface is easily obtained by passing the retrieved suture limb through the half hitch on the Scorpion post. It is time saving, technically simple, and relatively cost-effective because it mimics the function of the cinch loop created by using the more costly FiberSnare or FiberLink (Arthrex) described in previous Technical Notes.²⁷⁻³² Third, unsought iatrogenic injury to the meniscus is minimized with just one piercing of passing device. Fourth, using the 2-mm-width Fibertape (Arthrex) preloaded on the tibial-fixating SwiveLock (Arthrex) in making the second slip knot on the meniscus provides further stability to the suture construct without an additional cost to the surgery. And lastly, the creation of tibial bone socket offers 3 amenities: (1) enhancing the meniscal healing potential with bone marrow exudation, (2) preserving tibial bone stock, especially in the setting of a

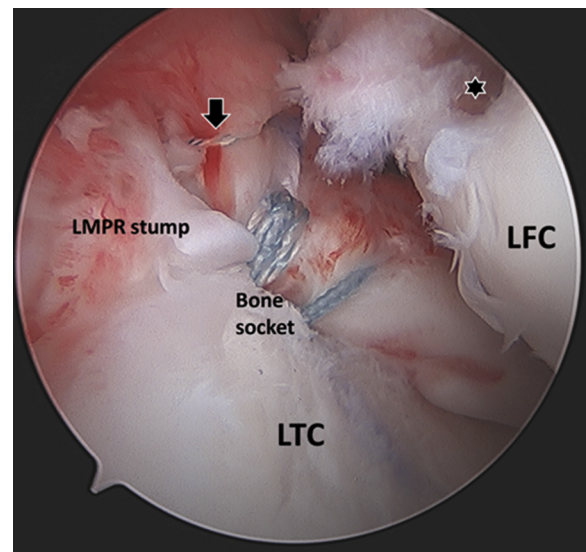


Fig 7. Left knee arthroscopy of posterior lateral compartment, viewing from the anteromedial portal with knee in 90° flexion (figure-of-4) position. After all 4 suture limbs of the 2 slip knots been shuttled through the transtibial tunnel, the meniscal root is securely reduced to the bone socket with the prominent knots nicely embedded to avoid chondral abrasion. An additional side-to-side approximation of torn end of LMPR and its stump is made by using an all-inside suture (Jugger-Stitch, Zimmer Biomet, Warsaw, IN, USA) (arrow). Asterisk indicates the ACL femoral tunnel. ACL, anterior cruciate ligament; LFC, lateral femoral condyle; LMPR, lateral meniscus posterior root; LTC, lateral tibial condyle.



Fig 8. Placement of a 4.75-mm Swivelock anchor for tibial fixation of the pull-out suture construct on the anteromedial tibial cortex.

concomitant cruciate ligament reconstruction, and (3) rendering a “knotless” effect to the construct by embedding the suture knots, thus avoiding possible chondral abrasion.

Table 3. Advantages and Disadvantages of Arthroscopic Meniscal Root Repair with the Slip Knot Technique

Advantages	
Anatomic restoration of either meniscal posterior root via standard arthroscopic AM and AL portals	
Technically simple, time-saving and strong loop created at the meniscus-suture interface	
Further iatrogenic trauma to the meniscus is minimized with just single needle-piercing needed per loop	
Using the Fibertape preloaded on the tibia-fixating Swivelock anchor for the pullout suture provides not only additional stability to the repair construct without an additional cost to the surgery, but also decrease the risk of suture cutout at the meniscus-suture interface	
Creation of bone socket not only enhances the biologic healing of repair but also renders a “knotless” effect at the meniscus-suture interface in preventing chondral abrasion	
Disadvantages	
Persistent meniscal extrusion and progressive degeneration of tibiofemoral joint despite healed meniscal root	
Risk of tunnel convergence with concomitant cruciate ligament reconstruction	
Risk of suture cutout from the friable meniscal tissue	
Requires specific instrumentation that may not be available to all surgeons	

AL, anterolateral; AM, anteromedial.

There are some inherent limitations to this pullout suture technique. First, despite improved clinical outcomes and healed meniscal roots, persistent meniscal extrusion and progressive chondral degeneration might still be noted on postoperative magnetic resonance imaging.^{33,34} Second, the transosseous pullout tunnel may interfere or converge with the tibial tunnel of concomitant procedure such as cruciate ligament reconstruction. Last, friable meniscal tissue may render the possibility of suture cutout causing further damage to the meniscus; however, this “cheese cutter” effect can be minimized by using FiberTape as suture material that provides a wider contact surface with the meniscus for a better grip. The technique described in this Technical Note provides a simple, time-saving, and effective alternative method to repair often challenging meniscal root tears. Further biomechanical and clinical studies are warranted to validate the superiority of this slip knot technique in pullout strength and patient outcomes.

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