Technical Note

Using a Combined All-Inside, Inside-Out, and Outside-In Technique to Repair Bucket-Handle Medial Meniscal Tears Without a Safety Incision

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Abstract: We describe a combined all-inside, inside-out, and outside-in technique for the repair of unstable bucket-handle medial meniscal tears. Notably, a greater incidence of neurovascular complications has been associated with meniscal repair techniques that employ an accessory skin incision, especially when damage involves the body of the medial meniscus. However, with the operative knee in relative extension, passing inside-out needles anteromedial to the posterior horn and posterior to the semitendinosus tendon and saphenous nerve allows for the needles to exit the posteromedial knee through a "safe zone." Therefore, we reduce iatrogenic damage by avoiding the necessity of a large safety incision while still maintaining suture placement versatility and meniscal fragment stabilization. Thus, the objective of this Technical Note is to outline an efficient technique for treating bucket-handle medial meniscal tears that yields a strong, durable repair while avoiding damage to adjacent neurovascular structures and eliminating the need for a posteromedial safety incision.

Menisci are fibrocartilaginous structures that play an essential role in knee kinematics, stability, and distribution of contract pressure forces across articular cartilage surfaces. Meniscal tears can result from acute trauma, chronic degeneration, or congenital malformation and are one of the most common orthopaedic injuries.[1] Although partial or complete meniscectomies were previously considered the standard treatment, a plethora of long-term evidence demonstrating superior functional and radiographic scores for patients undergoing meniscal repair has encouraged orthopaedic surgeons to repair torn menisci whenever possible.[2]

Bucket-handle meniscal tears in particular comprise 10% to 25% of all meniscal tears and are associated with high failure rates after repair when compared with simple tears.[3] Hupperich et al.[4] reported the failure rate to be 34.2% and identified risk factors for re-rupture to include lower patient age, male sex, and a high baseline activity level. Since bucket-handle meniscal tears are common among young, male athletes, surgical repair techniques that offer stability and minimal postoperative complications are essential for orthopaedic surgeons. Although inside-out techniques are considered the gold-standard, all-inside and outside-in repair techniques have proven useful in certain locations that are challenging using the traditional inside-out technique, for example, the posterior and anterior meniscal horn, respectively. Since no single approach has proven to be universally superior, surgeons often implement multiple techniques throughout the repair depending on the dimensions and location of the tear.[5,6]

Whereas inside-out techniques are associated with superficial or deep infections and saphenous or peroneal nerve palsies, all-inside techniques are associated

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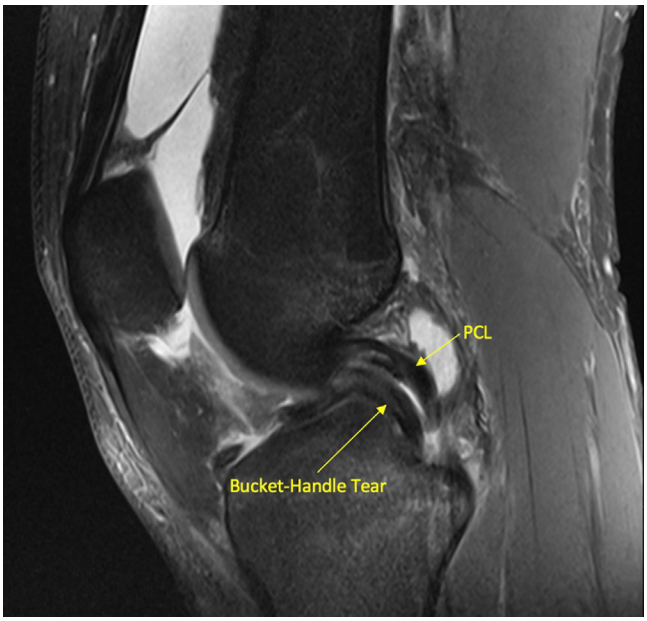

Fig 1. Magnetic resonance imaging of a right knee sagittal section, in the proton density fat-saturated sequence, demonstrating a "double posterior cruciate ligament" sign with a hypointense, arciform band indicative of a medial meniscus bucket-handle tear with a flipped meniscal fragment within the intercondylar notch. (PCL, posterior cruciate ligament.)

