Inside-Out Meniscus Repair

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Abstract: Meniscus repair over resection, when feasible, should be strongly considered in an effort to preserve meniscus integrity and function, especially in younger patients. Currently, a number of techniques and implants may be used to achieve a successful result. Although all-inside meniscus repair devices have evolved significantly since their introduction and have become the repair technique of choice for many surgeons, the classic inside-out repair technique is still very useful to have in one's armamentarium. Though less popular because of the ease of current-generation fixators, the inside-out technique can still offer advantages for those surgeons who are proficient. With the versatility to address most tear patterns, the ability to deliver sutures with smaller needle diameters, and proven long-term results, it has been considered the gold standard in meniscus repair. We review the inside-out repair technique for both a medial and lateral meniscus tear with some helpful tips when performing the technique, and we present a video demonstration of the lateral meniscus repair technique.

Clearly, all-inside techniques, which obviate the need for a posterior incision and an experienced assistant, are quite appealing. Inside-out repair may also be associated with an increased risk of neurovascular injury, increased surgical time, and postoperative pain, as well as needlestick injury to the surgical team. Current-generation all-inside devices have also improved significantly to the point that fixation strength and clinical results may be fairly comparable to inside-out repair.[1-3] For these reasons, all-inside repair has become the preferred technique for many orthopaedic surgeons.

However, there are also potential disadvantages to contemporary all-inside repair techniques and devices. These include neurovascular risk, increased incidence of technical errors and device problems, cost, and theoretically, iatrogenic meniscus damage as a result of larger-diameter insertion needles.[3-5] Although in vitro studies have shown comparable strength to inside-out mattress sutures when there is a peripheral rim in which the "backstop" peripheral fixation implant can rest, it is unknown whether the same is true if the fixation device rests on the posterior capsule only, albeit this latter situation may not be very common. It is also unknown whether the extra-articular fixation implants are more or less irritating to the soft tissues relative to an inside-out approach and knots.

The inside-out technique, the outside-in technique, and the all-inside technique each has its own indications, advantages, and disadvantages. The inside-out technique has long been considered the gold standard for arthroscopic meniscus repair, although current-generation all-inside repair may be comparable for most tears. The senior author will routinely use all-inside repair devices for many tear patterns. However, despite some of the advantages of the all-inside repair, we believe there is still a role for inside-out meniscus repair. We review the inside-out repair technique for both a medial and lateral meniscus tear, and we present a video demonstration of the lateral meniscus repair technique (Video 1). Table 1 reviews the indications, contraindications, risks, pearls, and pitfalls when performing the inside-out technique.

Surgical Technique

The patient is placed in a supine position with the knee distal to the break in the table, which allows for easier access to the posteromedial or posterolateral knee when the foot of the table is flexed. We use a lateral thigh post and the figure-of-4 position to create an opening stress to the medial and lateral compartments, respectively. Alternatively, a well-padded leg

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Table 1. Indications, Contraindications, Risks, Tips, Pearls, and Pitfalls of Inside-Out Technique

	Description
Indications	
	• Similar to other meniscus repair indications • Repairable tears involving posterior horn and body of meniscus (anterior horn tears may be difficult)
Contraindications	
	• Degenerative tears and tears with minimal healing capacity
Risks	
	• Unsuccessful healing • Recurrent tearing • Infection: rates are low (0%-2%) • Saphenous and peroneal nerve injury • Popliteal vessel injury • Stiffness/contracture • Complex regional pain syndrome
Tips and pearls	
	• Fat pad debridement can enhance instrument access and passage. • In the setting of a displaced bucket-handle tear, access to and preparation of the posterior meniscal edge can often be easier with the meniscal fragment displaced anteriorly. • Palpating the gastrocnemius with dorsiflexion and plantar flexion of the foot can assist in confirming proper retractor placement. • Attempt to place suture cannulas from the contralateral portal of the meniscus repair if possible to avoid injury. • One should retract the suture cannula slightly to visualize exact needle placement. • Tying the sutures with the knee close to full extension will help prevent a flexion contracture (medial only). • In isolated repairs, a limited notchplasty can be performed to create a postoperative hemarthrosis.
Pitfalls	
	• Improper anatomic interval identification and retractor placement • Neurovascular injury

holder may be used. A proximal thigh tourniquet is placed and may or may not be used, based on the surgeon's preference.

