Technical Note

Concurrent Repair of Medial Meniscal Ramp Lesions and Lateral Meniscus Root Tears in Patients Undergoing Anterior Cruciate Ligament Reconstruction: The "New Terrible Triad"

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Abstract: Recent studies have suggested that up to 8% of patients with anterior cruciate ligament (ACL) tears can present with a combined medial meniscal ramp lesion (MMRL) and lateral meniscus root tear (LMRT). MMRLs and LMRTs often are missed preoperatively and can increase the risk of ACL graft failure if left untreated. Given the potential synergistic biomechanical consequences and challenging repair techniques used for treatment, our group commonly refers to this presentation (MMRL-LMRT-ACL) as the "new terrible triad" of ACL pathology. This Technical Note aims to describe a systematic approach for arthroscopic assessment and our preferred inside-out and transtibial pull-out repair techniques to efficiently diagnose and treat a combined MMRL and LMRT at the time of ACL reconstruction surgery.

Medial meniscal ramp lesions (MMRLs) and lateral meniscus root tears (LMRTs) are injuries that typically are described individually in patients with acute anterior cruciate ligament (ACL) tears.[1,2] However, recent studies have suggested that up to 8% of patients with ACL tears can present with a combined MMRL and LMRT, although further studies are needed to confirm these findings.[2-4] Although preoperative magnetic resonance imaging (MRI) can be useful for diagnosing these meniscal injuries, DePhillipo et al.[5] and Krych et al.[6] reported sensitivities of 48% and 33% for the detection of MMRLs and LMRTs on MRI, respectively. As a result, these injuries frequently are missed preoperatively and require a thorough arthroscopic assessment at the time of ACL reconstruction surgery.[7,8]

In ACL-deficient knees, biomechanical studies have demonstrated that the presence of MMRLs increases the degree of anterior tibial translation and external rotation.[9-11] Clinically, repair of MMRLs can restore these increased laxities when compared with isolated ACL injuries.[2,9] Similar to MMRLs, cadaveric studies have demonstrated that an LMRT has important rotational and translational effects on both an ACL-deficient and an ACL-reconstructed knee.[12-14] As such, ignoring or missing a MMRL or LMRT at the time of ACL reconstruction may increase the risk of postoperative graft failure.[9-11] Although these consequences have been reported individually, missing a combined MMRL and LMRT may confer an even greater risk of ACL graft failure. In addition to being frequently missed and difficult to diagnose, surgical treatment is technically challenging, and reports on concurrent repair techniques are limited.[3,4] Given the unique characteristics of this injury pattern, our group commonly refers to this presentation (MMRL-LMRT-ACL) as the "new terrible triad" of ACL pathology.

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This Technical Note describes a systematic approach for arthroscopic assessment and our preferred inside-out and transtibial pull-out repair techniques to efficiently diagnose and treat a combined MMRL and LMRT at the time of ACL reconstruction surgery. This Technical Note also provides important tips and pearls for performing these concurrent repair techniques.

Objective Diagnosis

A standard radiographic series is performed on each patient with a suspicion for ACL injury, including anteroposterior, lateral, sunrise, Rosenberg, long-leg standing, and full tibia lateral views. The full-length tibia views are scrutinized to measure the lateral posterior tibia slope to assess the need for a possible lateral extra-articular tenodesis. The senior author will consider the addition of an lateral extra-articular tenodesis (LET) to a primary ACL reconstruction if the lateral posterior tibial slope is greater than 12° and/or if there is hyperlaxity as determined by knee hyperextension (heel height >5 cm), as these have been shown to increase forces on the ACL graft in biomechanical studies[15] and are associated with greater rates of failure in clinical studies.[16-18] Getgood et al.[19] reported the addition of an LET to ACL reconstruction in high-risk patients significantly improved failure rates. Similarly, long-leg radiographs are used to assess coronal alignment because varus and valgus forces have been demonstrated to increase forces on the ACL graft.[20]

Finally, an MRI is obtained to confirm the presence of an ACL tear, as well to assess for additional ligament, chondral, and meniscal injury in the knee. Particular attention is paid to the medial meniscus ramp and lateral meniscus root attachments; however, as stated previously, the lack of identification of injury to these structures on MRI should not preclude a thorough arthroscopic evaluation of these structures at the time of surgery. The lateral meniscus root if injured will commonly show a "ghost sign" (Fig 1).

Surgical Technique (With Video Illustration)

The technique is detailed in Video 1. Pearls and pitfalls and advantages and disadvantages of this approach are discussed in Tables 1 and 2, respectively.

Patient Positioning and Anesthesia

Per our institutional protocol, a single-shot adductor canal regional block is performed in the preoperative

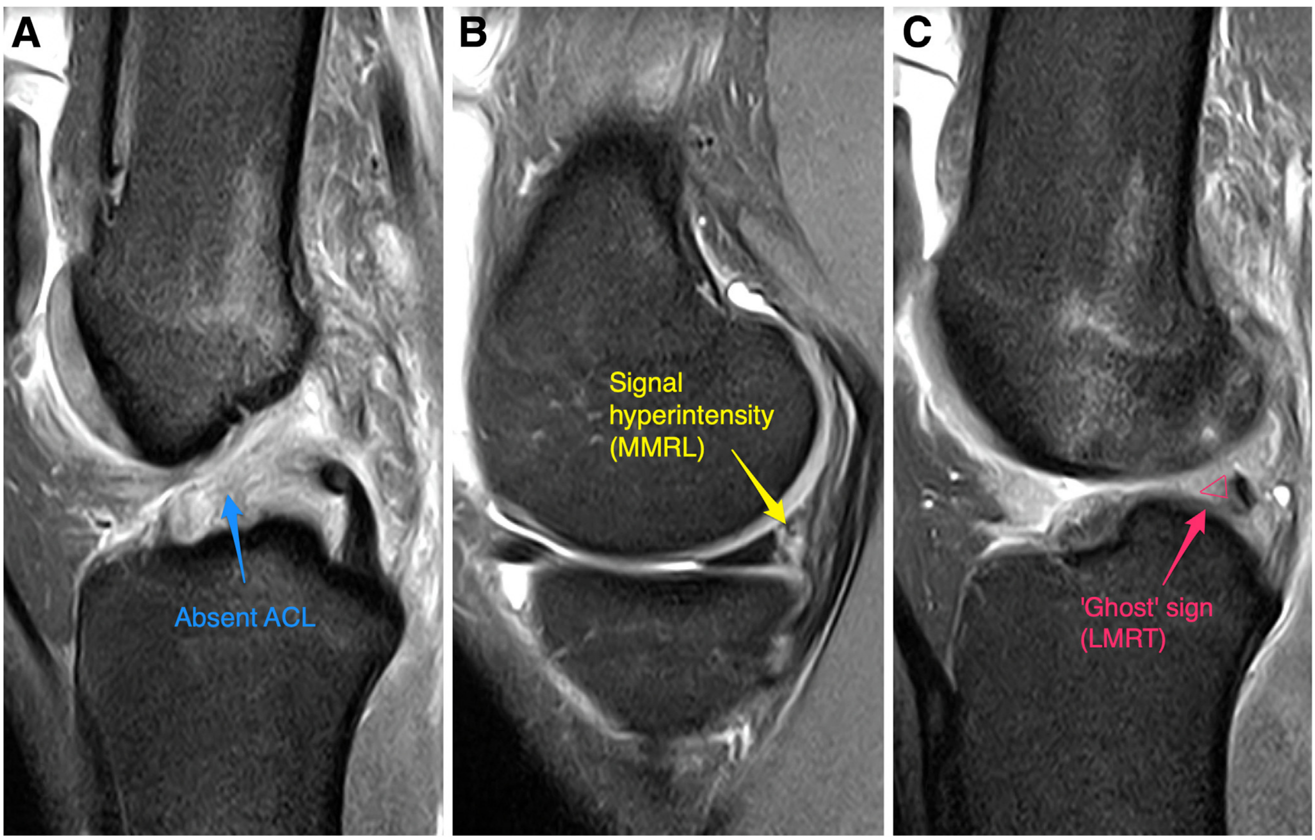

Fig 1. T2-weighted sagittal magnetic resonance imaging sections of a left knee depicting "the new terrible triad;" (A) Anterior cruciate ligament (ACL) tear as seen by the absence of the ligament, (B) medial meniscal ramp lesion (MMRL) as evidenced by the signal hyperintensity between the meniscus and the capsule, and (C) lateral meniscal root tear (LMRT), which is shown here with a classic "ghost" sign, where the meniscal root is simply missing from the plane in which it should be seen.