with implant breakage/migration, aseptic synovitis, cyst formation (i.e., parameniscal or ganglion), foreign-body reactions (i.e., granuloma formation), iatrogenic chondral damage, and associated greater costs.[5,7-10] Furthermore, studies have reported a greater risk of injury to the saphenous nerve or its branches for meniscal repair techniques that employ an accessory skin incision, especially in patients with damage involving the body of the medial meniscus.[11-14] Thus, the objective of this Technical Note is to describe an efficient, combined technique for treating bucket-handle medial meniscal tears that yields a strong, durable repair while avoiding damage to adjacent neurovascular structures and eliminating the need for a posteromedial safety incision.

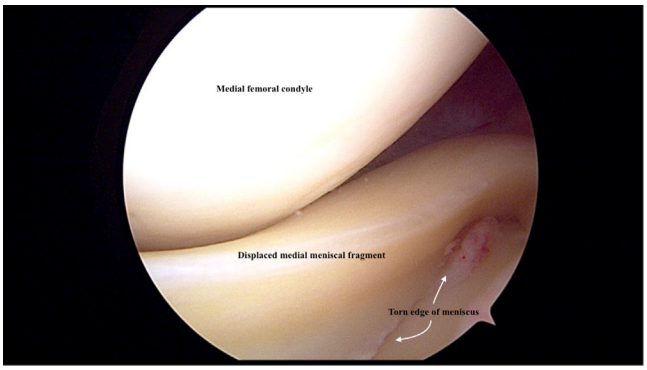

Fig 2. Right knee in 80° flexion: Arthroscopic visualization of a flipped meniscal fragment within the intercondylar notch (viewing portal: anterolateral).

Table 1. Indications and Contraindications for the Repair of Bucket-Handle Meniscal Tears

Indications	Contraindications
Acute	Chronic asymptomatic
Chronic symptomatic	Significant comorbidities
Age (younger > older) ± consideration for activity level	Severe osteoarthritis (grade 3-4)
No significant comorbidities	Inability to successfully reduce the meniscal fragment
Ability to successfully reduce the meniscal fragment	

Surgical Technique (With Video Illustration)

Preoperative Assessment

Patients with bucket-handle meniscal tears are typically young, physically active men who often present acutely with swelling, pain over the joint line, mechanical symptoms (catching and/or locking), limited range of motion when the meniscal fragment is displaced, and an antalgic gait. Notably, the stabilizing effect of any displaced meniscal fragment may create a false/equivocal physical examination even when concomitant anterior cruciate ligament insufficiency is present. Plain radiographs should be used to rule out a loose body as a potential source of mechanical symptoms. Magnetic resonance imaging of the affected knee may reveal a flipped meniscal fragment within the intercondylar notch yielding a double posterior cruciate ligament sign when the medial meniscus is involved (Fig 1). Displacement of the meniscal tissue requires reduction and surgical treatment.

Preparation

The correct knee is marked/signed in the preoperative area. In the operating room, the patient is positioned supine on the operating table and administered general anesthesia. A tourniquet is applied to the proximal thigh of the operative knee. A lateral post is placed at the level of the tourniquet for intraoperative valgus stress and a foot post is placed distally to position the knee at 90° flexion. A repeat physical examination is performed under anesthesia to confirm meniscal pathology. The patient is then prepped and draped in a sterile manner using aseptic technique. A hard-stop timeout is performed before surgical incision.