An initial diagnostic arthroscopy is performed with traditional anterolateral and anteromedial portals. The anteromedial portal is made with the aid of a spinal needle to optimize its position and access to the medial or lateral compartments. Creating additional portals or switching the viewing and working portals may be necessary to access posterior tears or enhance angles for needle cannula placement over the tibial spines. After it has been determined that a meniscus tear is repairable, it is often beneficial to debride a portion of the fat pad (and tibial anterior cruciate ligament [ACL] stump if ruptured) to improve instrument access and passage.

Meniscus tear preparation is the next basic step, which should not be overlooked to achieve a successful repair. Granulation tissue debridement on both sides of the tear is performed with a meniscal rasp (Acufex, Andover, MA) or, alternatively, a 3.5-mm full-radius shaver. Taking the time to debride the granulation tissue and meniscal edges is crucial for maximizing the healing response at the tear site. In the setting of a displaced bucket-handle tear, access to and preparation of the posterior meniscal edge can often be easier with the meniscal fragment displaced anteriorly. Once prepared, the meniscus is reduced into its appropriate anatomic position. Rasping or shaving of the perimeniscal synovium superior and inferior to the tear site is also performed because vascular infiltration from this adjacent tissue often contributes to a successful healing response.

Medial Meniscus Tear

After tear preparation, the posteromedial incision is made to retrieve needles passed through the capsule. Incision placement may be facilitated by transillumination of the medial compartment. Transillumination also helps visualize the saphenous vein. A 2.5- to 4-cm incision is made posterior to the medial collateral ligament. Because the needles often angle downward as they exit the joint capsule, it is helpful to have two-thirds of the incision distal to the joint line with one-third above.

The approach is made with the knee in flexion. The oblique pes fascia should be identified as one dissects deep to the subcutaneous tissue. By use of Metzenbaum scissors, the anterior fascia should be dissected proximal to distal. With the knee in flexion, the sartorius, gracilis,

and semitendinosus tendon should be retracted to protect the saphenous nerve, which lies posteromedial to the tendons (Fig 1). By continuing the dissection deeper, one should identify the interval between the medial head of the gastrocnemius and the joint capsule. The muscle of the gastrocnemius can be bluntly dissected off the capsule using a pair of Metzenbaum scissors, followed by using a blunt key elevator. The surgeon's finger may be useful to aid in the separation of the muscle from the capsule. Working distal to proximal facilitates the dissection of the gastrocnemius off of the posterior capsule. The proper plane may be verified by palpating the gastrocnemius on the posterior side of the surgeon's finger while the surgeon performs dorsiflexion and plantar flexion of the foot (the muscle posterior will move and the capsule anterior will not).

A popliteal retractor is placed within this plane, which will serve to retract and protect the neurovascular structures located lateral to the medial head of the gastrocnemius. A Henning retractor, half of a pediatric speculum, or a bent spoon may be helpful in this setting, if available. The retractor should be held so that the needles piercing the posterior capsule are deflected medially toward the assistant. Keeping the knee in 20° to 60° of flexion relaxes the hamstring and gastrocnemius, which improves visualization of the needles as they exit the posterior capsule.

Commercially available zone-specific cannulas are used to place sutures into the medial meniscus from the anterolateral portal. Entry from the anterolateral portal decreases the risk of damaging the reflected neurovascular structures and optimizes the direction of the needle as it exits the capsule. If the initial anterolateral portal is not optimal to access the posterior horn of the medial meniscus, one should create an additional portal with the aid of a spinal needle (often slightly more superior and medial). Single- or double-lumen zone-specific suture cannulas can be used based on the surgeon's preference. Single-lumen cannulas allow for increased mobility and independence when one is placing sutures. Ten-inch flexible needles preloaded with a No. 2.0 Ethibond suture (Ethicon, Summerville, NJ) versus newer high-strength braided suture, such as No. 2.0 FiberWire (Arthrex, Naples, FL), are typically used for the repair.