Table 1. Steps and Associated Pearls and Pitfalls for an Efficient Anterior Cruciate Ligament (ACL) Reconstruction With Associated Medial Meniscal Ramp Lesion (MMRL) and Lateral Meniscus Root Tear (LMRT)

Step	Pearls	Pitfalls
Patient positioning	Ensure leg holder is proximal enough for the femoral ACL tunnel drilling and medial inside-out meniscal procedure	Failure to set up for adequate knee range of motion may lead to difficulty with, or even inability to create an anatomic ACL femoral tunnel
	Tilt the leg holder leg holder proximally to allow for needed hyperflexion for anatomic drilling of the ACL femoral tunnel	
ACL graft harvest	Doing the ACL graft harvest first increases procedural efficiency by allowing the assistant time to prepare the graft on the back table	Failure to create a large enough bone plug may result in decreased fixation and bony graft incorporation, and thus lose the advantages of BPTB autograft
	Create a 10-mm wide graft of the patellar tendon using a scalpel followed by an oscillating saw for the patellar and tibial tubercle bone plugs before ultimately freeing the graft with a thin straight osteotome	
	Following graft harvest, use a #10 scalpel to create the medial and lateral portals to allow for efficient instrument passing and swapping the arthroscope and instruments between portals	
Arthroscopic evaluation	First, debride the redundant fat pad to allow for appropriate visualization of the ACL lateral wall attachment and the medial and lateral compartments	Nonanatomic placement of ACL tunnels results in increased risk of failure due to altered tibiofemoral biomechanics
	An accessory anteromedial portal is placed to ensure that an anatomic ACL femoral tunnel can be drilled	
	To have an appropriate anatomic positioning of the ACL femoral tunnel, the back wall is completely visualized by cleaning off all soft tissues followed by a bur to mark the intended location of drilling	
	Drill the first 5 mm of the femoral tunnel and switch the camera to the anteromedial portal to ensure that there is an appropriate back wall (>2 mm) before reaming the socket to a depth of 25 mm	Lack of adequate back wall may result in inadequate fixation and may necessitate alteration in fixation strategy
MMRL	Perform the Gillquist maneuver in all ACL reconstructions by passing the camera between the medial femoral condyle and the posterior cruciate ligament. In addition, a probe should be used to displace the posterior capsule and ensure no hidden lesions are present	Failure to adequately visualize all meniscocapsular and meniscotibial attachments may result in missed lesions which have been shown to result in higher risk of graft failure
	Perform medial collateral ligament trephination through the medial inside-out meniscal repair approach to ensure adequate visualization is possible for the ramp repair and to avoid iatrogenic cartilage damage during instrumentation	
	Typically, 8 to 12 sutures are used to place suture that alternate at the superior and inferior aspects of the medial meniscus and corresponding capsule	One of the most common reasons for meniscal repair failure is the lack of an adequate number of sutures
	Sutures tied at 90°of knee flexion	
LMRT	Bony bed preparation should be accomplished with a combination of a ring tip curette and a curved shaver	Non-anatomic placement of the tibial tunnels for LMRT may result in inadequate reduction of the meniscus, which leads to failure in removal of increased tibiofemoral cartilaginous point-loading, and does not restore proper tibiofemoral translational stability
	The distal aspect of the tibial guide is used to drill two transtibial tunnels approximately 5 mm apart from the anterolateral tibia to the anatomic lateral posterior root attachment	
	A meniscal root self-capture suture passing device is used to place 2 suture tapes in vertical mattress fashion that are then pulled down the cannulated sleeves and later tied down over the tibia after ACL tibial tunnel preparation to prevent accidental amputation of sutures	Meniscal root tears are, by the nature of the stresses placed upon them, more fragile than some other meniscal repairs; failure to provide a strong suture attachment (e.g., using a simple suturing technique) will increase the risk of failure
ACL tibial tunnel	The anterior root attachment of the lateral meniscus is used as the landmark for the ACL tibial tunnel. The ACL tunnel should not exit more posterior to the posterior margin of the anterior root attachment of the lateral meniscus	Tibial tunnels with a nonanatomic posterior exit point have reduced ability to restore native restraints to tibial external rotation
Final fixation	The BPTB bone graft is first secured into the femoral tunnel with a titanium interference screw	Fixation of the LM root at an earlier point in the surgery may lead to iatrogenic stress and even rupture of the new repair during high flexion of the knee in the following ACL femoral tunnel graft passage and fixation
	The lateral meniscus root is then fixed with the suture tapes tied over a cortical button on the anterior aspect of the tibia with the knee in approximately 75-90° of flexion	
	Lastly, the tibial bone plug of the ACL is fixed in the tibial tunnel with a titanium interference screw in knee extension	

BPTB, bone—patellar tendon—bone.

Table 2. Advantages and disadvantages of Anterior Cruciate Ligament (ACL) Reconstructions With Associated Medial Meniscal Ramp Lesion (MMRL) and Lateral Meniscus Root Tear (LMRT)

	Advantages	Disadvantages
Single-staged procedure	Reduced patient cost and recovery time	Longer operating time
BPTB autograft	High tensile strength and increased bony incorporation of graft with no loss of strength	Increased anterior knee pain at graft site
Inside-out meniscal ramp repair	Increased strength of meniscal repair compared to all-inside repairs, and better restoration of native knee stability compared to ACL reconstruction alone	Technically challenging technique
Transtibial LM root repair	Increased biomechanical strength of repair compared with other methods of LM root repair, and better restoration of native stability compared to ACL reconstruction alone with decreased rates of ACL graft failure	Technically challenging technique

BPTB, bone–patellar tendon–bone.

area. The patient is then placed in a supine position on the operating table. Following general anesthesia, a standard examination under anesthesia is performed on both knees. In the experience of the senior author, a Lachman or pivot shift of 3+ is not an isolated ACL injury and indicates a high likelihood of a concomitant MMRL or LMRT. A well-padded tourniquet is then placed as proximal on the thigh and the leg is placed into a leg holder (Mizuno OSI, Union City, CA), while the contralateral leg is placed in an abduction stirrup. The leg holder should be elevated off the bed and angled proximally to allow for hyperflexion for drilling of the ACL femoral tunnel (Fig 2). The foot of the table is then lowered.