Diagnostic Arthroscopy

A #10 blade is used to create an anterolateral portal by making a vertical incision lateral to the patellar tendon. The portal is dilated with a blunt trocar and an arthroscopic sheath. An arthroscope is then inserted into the anterolateral portal to visualize the bucket-

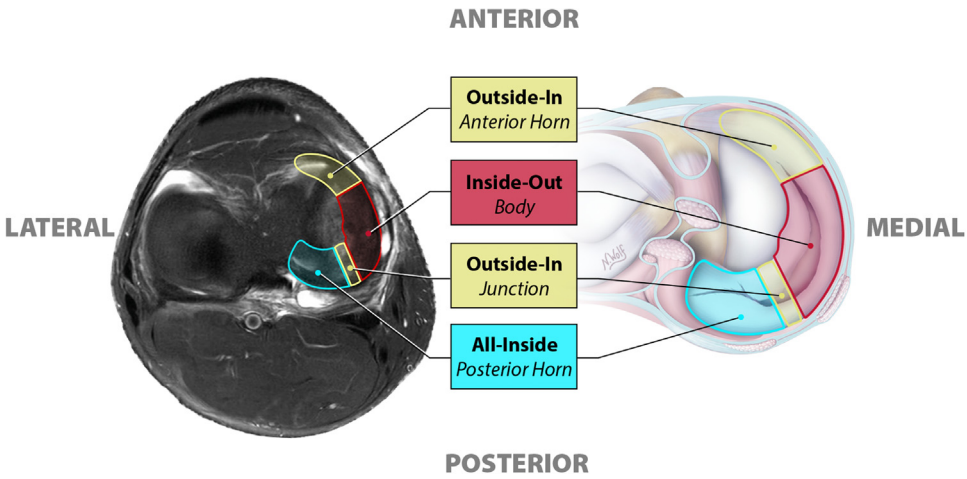

Fig 3. Illustration (right) and axial T2-weighted fat suppressed magnetic resonance imaging section (left) displaying a right knee with a medially displaced bucket-handle medial meniscal tear with associated shallow cartilage fibrillation of the medial compartment. The colored overlayed sections depict the combined suture technique used by anatomic region of the tear. (Illustration by Nicole Wolf, M.S., 2022.)

handle meniscal tear. Next, the anteromedial portal is established under direct visualization to serve as a utility portal. The entire knee joint is examined, including the suprapatellar pouch, medial gutter, lateral gutter, patellofemoral compartment, medial compartment, lateral compartment, and intercondylar notch (Fig 2). Using a blunt obturator probe from the scope cannula, the bucket-handle tissue is reduced while applying a valgus stress and bringing the knee into extension (Video 1). The anatomy of the tear is then outlined with the probe, checking for horizontal, vertical, and radial tear components of the reduced fragment. To conserve as much tissue as possible, debridement of the meniscal fragment is avoided. The decision of surgical repair should be assessed based on the quality of the tissue, complexity of the tear, and the probability of healing based on the zone of the lesion (Table 1).

Repair Technique

A combination repair is often carried out when dealing with bucket-handle tears. The senior author prefers using an all-inside repair for the posterior horn, inside-out for the body, and outside-in for the anterior horn and junction of the body with the posterior horn to ensure adequate fixation of the tear (Video 1; Fig 3). To start, the arthroscope is switched to the medial portal and the zone-specific cannula is introduced through the

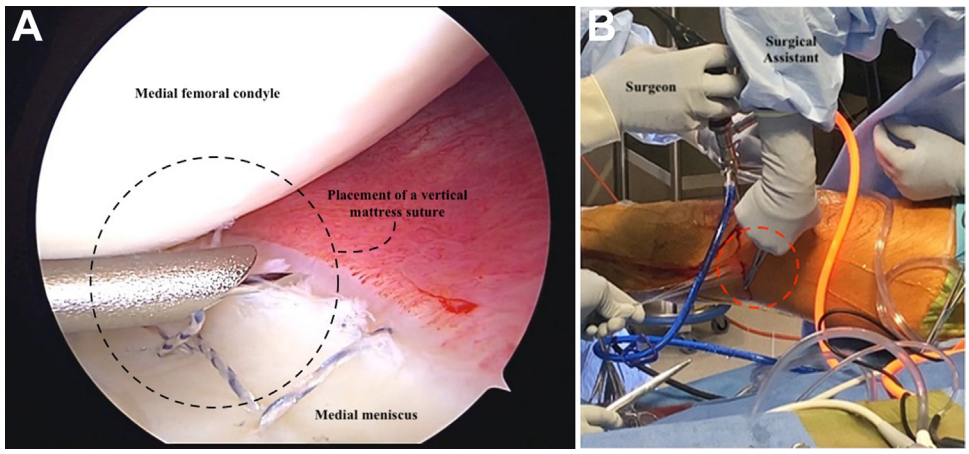

Fig 4. (A) Arthroscopic visualization of a vertical mattress suture being placed through the meniscus (viewing portal: anterolateral). (B) Retrieval of the suture needle (red circle) on the posteromedial aspect of the right knee with a needle driver. Note the patient is in a supine position and the right leg is held in relative extension with support distally.