With the surgeon applying a valgus force to the joint, the cannula is directed toward the tear under arthroscopic

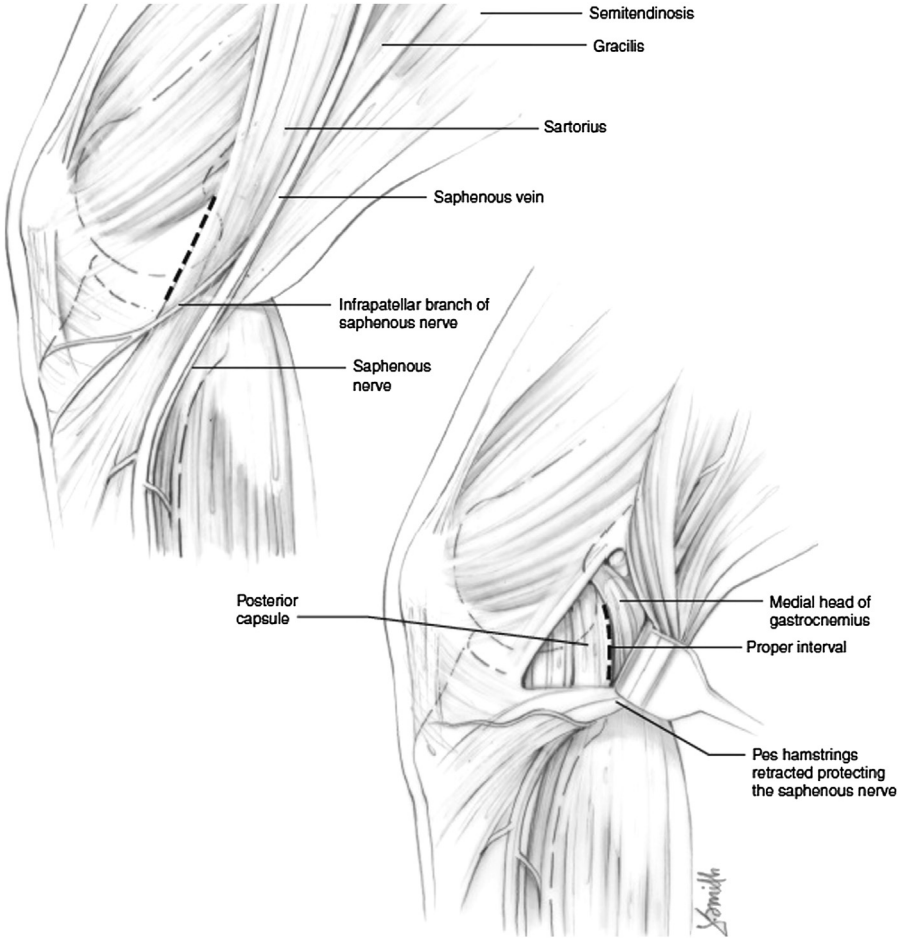

Figure 1. The proper location for the posteromedial incision is shown. A 2.5- to 4-cm incision is made posterior to the medial collateral ligament with two-thirds of the incision distal to the joint line. The pes tendons are retracted posterior with the saphenous nerve. The proper interval is continued between the medial head of the gastrocnemius and the joint capsule. (Reprinted with permission.[6])