ACL Graft Harvest

The senior author prefers to use a single-bundle reconstruction with a bone–patellar tendon–bone (BPTB) autograft as the first option for a primary ACL reconstruction in skeletally mature patients. In a revision or if BPTB is unavailable or undesirable, the second autograft choice is either a contralateral BPTB or quadriceps tendon autograft with bone block. The ACL BPTB harvest technique has been previously described in detail by Chahla et al.[21]

The first step of the procedure is to harvest the BPTB autograft with a standard anterior incision with the knee flexed to 90°. The paratenon is preserved and flaps are created for later closure. A ruler is used to measure the width of the patellar tendon to ensure the central 10 mm of the tendon is harvested. A scalpel is used to cut the tendon from proximal to distal. Electrocautery is used to mark the bone plugs for the patella (20 mm × 10 mm) and tibial tubercle (25 mm × 10 mm). A small oscillating blade with a 10-mm blade (Stryker, Kalamazoo, MI) is used to create a trapezoidal cut on the patella and a triangular shape on the tibia. Thin straight osteotomes are there used to free up the bone plugs. The graft is then brought to the back table for preparation. The 20-mm patellar bone block is typically used for the femoral attachment and the 25-mm tibial tubercle bone block is intended for the tibial side. At this time, if the plan is to proceed with an LET, the open dissection and preparation of the graft is performed at this time, before fluid extravasation. The final implant insertion is not completed until the final steps of the case to ensure the LET graft is not accidentally injured during the ACL femoral tunnel preparation. The full LET procedure is described in full detail by Bernholt et al.[22]

Arthroscopic Evaluation

Following graft harvest, the arthroscopic evaluation is begun by using a #10 blade to make standard medial and lateral parapatellar portals. Use of a #10 scalpel blade helps to facilitate efficient instrument passing and swapping the arthroscope and instruments between portals. Following portal creation, the impinging portion of the fat pad is first debrided to allow for appropriate visualization, including a view of the lateral wall of the ACL. In addition, a spinal needle is placed through the original BPTB harvest incision site medial to the patellar tendon and used to ensure appropriate positioning for anatomic drilling of the ACL femoral tunnel through an accessory anteromedial drilling portal.

Attention is then paid to the preparation and drilling of the ACL femoral tunnel. A 4.5-mm curved arthroscopic shaver and electrocautery device are used to clear off the lateral wall of the ACL to allow for the use of anatomic landmarks for the ACL as described by Ziegler et al.[18] Specifically, for the femoral attachment, the center of the ACL is located 6.1 mm posterior to the lateral intercondylar ridge and midway between the anteromedial and posterolateral bundle attachments. In order to best later visualize the posterior wall of the femoral tunnel, one needs to ensure the back wall is completely visualized by cleaning off all soft tissues. An arthroscopic burr is used to mark the intended position of the femoral tunnel, with confirmation of appropriate

Fig 2. Setup of operative leg for arthroscopic procedures including anterior cruciate ligament reconstruction, demonstrating angled leg holder for ease of left knee hyperflexion, shown here on a left leg with the patient in supine position.

positioning by switching the camera to the anteromedial portal. A 7-mm over-the-top drill guide is used over the back wall through the anteromedial portal while in the knee is in hyperflexion. A Beath pin is drilled into the lateral wall followed by a 10-mm low-profile reamer for a depth of 5 mm. The area is then cleaned with an arthroscopic shaver from the standard medial parapatellar portal for clear visualization. The positioning of the tunnel is once again confirmed, including verification that 2 mm of the back wall will remain. Once the anatomic tunnel positioning has been confirmed, the reamer is then advanced to a depth of 25 mm. A passing suture is then pulled out the anterolateral femur and clamped for later use in the case.

Medial Meniscus Ramp Lesion

Following the ACL femoral tunnel drilling, attention is then paid to the medial compartment and medial meniscus. This first begins with an arthroscopic evaluation of the medial compartment with a particular emphasis on probing the undersurface of the posterior medial meniscus for a ramp lesion and the medial meniscal root. Oftentimes, if a ramp lesion is present, there will be a clear meniscocapsular disruption with probing of the undersurface of the posterior horn (Fig 3A).

Following this, the senior author then performs a modified Gillquist maneuver to assess for a posterior meniscocapsular lesion. This is performed with the camera positioned in the anterolateral portal, and the knee at 90° of flexion. The camera is passed between the medial femoral condyle and the posterior cruciate ligament. Once in the posterior aspect of the knee, the camera is turned towards the posterior medial meniscus to evaluate for a ramp lesion (Fig 3B). In addition, a probe is used to displace the posteromedial capsule from the meniscocapsular attachment to assess for a ramp tear. This probe can be placed through the intercondylar notch or the medial compartment to assess for a meniscocapsular separation. We do not routinely use a posteromedial portal to assess for a ramp lesion because we feel that we are able to adequately assess for a ramp lesion using this technique in the vast majority of patients.

Once a ramp lesion has been confirmed, the medial approach for an inside-out meniscal repair is made (Fig 4A). As described by DePhillipo et al.,[23] the medial approach is performed in 90° of flexion. A probe is inserted from the anteromedial portal to help identify the joint line. The adductor tubercle and posterior tibia are then marked for localization and an oblique incision is made from the adductor tubercle to 2 cm distal to the joint line along the posterior aspect of the medial tibial plateau. The sartorial fascia is incised to find the "anatomic triangle" of the posteromedial capsule anteriorly, medial gastrocnemius tendon posteriorly, and semimembranosus tendon inferiorly.[23] A Cobb elevator is used to help develop this interval before placement of a spoon to serve as a retractor to protect the neurovascular structures during the meniscal repair (Fig 4B). Through the medial incision, the meniscofemoral portion of the medial collateral ligament is then trephinated with a spinal needle in order to improve the medial opening and ensure that the necessary visualization is possible for the ramp repair and to avoid iatrogenic cartilage damage during instrumentation.

The preferred method of the senior author is to use a self-delivery gun fitted with a cannula (SharpShooter; Stryker, Kalamazoo, MI) to pass double-loaded nonabsorbable sutures (No. 2 FiberWire, Arthrex, Naples, FL). The knee is placed in approximately 20 to 30° of flexion with a valgus force on the knee in order to access the medial compartment. Starting most typically at the medial aspect of the ramp lesion, alternating sutures are placed at the superior and inferior aspects of the medial meniscus and corresponding capsule. For example, for the superior suture, the first suture of the double-loaded suture is passed through the superior aspect of the medial meniscus with the second suture of the double-loaded suture passed superiorly in the superior capsule (Figs 5 and 6). An assistant uses a needle driver to retrieve each of the suture needles through the medial incision (Fig 4C). Sutures are then placed more laterally (towards the root) and typically it requires approximately 8 to 12 sutures to adequately fixate the ramp lesion. Tie down all the sutures at 90° of knee flexion and again assess the quality of the repair.