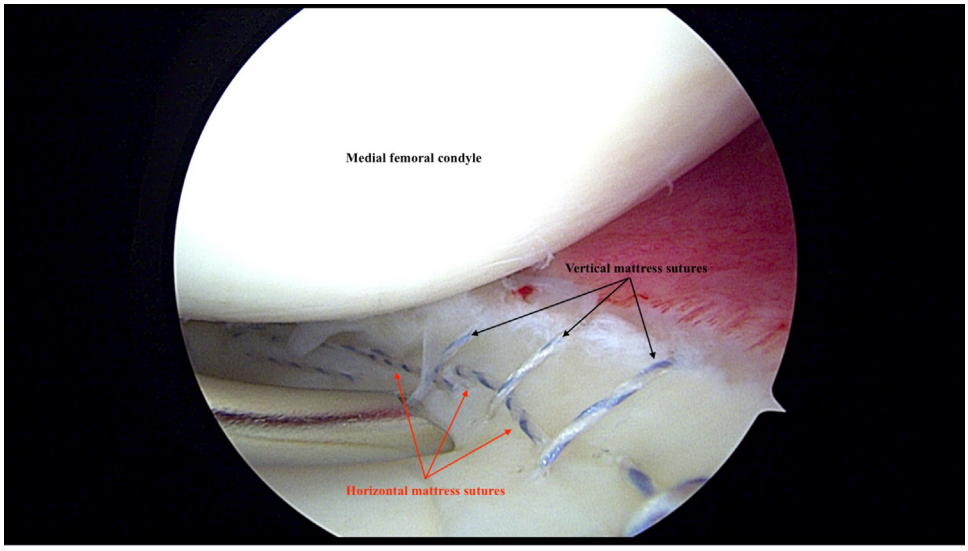

Fig 5. Right knee in slight flexion: Arthroscopic visualization of multiple horizontal (red arrows) and vertical (black arrows) mattress sutures for the repair of a bucket handle medial meniscus tear (viewing portal: anterolateral).

anterolateral portal to repair the body of the medial meniscus. With the knee in relative extension, the saphenous nerve and its infrapatellar branches cross the medial joint line anterior to the semitendinosus tendon.[15,16] For the inside-out technique, the senior surgeon uses zone-specific cannulas (Arthrex, Naples, FL) with #0 Swaged FiberWire sutures (Arthrex). The zone-specific cannula is used to help reduce the meniscal fragment, while the needle is advanced by an assistant through the meniscus and retrieved with a needle driver as it exits the posteromedial knee, posterior to the saphenous nerve (Fig 4). Following the first horizontal

Fig 6. Suture tails (red circle) exiting the posteromedial aspect of a right knee. Note that the patient is positioned supine with the knee in approximately 90° of flexion.

Fig 7. Right knee in approximately 90° of flexion: The incisions are spread down to the joint capsule using a hemostat (black arrow). Note the additional tibial incision (red circle) for the concomitant anterior cruciate ligament reconstruction that was performed.