visualization (Fig 2A). One should place the suture cannula in the desired location at the tear site and pass the tip of the needle just past the end of the cannula to visualize its exact entry point into the meniscus or capsule. Retracting the cannula 3 to 5 mm allows the surgeon to visualize the needle before penetrating the needle into the desired location. The tear should be anatomically reduced. The needle and cannula can actually be used to aid in the reduction of the meniscus. The surgeon places the knee in 10° to 20° of flexion as he or she passes the needle through the meniscus. Once the needle is through the posterior capsule, flexing the knee to 70° to 90° may assist in needle retrieval. The single-barrel cannula is then redirected to deliver the second needle and place the suture adjacent to the first. It is important to keep slight tension on the suture to avoid inadvertent puncture and laceration of the suture with the second needle. The second suture is placed similarly to the first to create a vertical, oblique, or horizontal pattern. One must pay particular attention when placing the needle through the more central meniscus segment and then continuing into the peripheral segment or capsule that, ultimately, the tear will be anatomically reduced. If possible, a vertical suture pattern is preferred because it allows for greater capture of the strong circumferential fibers of the meniscus; however, oblique and horizontal patterns are often used as well.

An assistant should be prepared to retrieve the needle using a needle driver and optimal lighting to visualize the needle's delivery through the posterior capsule. If the needle cannot be visualized after being inserted 1 to 1.5 cm, the needle should be retracted and retractor placement should be reassessed. As the needle tip is visualized, the assistant often has to bend the needle to deliver the 10-inch needle. Sutures are typically placed from posterior to anterior; however, if there is difficulty visualizing the first needle, an anterior suture may be placed because it is typically easier to locate and can help to guide the expected delivery location of subsequent posterior sutures. In the setting of a very unstable bucket-handle tear, a suture placed in the middle (*v* posterior) may assist in maintaining the reduction before placement of other sutures.

In a similar fashion, multiple sutures are placed between 3 and 5 mm apart. For tears at the meniscocapsular junction, often the first needle is passed through the meniscus and the second just through the capsule adjacent to the tear. Both femoral- and tibial-sided sutures may be placed. Typically, femoral-sided sutures are placed first. Sometimes, this will create a "puckering" of the meniscus superiorly and resultant gapping of the tear on the tibial side. This should be reduced with tibial-sided sutures placed in a similar fashion. One of the benefits of the inside-out repair technique is that the needle diameters are smaller, which allows for the passage of a greater number of sutures and fixation points without creating as much iatrogenic damage to the meniscus tissue (in the opinion of the senior author).

As the assistant delivers the needles and sutures, the needle is cut off, and the sutures are tagged with a hemostat. Either sutures can be tied immediately or several sutures can be clamped and tied as a group at one time. It is important not to overtighten the sutures. It is also important to make sure that one does not, in essence, perform a "capsulorrhaphy" of the posteromedial capsule and thus create a flexion contracture. Tying the sutures with the knee closer to full extension or perhaps slight flexion will help avoid this problem. This is typically not a problem on the lateral side.

When a repair is not combined with a concomitant ACL reconstruction, a shaver or bur can be used to create a limited notchplasty for the purpose of creating a postoperative hemarthrosis. Alternatively, a microfracture awl can be used on the lateral notch. The use of fibrin clot has been well described as well but will not be discussed in this article.

Drains are not used. Closure of the subcutaneous tissue and skin occurs in 2 separate layers. After the wound is dressed, a brace locked in full extension is placed in the operating room.

Lateral Meniscus Repair

For a lateral meniscus repair, the knee is placed in the figure-of-4 position with the knee at 70° to 90° of flexion. This position both allows a varus stress on the joint and releases the tension on the peroneal nerve, biceps tendon, and gastrocnemius.

For more optimal access to the posterior horn and body of the lateral meniscus from the medial side, the anteromedial portal often needs to be more superior and possibly more medial than the standard medial portal. This allows placement of the suture cannula from the medial portal to the lateral meniscus without obstruction from the tibial eminence.

After one characterizes the tear, the meniscal edges are prepared in the exact manner as the medial meniscus repair (Video 1).

Transillumination of the lateral compartment can again assist in determining the proper level for incision placement, especially when one is trying to make a smaller incision. The surgeon places the knee in 90° of flexion as he or she makes this approach to the posterolateral capsule. A 2.5- to 4-cm vertical skin incision is made posterior to the lateral collateral ligament. Again, approximately two-thirds of the incision should be below the joint line. The incision should be made between the iliotibial band and the biceps tendon (Fig 3). It is important to stay anterior to the biceps tendon because the peroneal nerve is located posteromedial to the biceps tendon.