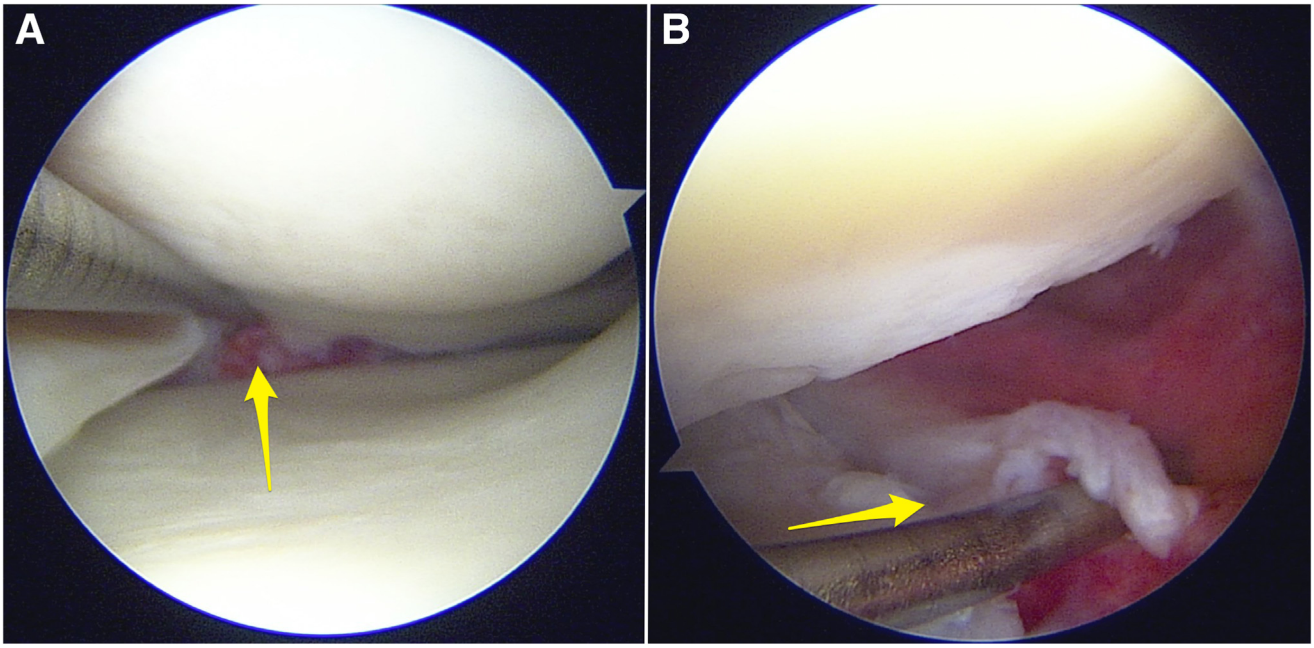

Fig 3. Arthroscopic views of a probe reflecting the medial meniscal posterior horn revealing (A) meniscotibial and (B) meniscocapsular disruptions (yellow arrows) indicative of a medial meniscal ramp lesion. View B is obtained via the Gillquist maneuver to visualize posterior to the medial femoral condyle (left knee).

Lateral Meniscus Root

Attention is next directed to the lateral compartment where the lateral meniscus is assessed and any injury to the meniscal root or body is confirmed. If there is a LMRT and excess scar tissue and adhesions have formed between the posterior horn and capsule, these are released to allow for the lateral meniscus to be mobilized sufficiently to restore it to its native root

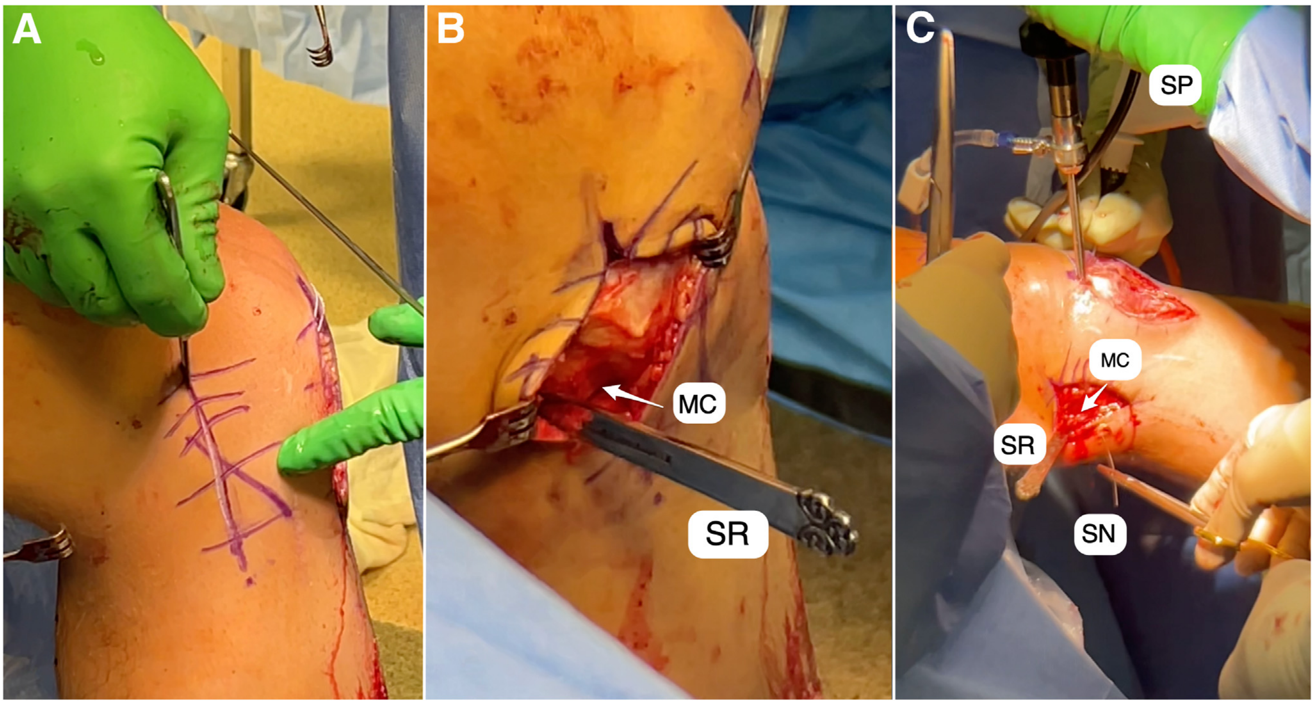

Fig 4. Intraoperative views of a left knee depicting (A) the approach to the medial capsule, (B) exposed medial capsule (MC) and spoon-type retractor (SR) to protect neurovascular structures, and (C) extra-articular view of inside-out suturing technique with assistant catching the suture needle (SN). (SP, suture-passing device.)

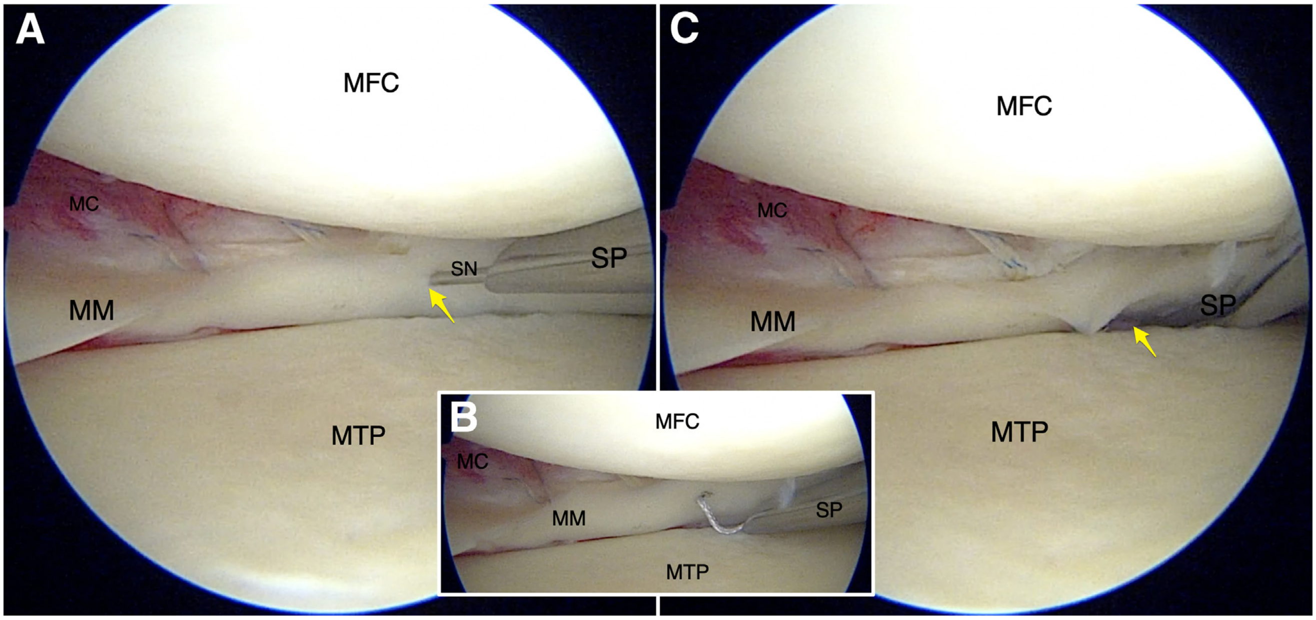

Fig 5. Arthroscopic view of a left knee medial meniscus depicting the step-by-step process of an inside-out suture using a double-ended suture needle. (A) Self-passing suture device (SP) advances the suture needle (SN) into the inferior aspect of the medial meniscus (MM). (B) After the assistant has caught and extracted the suture needle through the medial capsule, the suture-passing device is moved so the next pass will exit (C) through the medial capsule inferior to the meniscus. The yellow arrows indicate the 2 arthroscopic suture needle insertion sites. (MC, medial capsule; MFC, medial femoral condyle; MTP, medial tibial plateau.)