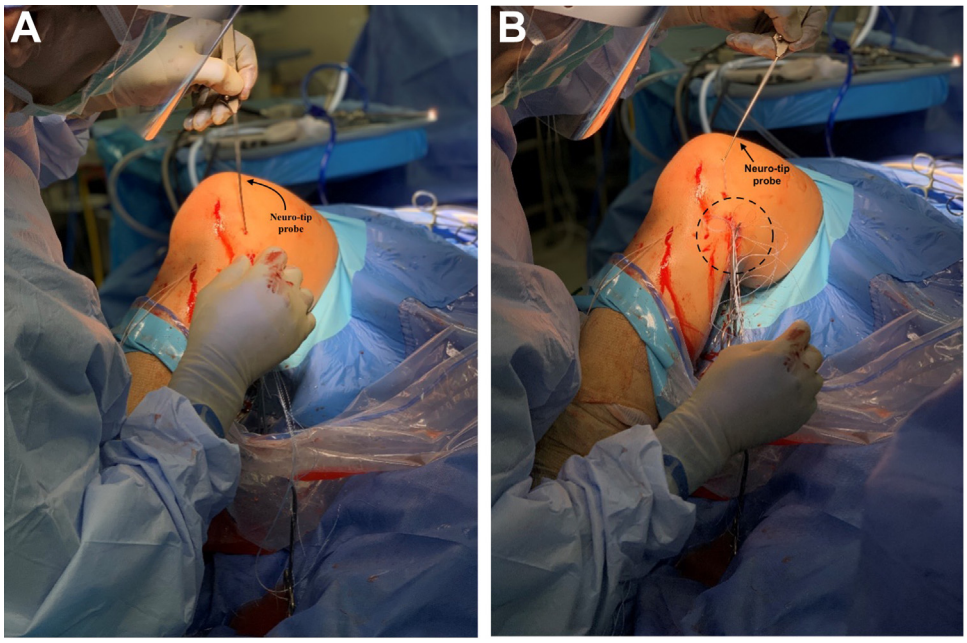

Fig 8. Right knee in approximately 90° of flexion: Neuro-tip probe (black arrow) retrieval of the sutures as they exit the capsule at the level of the joint line (black circle).

Fig 9. Right knee in approximately 90° of flexion: The sutures are paired off with approximately half through each incision (black circles). Their respective tails are brought together using a hemostat.

mattress, multiple pairs of horizontal and vertical mattress sutures are placed, including an oblique mattress across any radial split. Sutures are separated by approximately 7 mm (Fig 5). To avoid iatrogenic injury to the saphenous nerve and its branches, the inside-out technique should be employed with the knee in extension and finger palpation may help ensure that the passage of the needle is posterior to the semitendinosus tendon. In addition, transillumination of the medial compartment and introduction of the zone-specific cannula through the anterolateral portal may further aid in maximizing the margin of the "safe zone" as the needle exits the posteromedial knee.[11,12] As the repair progresses into the posterior aspect of the meniscal body, the medial femoral condyle may begin to obscure arthroscopic view and access to the posterior horn. Therefore, the knee is placed into approximately 20° of flexion with a valgus stress to facilitate access, visualization, and passage of the needle as it travels inferior and slightly posterior to the joint line, while the saphenous nerve courses anterior and superior to the joint line (Video 1). To facilitate easier access and allowance of more versatile suture placement, the senior author prefers an all-inside repair for the posterior horn of the meniscus using one of the various commercially available implants.[17,18] Although all-inside repair theoretically reduces the risk of iatrogenic nerve and vascular injury, surgeons should exercise caution and rely on tactile feedback to avoid overpenetration and mitigate

