Technical Note

Inside-out Repair of Extensive Meniscal Tears Using Posteromedial and Posterolateral Neurovascular Protective Windows

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Abstract: Three popular repair techniques for preserving the torn meniscus are the all-inside, outside-in, and inside-out techniques. Among these, the inside-out technique has shown low failure rates, and it therefore remains the gold-standard technique for repairing the torn meniscus. For extensive and chronic meniscal tears, proper use of this technique has become fundamental for knee surgeons. Nevertheless, challenges in using this technique include a higher risk of catching the neurovascular bundles on the posteromedial and posterolateral sides of the knee and difficulties in reducing and stabilizing chronically displaced meniscal fragments. In this article, the inside-out technique is revisited with an emphasis on anatomic details of how to avoid the neurovascular bundles while addressing extensive and chronic meniscal lesions.

The importance of preserving the meniscus as a valuable contributor to the maintenance of healthy articular knee cartilage has recently been re-emphasized.[1] Three popular repair techniques for preserving the torn meniscus are the all-inside, outside-in, and inside-out techniques. Among these, the inside-out technique has shown low failure rates.[2] The superiority of the inside-out technique in terms of failure rates may be attributed to several factors including (1) small-diameter suture needles that are almost harmless to the meniscal tissue as opposed to all-inside devices, which create larger holes that may harm the integrity of the tissue; (2) use of a 360° secure suture around the meniscus and capsule as opposed to deployment of extracapsular all-inside anchor devices that are invisible to the surgeon during anchor deployment and may disengage and migrate into the knee joint; and (3) the ability to relatively easily and accurately locate the needle at a desired point in the meniscal fragment under vision and push the meniscal fragment to the periphery into reduction as opposed to the outside-in technique, which may be challenging particularly in chronically displaced or deformed meniscal fragments because the needle in entering the joint from the capsule direction. On the other hand, creating a 360° circumferential suture construct via the inside-out technique increases the risk of catching the neurovascular bundles within the suture.[3,4] To avoid iatrogenic lesions to the neurovascular bundles, familiarity with the extra-articular knee anatomy and proper use of safety windows on the posteromedial and posterolateral aspects of the knee have become mandatory. In this article, the inside-out technique is revisited with an emphasis on anatomic details of how to avoid the neurovascular bundles while addressing extensive and chronic meniscal lesions.

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Surgical Technique

1. The patient is placed in the supine position, and the knee is routinely examined under anesthesia for range of motion and ligamentous laxity (Video 1). A tourniquet cuff (Zimmer, Dover, OH) is placed around the proximal thigh. A lateral thigh post (Maquet, Rastatt, Germany) is used to enable valgus load during surgery.

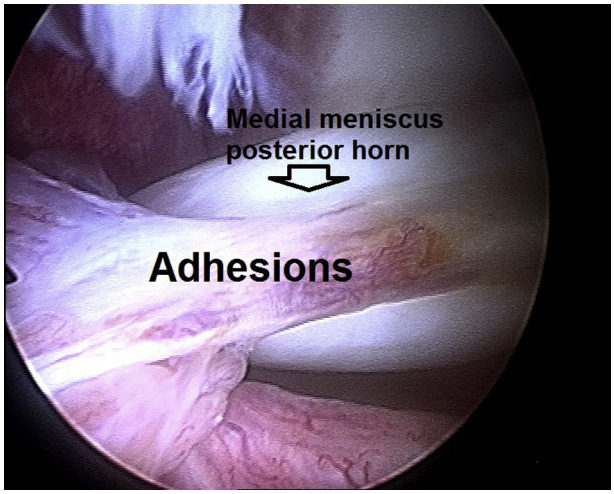

Fig 1. Arthroscopic view of a right knee using a 30° arthroscope through the anterolateral portal. The posterior horn of the medial meniscus is dislocated anteriorly as a result of a bucket-handle tear. Chronic anterior adhesions created between the anteriorly displaced posterior horn of the meniscus and the surrounding soft tissues at the front of the knee prevent reduction of the meniscal fragment.

2. Systematic arthroscopic evaluation of all knee compartments is performed with a 30° arthroscope (Olympus, Center Valley, PA) using standard anterolateral (AL) and anteromedial (AM) portals. When there is a suspicion that the posterior horn of the lateral meniscus is dislocated and flipped anteriorly based on magnetic resonance images or lack of knee extension, caution is applied during establishment of the AL portal. In this case, only the skin and subcutis are opened with a No. 11 blade, avoiding an inadvertent radial split of the anteriorly flipped posterior horn of the lateral meniscus, and the capsule is opened with a blunt arthroscopic trocar.
3. In chronic extensive meniscal tears, the posterior horn and body of the meniscus may be displaced anteriorly and show rounded edges, degenerated areas, and sometimes, adhesions to the surrounding tissues that prevent reduction (Fig 1).
4. Any adhesions that prevent reduction of the meniscus should be gently resected using arthroscopic tools such as a medium–bite width meniscal