attachment. The technique used for the root tear repair is similar to a previously described technique.[1,24] The native root attachment should be centered approximately 4.2 mm medial and 1.5 mm posterior to the lateral tibial apex eminence.[25] Careful and meticulous bony bed preparation should be accomplished with a combination of a ring tip curette and a curved shaver (Fig 7A). During this preparation one must be sure to

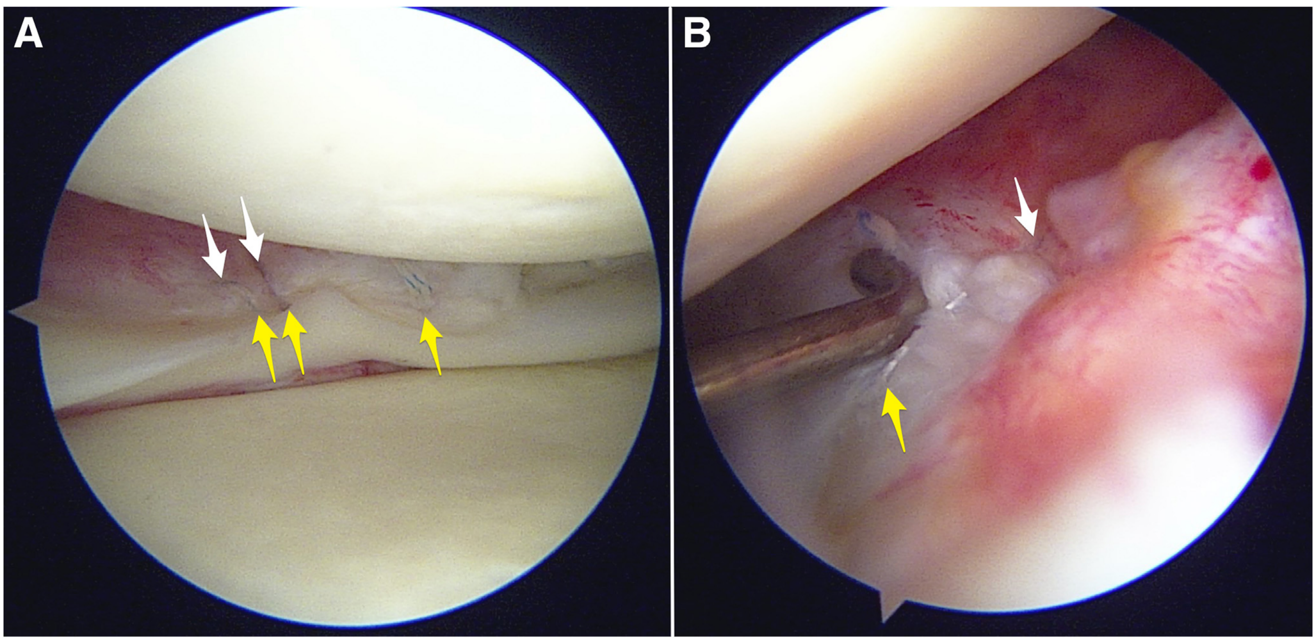

Fig 6. Arthroscopic views of the medial meniscus depicting completed inside-out repair sutures in vertical mattress configuration (A, B). White arrows depict sutures passing through the superior capsule, whereas yellow arrows denote suture passing through the superior edge of the peripheral meniscus (left knee).

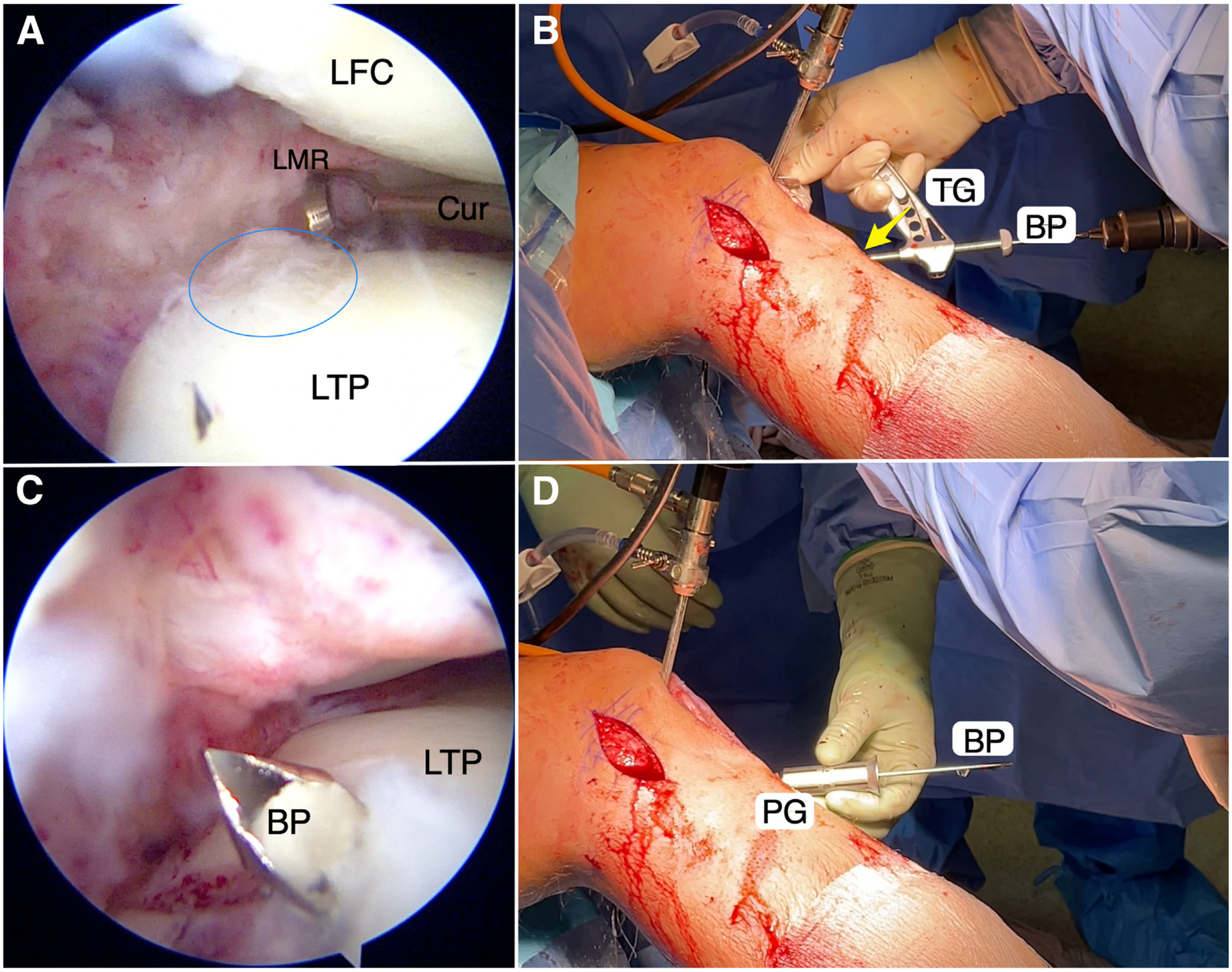

Fig 7. Arthroscopic (A, C) and intraoperative (B, D) views of a lateral meniscus root repair using double transtibial tunnels. (A) Preparation of the bony attachment site of the lateral meniscal root (LMR) at the posteromedial aspect of the lateral tibial plateau (LTP) using a ring curette (Cur). (B) A tibial guide (TG) is oriented to drill the first transtibial tunnel aiming from the anterolateral tibia to the posterior aspect of the root attachment site using a Beath pin (BP). (**C**) The second tunnel is aimed approximately 5 mm anteriorly with the help of (D) a parallel guide (PG; left knee). (LFC, lateral femoral condyle.)

avoid iatrogenic damage to cartilage of the lateral tibial plateau.