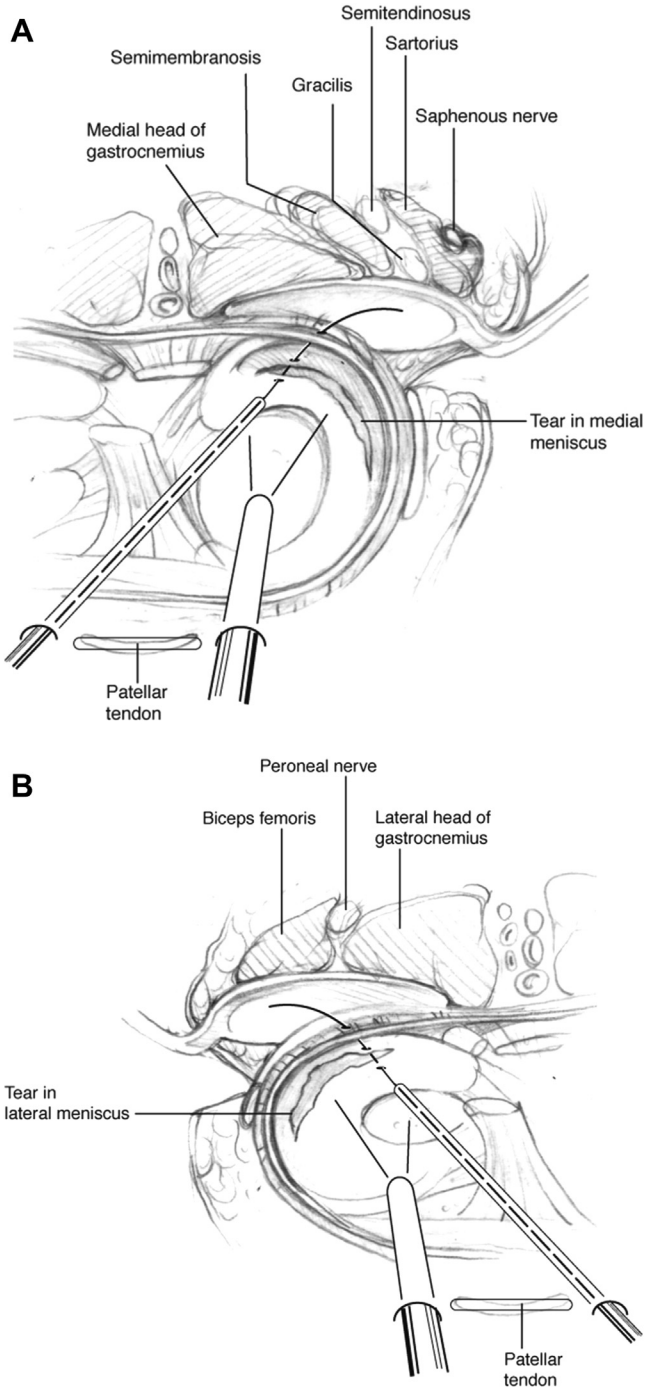

Figure 2. (A) Illustration showing inside-out medial meniscus repair. The needle is deflected toward the assistant with the retractor placed anterior to the medial head of the gastrocnemius. (B) Illustration showing inside-out lateral meniscus repair. A retractor placed anterior to the lateral head of the gastrocnemius protects the neurovascular structures. (Reprinted with permission.[6])