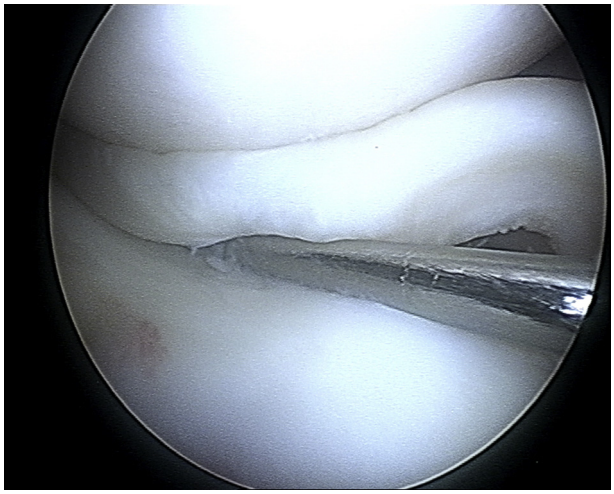

Fig 2. Arthroscopic view of a right knee using a 30° arthroscope through the anterolateral portal. After the anterior adhesions have been resected, the meniscus is pushed into reduction using an arthroscopic probe.

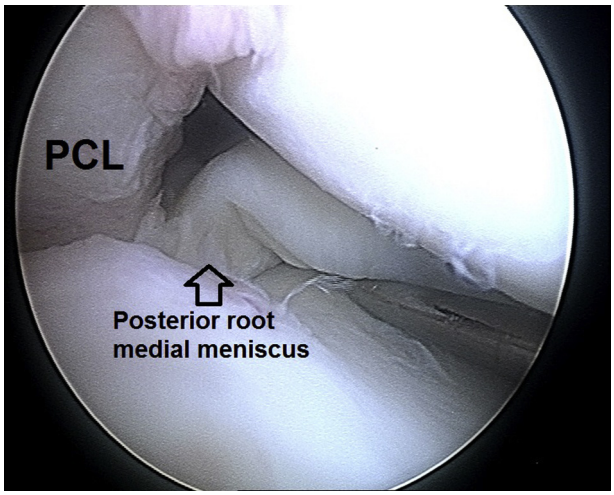

Fig 3. Arthroscopic view of a right knee using a 30° arthroscope through the anterolateral portal. The posterior horn of the medial meniscus is reduced, and the posterior meniscal root is assessed to verify an intact attachment. (PCL, posterior cruciate ligament.)

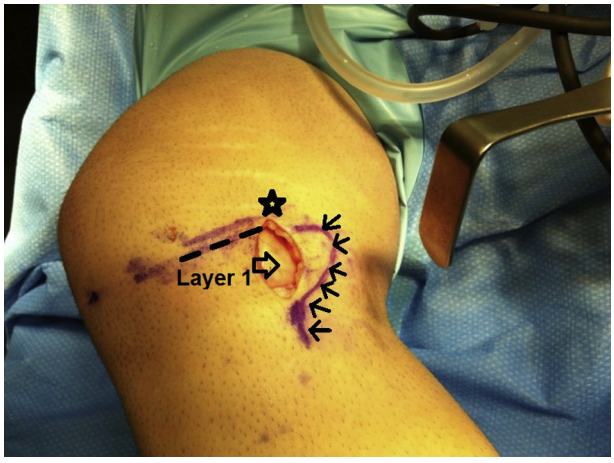

Fig 4. As shown in a right knee, skin markings for preparing the posteromedial safety window include (1) the medial joint line (dashed line), (2) the posteromedial tibial ridge (black arrows), (3) the medial epicondylar area (star), and (4) a 3- to 4-cm longitudinal mark from the medial epicondyle and running distally to about 2 cm below the level of the joint line. The skin and subcutis are opened along this mark, and the thin fascia (i.e., layer 1) overlying the superficial medial collateral ligament is identified.

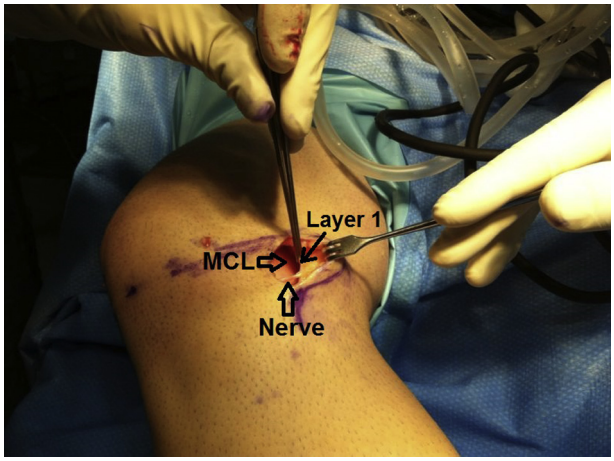

Fig 5. As shown in a right knee, the thin fascia (i.e., layer 1) is opened. A nerve branch is identified and protected. The superficial medial collateral ligament (MCL) layer is exposed.

punch (Arthrex, Naples, FL), and the meniscus is pushed into reduction. An arthroscopic probe is used for this purpose (Fig 2).