Once bony bed preparation has been completed, a meniscal root guide can be inserted and then centered upon the native root attachment (Fig 7B). The BPTB harvest incision is then extended distally so that the anterior compartment musculature below Gerdy's tubercle can be released for approximately 1 to 1.5 cm. The distal aspect of the tibial guide is brought down to bone to drill 2 transtibial tunnels approximately 5 mm apart from the anterolateral tibia to the area of decorticated bone at the lateral meniscus root attachment. The tunnels are drilled one at a time, the first using the tibial aiming guide (Meniscus Root Repair; Smith & Nephew, Andover, MA), and the second using an offset guide to set the distance between the 2 tunnels; ideally, the first tunnel is drilled posterior, and the second tunnel 5 mm anterior to the first (Fig 7 B-D).

Upon confirmation of the tunnel locations the drill pins can be removed and the cannulated sleeves are left in place. A meniscal root self-capture suture passing device (FIRSTPASS; Smith & Nephew, Andover, MA) is then inserted into the joint and 2 suture tapes are passed in vertical mattress fashion (Fig 8). A passing wire is then used to pass the posterior of the 2 meniscal sutures into the posterior tunnel and the anterior suture into the anterior tunnel (Fig 9A). The sutures are then left in place and attention is then paid to the ACL tibial tunnel.

First, for the ACL tibial attachment, electrocautery is used to mark the intended position of the ACL tibial tunnel. The preferred landmark of the senior author is

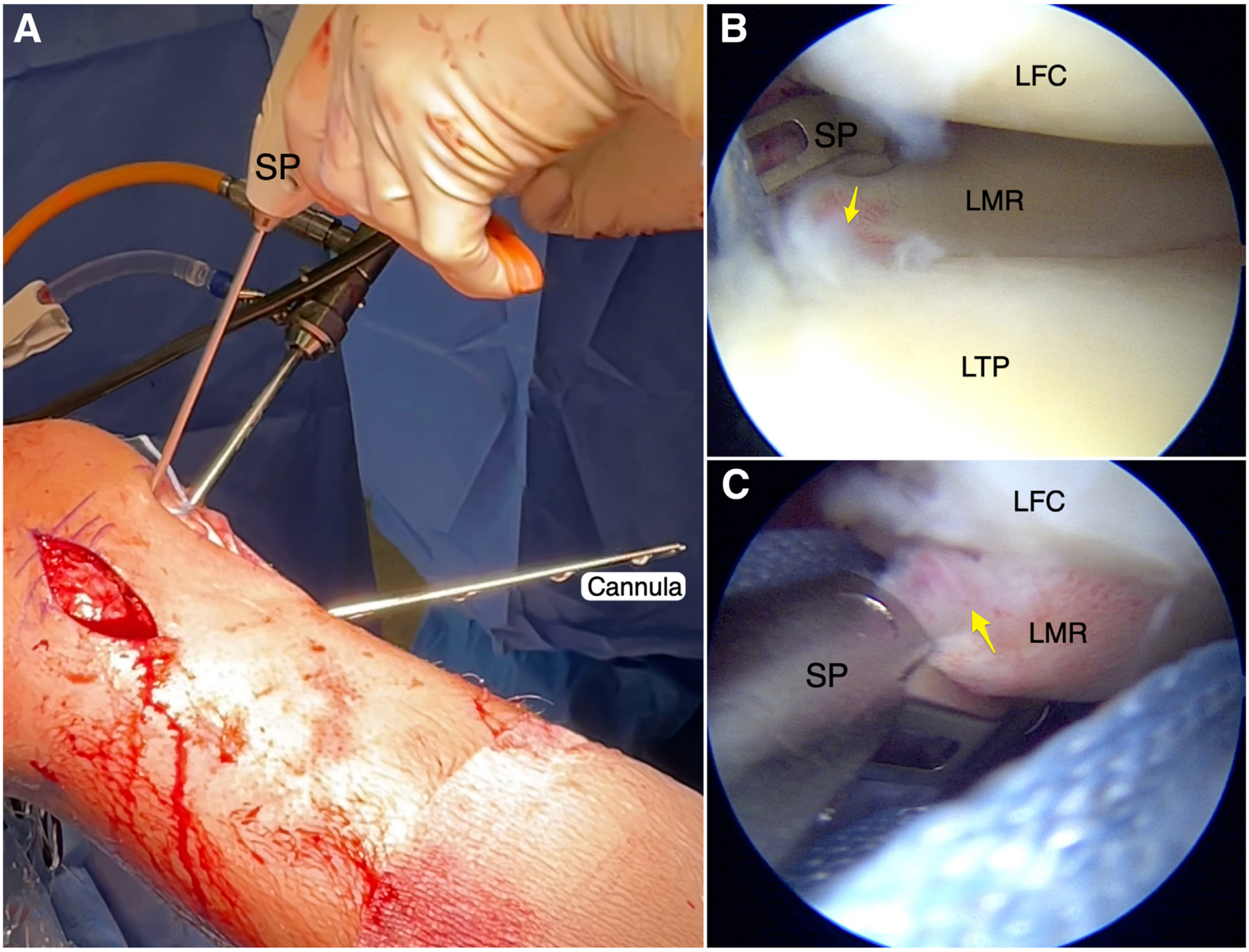

Fig 8. Intraoperative (A) and arthroscopic (B, C) views of a left knee depicting the steps of passing a vertical mattress suture through the lateral meniscal root (LMR). (A) The suture passing device (SP) is placed through the anteromedial portal and (B) the first suture is placed from top to bottom, followed by (C) a second suture placed from bottom to top. The yellow arrows denote the approximate direction of the suture passage. A cannula for passing suture, left behind after the Beath pin is removed, may be seen in (A). (LFC, lateral femoral condyle; LTP, lateral tibial plateau.)

to use the anterior root attachment of the lateral meniscus, which overlaps with the ACL and is readily identified.[26] The ACL tunnel should not exit more posterior to the posterior margin of the anterior root attachment of the lateral meniscus. The tibial ACL tunnel drill guide is set to 65° and should be placed down on the tibia approximately halfway down the tibial tubercle harvest site at 1.5 to 2 cm medial to the tibial tubercle. The guide pin is drilled, followed by a 10-mm acorn reamer. The tibial tunnel is thoroughly cleared with an arthroscopic shaver and rongeur to facilitate easy graft passage and the passing suture is pulled down then tibial tunnel.

The BPTB graft is then pulled into place and secured to the femur with a 7 × 20-mm cannulated titanium interference screw while the knee is hyperflexed. The attention is then brought back to the lateral meniscus root fixation as the suture tapes are then tied individually and then together over a cortical button on the anterior aspect of the tibia with the knee in approximately 75-90 degrees of flexion (Figs 9 B and C, 10, and 11). Finally, in extension, the tibial bone plug of the ACL is fixed in the tibial tunnel with a 9 × 20-mm cannulated titanium interference screw.