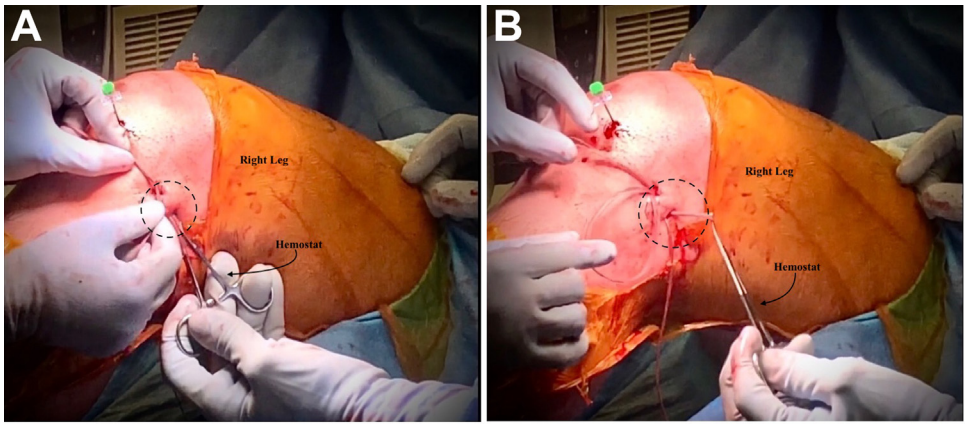

Fig 10. Right knee in approximately 90° of flexion: The tails of the sutures are shuttled subcutaneously (black circle) through the opposite incision using a hemostat (black arrow) to prevent knot irritation of the incisions.

damage to the nearby popliteal neurovascular bundle and/or entrapment of the posterior capsule.[17]

The knee is then placed in approximately 90° of flexion. In this position, the saphenous nerve lies posterior to the joint line, along the posterior border of the sartorius tendon (Video 1).[19] Based on the position of the inside-out sutures exiting the posteromedial knee (Fig 6), two 2- to 3-mm incisions are made proximal to the sutures at the joint line, anterior to the pes anserinus tendons and saphenous nerve branches and spaced approximately 3 cm apart.[15,19] The incisions are spread down to the joint capsule using a hemostat (Fig 7). A neuro-tip probe is then used to carefully retrieve the sutures as they exit the capsule at the level of the joint line (Video 1). Suture limbs are then paired and separated into the small anterior or posterior incisions with approximately half through each (Fig 8). Importantly, while the small incisions are both anterior to the course of the saphenous nerve with the knee in flexion, surgeons should be aware of the relative proximity and thus proceed with caution when retrieving sutures at the joint line as they exit the capsule. Then, by alternating tension, the sutures are paired off and their respective tails are brought together using a hemostat (Fig 9). If the opposite ends are exiting different incisions, a curved mosquito hemostat is used to bring the suture tails to the same one (Video 1).

Once the suture tails are appropriately paired off, limbs are tied down with alternating half hitches while arthroscopically observing the mattress sutures during tensioning. The sutures are then observed for stability while putting the knee through full range-of-motion.

Table 2. Pearls and Pitfalls of Repairing Bucket-Handle Medial Meniscal Tears Using a Combined Technique Without a Safety Incision

Pearls	Pitfalls
For medial meniscus tears, entry from the anterolateral portal and use of zone-specific cannulas optimizes the direction of needle passage as it exits the posteromedial capsule/knee	Misplacement of portals can make the repair challenging and risks damage to neighboring neurovascular bundles (popliteal laterally and saphenous medially).
With the knee in relative extension, pass the inside-out needles anteromedial to the posterior horn and posterior to the semitendinosus tendon and saphenous nerve	With the knee in relative extension, passing the inside-out needles anterior to the semitendinosus tendon, thus risking injury to the saphenous nerve
Achieve a stable repair and avoid meniscal flounce by placing both horizontal and vertical mattress sutures, with the added benefit of decreased risk of suture pull-out	Failure to observe suture tie down under direct arthroscopic visualization or during range of motion testing may risk overtensioning, pull-out, or instability of the meniscal repair.
Spread the small anterior and posterior accessory knee incisions down to the joint capsule using a hemostat	Creating small anterior and posterior incisions with knee in relative extension will risk iatrogenic injury to the saphenous nerve and its branches
Using a neuro-tip probe, retrieve the suture tails at the joint line as they exit the capsule and avoid forcing the neuro-tip probe through any resistance when retrieving the suture tails at the joint line as they exit the capsule	Forceful retrieval of suture limbs with the neuro-tip probe, thus risking injury to the saphenous nerve and surrounding tissue
Do not pair off the suture limbs until they are brought through the small anterior and posterior incisions	Failure to shuttle suture tails subcutaneously, before cutting the limbs, may result in knot irritation