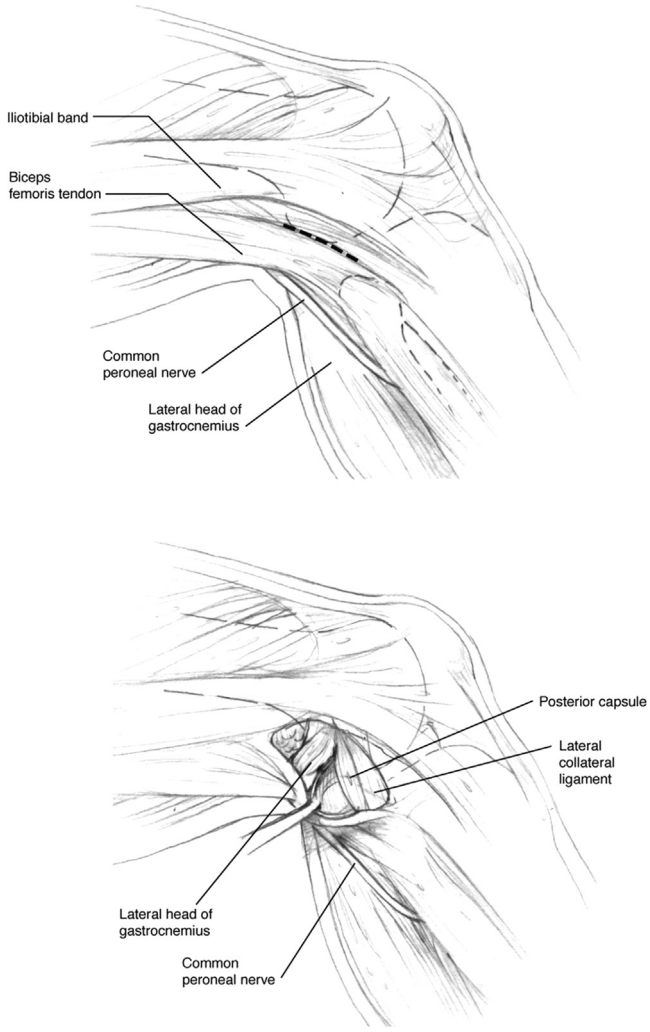

Figure 3. The proper location for the posterolateral approach is shown. A 2.5- to 4-cm incision is made posterior to the lateral collateral ligament with two-thirds of the incision distal to the joint line. The proper approach interval is between the iliotibial band and the biceps tendon. The proper interval is continued between the lateral head of the gastrocnemius and the joint capsule. (Reprinted with permission.[6])

The next interval lies between the lateral head of the gastrocnemius and the posterolateral joint capsule. The muscle of the gastrocnemius can be bluntly dissected off the capsule and verified in the same manner as the medial repair. A retractor within this plane will serve to retract and protect the neurovascular structures located medial to the lateral head of the gastrocnemius, as well as the peroneal nerve, which will lie on the posterior side of the biceps tendon. The retractor should be held so that the needles piercing the posterior capsule are deflected laterally toward the assistant.

Debridement of the fat pad is performed so that the suture cannula can be placed through the anteromedial portal. Entry from the anteromedial portal into the lateral compartment decreases the risk of damaging the reflected neurovascular structures and optimizes the direction of the needle as it exits the capsule.

The suture cannula is directed toward the tear under arthroscopic visualization (Fig 2B). Sutures are placed

similarly to the medial repair (Fig 4). The needle is driven through the lateral meniscus with the knee in 70° to 90° of flexion. An attempt should probably be made to place sutures adjacent to the popliteus tendon but not through it if possible. However, the literature has not reported problems with placing sutures through the tendon.[6] Tying the sutures with the knee in 70° to 90° of flexion on the lateral side has not been shown to be a problem in terms of creating a flexion contracture. Otherwise, repair principles are similar to the medial side.

Discussion

Inside-out repair offers a success rate of 60% to 80% for isolated meniscal repairs and 85% to 90% when performed with a concomitant ACL reconstruction.[3] The inside-out technique, though sometimes challenging and time-consuming, is quite versatile and can be used for most repairable tear patterns involving the posterior horn or body of the meniscus. Clearly, all-inside devices and techniques have evolved significantly over the years to the point where they are the technique of choice for many knee surgeons (including the senior author). Thus far, when the inside-out repair has been compared with contemporary all-inside techniques for isolated meniscal tears, a difference has not been shown between the 2 repair techniques in terms of clinical failure rate and overall subjective outcome.[2] Furthermore, there has been no evident difference in meniscal healing between the 2 techniques found on follow-up magnetic resonance imaging in patients with a meniscal tear in combination with an ACL reconstruction.[7] However, despite this evidence, we believe that there are certain benefits and that there is still a role for the classic inside-out repair, and it is important for surgeons to stay proficient with this technique.