Postoperative Rehabilitation

In order to prevent isolated hamstring activation and reduce any stress placed on the MMRL and LMRT repairs, patients are advised to remain non—weight-bearing in a knee immobilizer while at rest for the first 6 weeks after surgery. The patients initiate knee range of motion from 0 to 90° beginning on postoperative day 1. They transition to an ACL brace (CTi; Ossur, Reykjavik, Iceland) at week 6, when they begin to start weight-bearing and when they can initiate a straight leg raise without extension

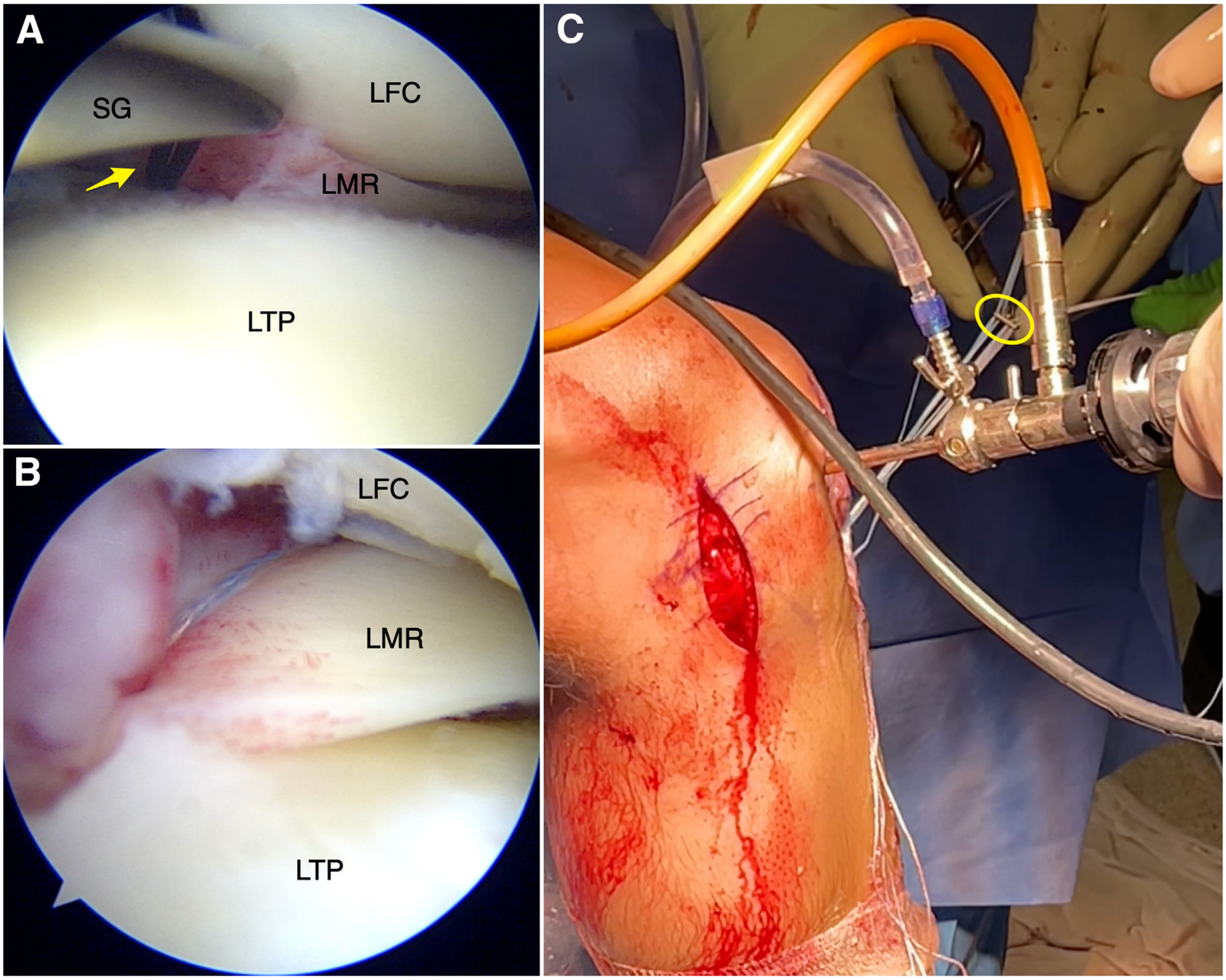

Fig 9. Arthroscopic (A, B) and intraoperative (C) views of a left knee depicting (A) retrieval of a wire suture loop (yellow arrow) using a suture grabber (SG) for passage of suture through the tibial tunnels, (B) tension placed on the suture through the tibial tunnels to evaluate the proper reduction of the lateral meniscal root (LMR), and (C) the application of a cortical button (yellow circle) for fixation of the lateral meniscal root repair to the anterolateral tibia. (LFC, lateral femoral condyle; LTP, lateral tibial plateau.)

sag. Endurance and strength exercises are recommended to start at two months postoperatively and are gradually progressed until normal. Patients may begin straight-ahead running exercises at 5 months, with restrictions on pivoting and twisting. After 6 months, a gradual return to activities is initiated by completing a functional sports test successfully.[1] Return to sports or activity is allowed when patients achieve normal strength, stability, and knee range of motion comparable to the contralateral side, typically occurring at 9 to 10 months postoperatively.[2]

Discussion

The presentation of an MMRL-LMRT-ACL injury ("New Terrible Triad") is not well reported throughout the literature. There are limited clinical outcome studies on this combination injury and reports to guide proper surgical treatment are lacking. Therefore, the primary goal of this Technical Note was to describe our preferred repair techniques for treating a combined MMRL and LMRT during ACL reconstruction. Proper arthroscopic assessment is an essential part of this procedure, because MRI has a low diagnostic sensitivity for both MMRLs and LMRTs.[5-7] In particular, patients with a 3+ Lachman or pivot shift likely have these secondary stabilizers injured.[2,27] Furthermore, acute treatment is recommended for both meniscal tears to maximize the healing potential and restore native biomechanics, thereby minimizing the risk of postoperative intra-articular injuries.[1,2,23]

For efficiency, we recommend reaming the ACL femoral tunnel first, as ensuring proper anatomic

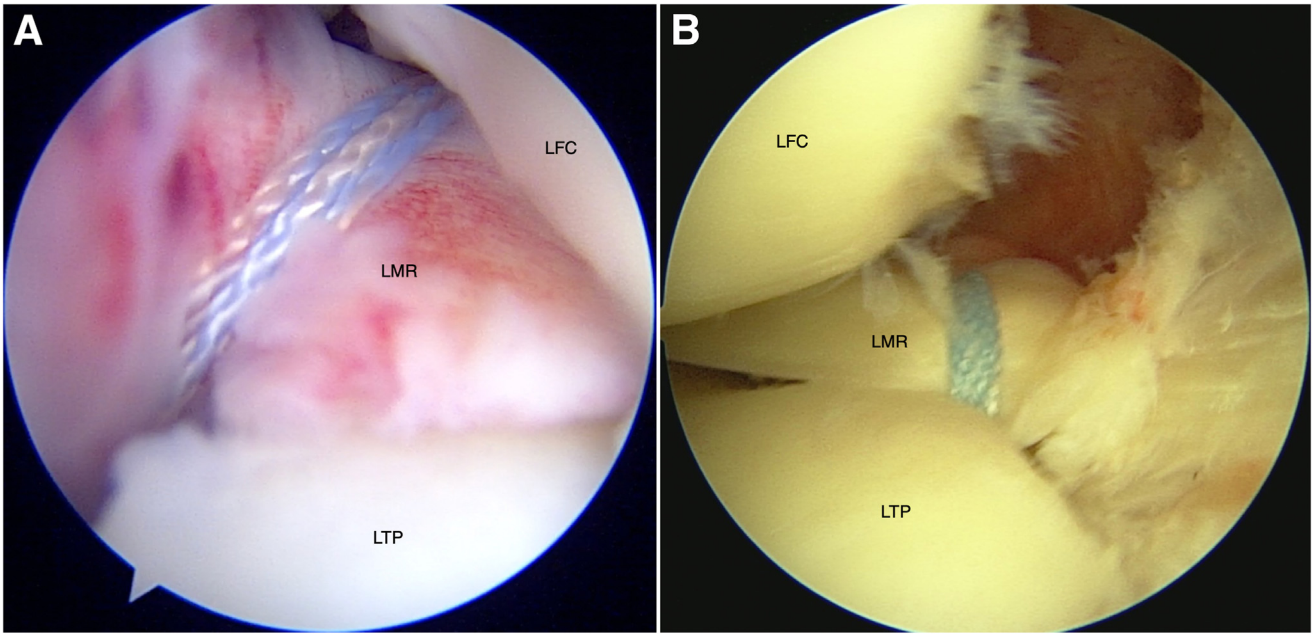

Fig 10. Arthroscopic images depicting a vertical mattress suture in a lateral meniscus posterior root (LMR) in (A) a left knee, and (B) a right knee (larger field of view). (LFC, lateral femoral condyle; LTP, lateral tibial plateau.)