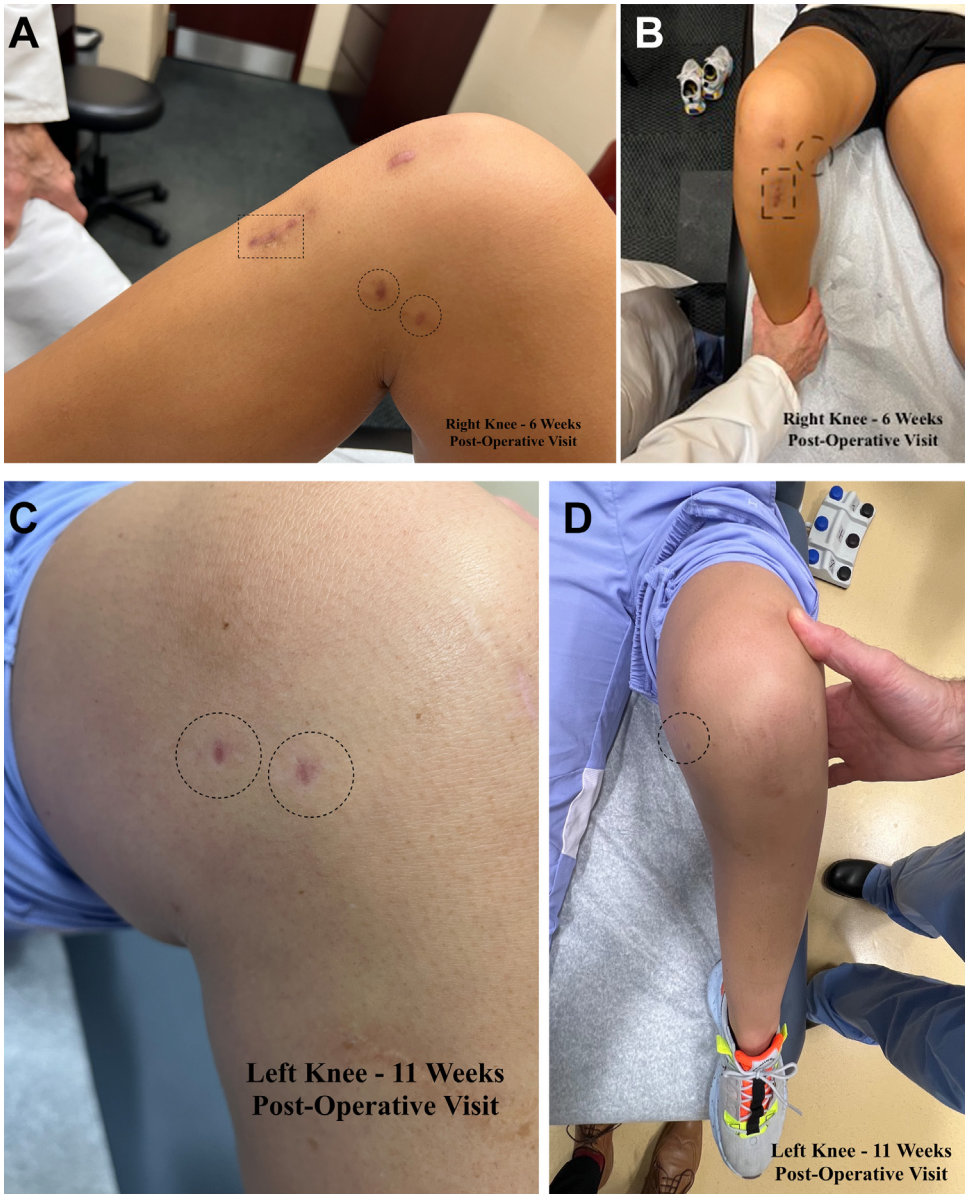

Fig 11. (A) Incisions (black circles) at 6 weeks' postoperative (right knee). (B) Note the additional healing tibial incision from the concomitant anterior cruciate ligament reconstruction that was performed (black rectangle). (C and D) Healed incisions (black circles) at 11 weeks' postoperative (left knee).

To prevent knot irritation of the incisions, the tails of the sutures are shuttled subcutaneously through the opposite incisions to bury the knots before cutting the limbs (Fig 10; Video 1). As a result, final sweep over the incisions reveals no cutaneous prominences. The wounds are closed using 3-0 nylon sutures and covered with Xeroform and sterile gauze, along with a thigh-high compression stocking and Bledsoe brace locked in extension. Pearls and pitfalls of the procedure are described in Table 2.