Clearly, there are risks, benefits, and limitations with the inside-out technique. Risks include increased morbidity because of the additional posterior exposure, neurovascular injury, postoperative stiffness or flexion contracture, and needlestick injury to the surgical team.[2] Potential benefits, which will be reviewed, include increased versatility for suture placement, less iatrogenic damage to the meniscus, the ability to place a greater number of sutures (increased fixation points), and lower implant cost.[2] Limitations of the inside-out technique include the need for an experienced assistant, appropriate instrumentation, and increased procedural time.[2,6]

Repair of far-posterior tears places the neurovascular structures posterior to the knee at a higher risk of injury with either repair technique.[8] In a systematic review comparing the inside-out technique with the all-inside technique for isolated meniscal tears, the rate of nerve injury after the inside-out technique was higher (9%) compared with the all-inside technique (2%).[2] However, the relative risk of major neurovascular injury is

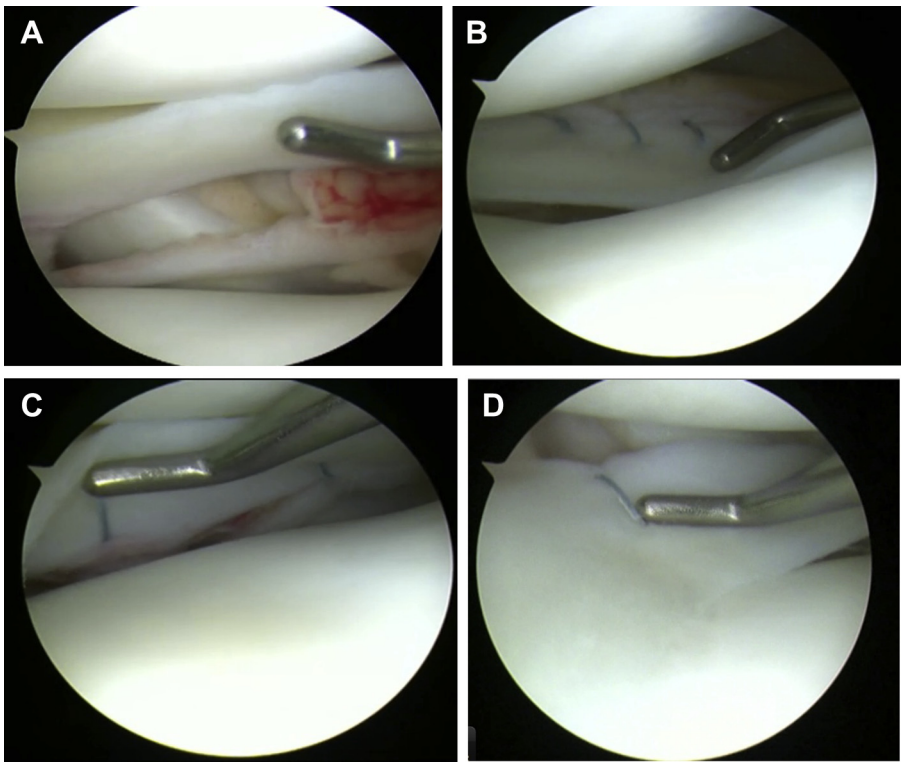

Figure 4. Arthroscopic images of right lateral meniscal tear and subsequent repair. (A) Unstable tear of lateral meniscus at the meniscocapsular junction before repair. Hemorrhage is present at the tear site. (B) Vertical mattress sutures are placed on the femoral side of the posterior horn of the lateral meniscus. (C) Tibial-sided vertical mattress sutures are placed in a similar fashion. (D) Capturing the popliteus tendon was avoided in this case.