placement is considered one of the most difficult parts of the procedure. After the femoral tunnel has been drilled, we recommend repairing the MMRL and then proceeding with the repair of the LMRT. MMRLs can be repaired via inside-out, all-inside, or hybrid combination techniques (outside-in, inside-in, and/or all-inside).[28,29] Although some believe that inside-out repairs are more technically challenging, the technique offers greater flexibility with suture placement and the number of sutures placed, potentially creating a stronger repair.[2,23] When performing an inside-out MMRL repair, surgeons should be comfortable with their medial knee anatomy and understand the various ways to decrease the chance of iatrogenic neurovascular damage.[2,23] We recommend that the placement of the posteromedial incision is facilitated by transillumination of the medial compartment and by palpation of an intra-articular probe at the medial joint to avoid injury to the saphenous vein or nerve. Once the posteromedial incision is made, it is also important to note that the saphenous nerve lies posteromedial to the pes tendons.[23] Similarly, when placing the sutures, surgeons should enter with the suture delivery device in the anterolateral portal to optimize the direction of the needles and which further decreases the risk of neurovascular damage.[15]

Clinically, repair of MMRLs using an inside-out technique with ACLR has been shown to restore excessive preoperative anterior knee instability compared with control patients who underwent isolated ACLR.[2] Inside-out MMRL repairs have a low reported secondary meniscectomy rate (2%) at a minimum of 2-year follow-up, while all-inside techniques appear to have higher secondary meniscectomy rates, ranging from 11 to 31%.[28-30] These greater secondary meniscectomy rates associated with all-inside techniques may potentially due to the inability to repair the meniscotibial ligament from the anterior portals.[12,22] To address this, suture hook repairs using a posteromedial portal are becoming a more popular option for MMRLs and have a significantly lower secondary meniscectomy rate compared with all-inside techniques (30.6% vs 19%).[29] Although these reoperation rates appear to still be greater than those reported for inside-out repairs, further clinical data are needed to adequately compare inside-out with all-inside techniques for MMRLs.

The consequences of missing meniscal root tears have been well established, and surgeons should repair these tears, especially in the setting of a MMRL.[1,31,32] Untreated LMRTs lead to knee instability and increase the tibiofemoral contact pressures which progresses the development of osteoarthritis.[13,31,33] Although LMRTs can have a wide range of pathology, the most common presentation is an avulsion of the posterior root or an adjacent radial tear of the lateral meniscus.[1,31,34] These tears are repairable via a transtibial double-tunnel-pull-out repair technique, which has shown favorable outcomes with improved function, pain, activity level, and minimal continued meniscal extrusion.[1] While

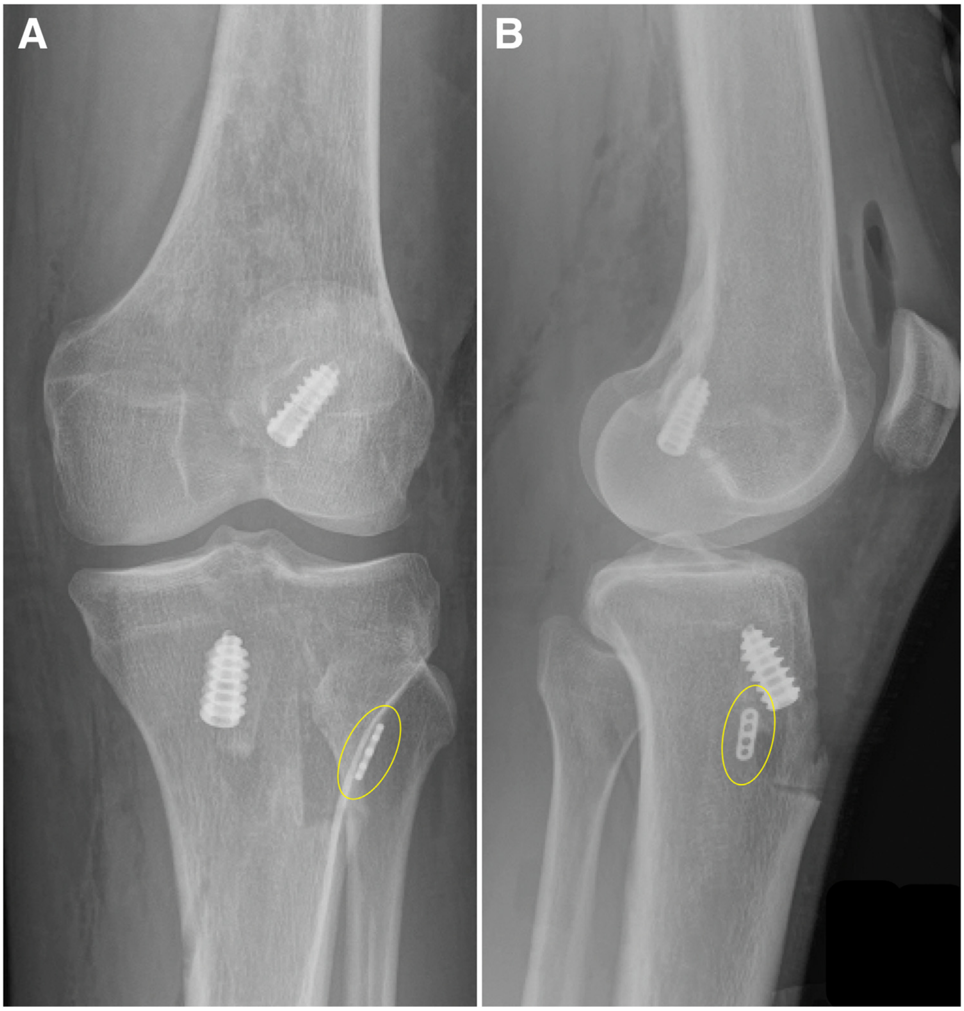

Fig 11. Anterior (A) and lateral (B) supine radiographs of a left knee following anterior cruciate ligament reconstruction using a bone–patellar tendon–bone autograft with inside-out medial meniscal ramp repair and lateral meniscal double-tunnel trans-tibial root repair. The hardware is seen in good condition, including femoral 7 × 20 mm and tibial 9 × 20 mm cannulated titanium interference screws, and a cortical button (yellow circles).

other studies have reported improved outcomes at short-term follow-up with inside-out or all-inside repairs of LMRTs, these techniques have been associated with higher failure rates and continued meniscal extrusion.[35-37] A potential concern using the transtibial double-tunnel-pull-out repair technique is convergence of the transtibial and ACL reconstruction tunnels.[1,24] It is important for surgeons to have a good understanding of both the qualitative and quantitative anatomy near the posterior root and the placement of the tunnels to mitigate the chance of convergence.[24,25] This technique's other advantages include being able to reduce and fix the lateral meniscal root to the broad anatomic footprint to maximize its healing potential and the potential release of biological factors from the tunnel to further enhance the healing of the repair.[24]

In summary, the combination of a MMRL-LMRT-ACL injury is becoming more commonly reported in the literature and has the potential to increase the risk of graft failure if the meniscal pathologies are left untreated. This Technical Note described 2 concurrent repair techniques to efficiently treat these meniscal pathologies at the time of ACL surgery. Lastly, there is a need for further biomechanical studies and long-term clinical outcome data pertaining to this combination injury.

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