Postoperative Care

Patients are allowed weight-bearing as tolerated with a foot flat gait, along with crutches for stability for the first 6 weeks postoperatively. The brace should be worn and locked in extension when ambulating, but patients are permitted to remove the brace with range-of-motion as tolerated when not weightbearing. At 2 weeks' postoperatively, sutures are removed. At 3 weeks, patients begin physical therapy with home exercises as necessary. At 6 weeks, the brace is

Table 3. Advantages and Disadvantages of Repairing Bucket-Handle Medial Meniscal Tears Using a Combined Technique Without a Safety Incision

Advantages	Disadvantages
Conserves meniscal tissue to maintain biomechanical properties of the knee	Requires trained assistants for passing inside-out sutures
Decreased risk of saphenous nerve injury with appropriate knee flexion/extension	Lessened risk of inducing iatrogenic cutaneous nerve injury from small anterior and posterior incisions
Increased versatility of suture placement and control of unstable meniscal fragments	Learning curve is crucial with potential for longer duration of surgery and risk of damage to saphenous nerve in inexperienced hands
Avoidance of a large iatrogenic safety incision by use of 2 small accessory incisions minimizes soft-tissue trauma, less postoperative pain, and smaller scar.	Repair of the posterior horn via all-inside technique has accompanied risk inherent to the implant employed (i.e., implant breakage/migration, etc.)
Direct arthroscopic visualization of suture tensioning during tie down	
Greater value and more cost-effective than repair with only commercially sold all-inside devices.	

unlocked and weaned as tolerated. Running and return to sport is permitted at approximately 9 to 12 months postoperative based on the patient's progress during clinical follow-up and the severity of the tear (Fig 11).

Discussion

Fillingham et al.[20] reported complication rates for meniscal repairs to be 4.6% and 5.1% for all-inside and inside-out techniques, respectively. However, these rates are likely an underestimation, as more than one-half of the studies included in their meta-analysis did not report complications, and previous studies have reported rates to be as high as 20%.[5,21] Although inside-out and all-inside techniques have been associated with different, common complications, neither technique has been shown to be superior in terms of patient-reported outcomes, healing, or overall incidence of failure or complications.[5,21] Consequently, efforts have been made to improve surgical practices, with the goal of incorporating different techniques where appropriate to provide the patient with the most stable repair, while minimizing the risk of postoperative complications.[22,23]

We describe a combined technique to ensure adequate fixation of unstable bucket-handle medial meniscal tears. The concept of using an inside-out technique without the use of a safety incision has been previously theorized in simulation and cadaver studies.[11,24] Using archival magnetic resonance imaging scans, Gupta et al.[11] stated that needle passage through the medial meniscus would be safe (with respect to popliteal vessels) assuming the needle passed medial to the 1-o'clock position for a right knee (medial to the 11-o'clock position for a left knee). Similarly, Espejo-Baena et al.[24] used an inside-out technique on cadaver medial menisci and found that no vascular or nervous structures were pierced by the needles.

Although other combinations of all-inside and inside-out techniques are suitable for an analogous repair, we believe this combination of techniques safely and efficiently yields a strong, durable, and secure repair with less risk of neurovascular injury. With the knee in relative extension, passage of the inside-out needles is anteromedial to the posterior horn and posterior to the semitendinosus tendon and saphenous nerve, placing the needles in a "safe zone" as they exit the posteromedial knee.[11,15] Additionally, when carefully retrieving the suture tails as they exit the capsule with the knee in flexion, surgeons should be aware of the relative proximity of the saphenous nerve, despite both small incisions being anterior to its course. The advantages and disadvantages of this technique are summarized in Table 3. Although not described in this Technical Note, a similar technique can be used for the repair of lateral bucket-handle meniscal tears.

Conclusions

This Technical Note outlines a combined technique for treating bucket-handle medial meniscal tears that safely yields a strong, secure repair while avoiding damage to adjacent neurovascular structures.

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