unknown relative to pure sensory nerve injury (saphenous nerve). Certainly, any injury is a problem, but injury to a major nerve or vessel is a dreaded complication. Each technique carries its own risk, and one must be careful with each. With the inside-out technique, the posteromedial or lateral approach should directly expose the capsule and retract the neurovascular structures at risk. Careful exposure, gentle retraction, visualization of exiting needles with an experienced assistant, and tying sutures directly onto the capsule are keys to avoiding this complication. However, clearly this can be difficult at times. With the all-inside technique, the more onerous inside-out technique is obviated. However, the major neurovascular structures are not far beyond the posterior capsule, and an inadvertent injury may be closer than some surgeons think when penetrating beyond the posterior capsule.[4]

Other potential disadvantages of the all-inside repair, when compared with the inside-out technique, include increased local irritation symptoms because of the extra-articular backstop implants. Fortunately, this is rare and certainly can occur with inside-out suture knots as well. The all-inside repair has also been associated with implant migration and failure.[2] Current-generation all-inside devices have improved significantly to the point that fixation strength and clinical results may be fairly comparable to inside-out repair[1-3]; however, most all-inside repair techniques rely on extra-articular implants, which sit beyond the capsule and require resistance to pull-through for fixation strength. Earlier-generation device manufactures have advocated using the device when there is at least 2 to 3 mm of intact peripheral meniscal rim to improve the fixation strength of the implant.[9] Furthermore, in vitro comparison studies, including current studies with contemporary devices, have also used methods in which the backstop implant rests on the peripheral meniscal rim, which is clearly more resistant to pull-through than capsule alone.[1] It is currently unknown whether the fixation strength of the implant is compromised significantly when used for a meniscocapsular tear if one arm of the suture is placed through the capsule only.

Most all-inside devices also have an inherent disadvantage of a larger-diameter insertion needle relative to the smaller inside-out delivery needle. A smaller delivery needle allows for the potential ability to place an increased number of sutures and fixation points with less iatrogenic tissue damage to the meniscus. The same collagen fibrils that are captured with mattress sutures may be injured with multiple passes from larger-diameter needles. Chondral damage is also a potential disadvantage with these larger all-inside devices if proper technique is not used.[3]

Iatrogenic damage may not be a problem for many tears but may be an issue with larger and more complicated repairs, as well as when the tissue is more tenuous, making the inside-out technique a good option for some of these more complicated repairs. In addition, the smaller inside-out needles may allow for greater versatility and finer placement precision for difficult repairs. Large radial tears extending into the periphery are another indication for the inside-out technique. Repair of these larger radial tears with this technique has been shown to improve the contact mechanics of the joint, which has translated into favorable clinical outcomes.[10-12]

Newer current-generation all-inside repair devices lack long-term outcomes data. In a recent systematic review of long-term meniscal repair results, the review was unable to identify reports of these newer devices' outcomes at greater than 5 years postoperatively.[13] Although all of the repair techniques show a trend of increasing failure rates from short-term to medium- and long-term follow-up, long-term data are not yet available on the contemporary all-inside devices.[13] However, studies published thus far have shown healing rates to be comparable with select prior-generation implants.[13] Devices that have implants and insertion needles that have not been modified significantly should prove to be at least as good as their predecessors. One concern with the larger-bore insertion needles is the observation that we have seen more complex radial tears propagate from the all-inside insertion sites, in previously healthy tissue, several years after clinically successful longitudinal repairs. As more long-term data on the all-inside devices are gathered, more definitive statements will be made on the longevity of these newer-generation devices compared with the inside-out technique.

The inside-out technique has long been considered the gold standard for arthroscopic repair since its introduction in the 1980s. Despite more contemporary all-inside repair devices having mechanical strength, clinical failure rates, and subjective outcomes similar to the traditional inside-out repair in early studies, the inside-out technique is still quite advantageous and more versatile for a subset of meniscus tear patterns. We believe that, even for surgeons who prefer the all-inside technique when feasible, it is still important to maintain proficiency with this classic technique. As technologies and techniques improve and long-term data are gathered, it is likely that each of these techniques will continue to play a role in meniscus repair, with each technique offering specific benefits in distinct clinical situations.

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