5. Once the meniscus is reduced with sufficient repairable tissue, the posterior meniscal root is assessed to verify an intact attachment (Fig 3).
6. The extra-articular safety window is prepared.
7. For repair of the medial meniscus, skin markings for preparing the posteromedial safety window include (1) the medial joint line, (2) the posteromedial tibial ridge, (3) the medial epicondylar area, and (4) a 3- to 4-cm longitudinal mark from the medial epicondyle and running distally to about 2 cm below the level of the joint line. The skin and subcutis are opened along this mark, and the thin fascia (i.e., layer 1) overlying the superficial medial collateral ligament (MCL) is identified (Fig 4).
8. The thin fascia (i.e., layer 1) is opened, and care is taken not to violate the nerve branches that may

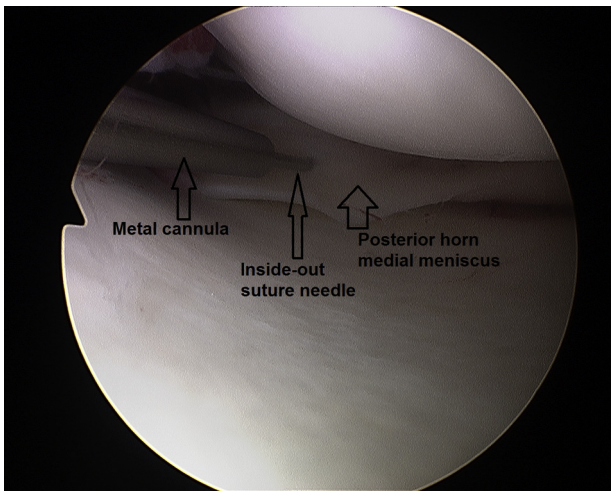

Fig 6. Arthroscopic view of a right knee using a 30° arthroscope through the anteromedial portal. The posterior horn of the medial meniscus is reduced. To properly aim the suture needle to the meniscal fragment at the most posterior location, a metal cannula (Acufex Meniscal Stitcher Set) is inserted through the anterolateral portal.

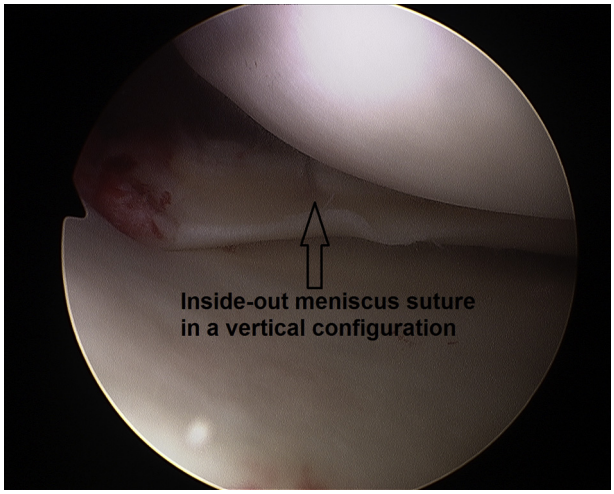

Fig 7. Arthroscopic view of a right knee using a 30° arthroscope through the anteromedial portal. An inside-out meniscal suture (No. 2-0 FiberWire meniscal repair needles) is placed in a vertical configuration.

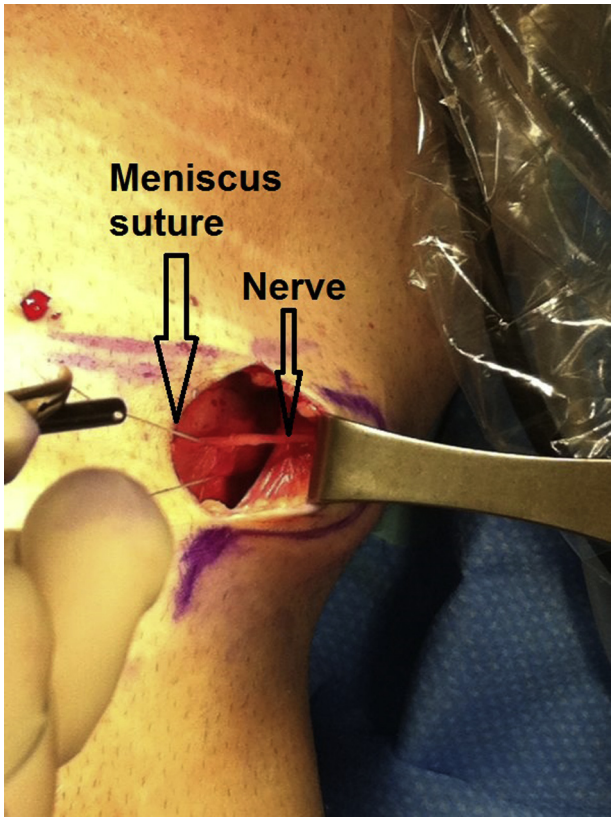

Fig 8. As shown in a right knee, the saphenous nerve is avoided by sliding the knots through the posteromedial safety window and tying the knots over the posteromedial joint capsule.

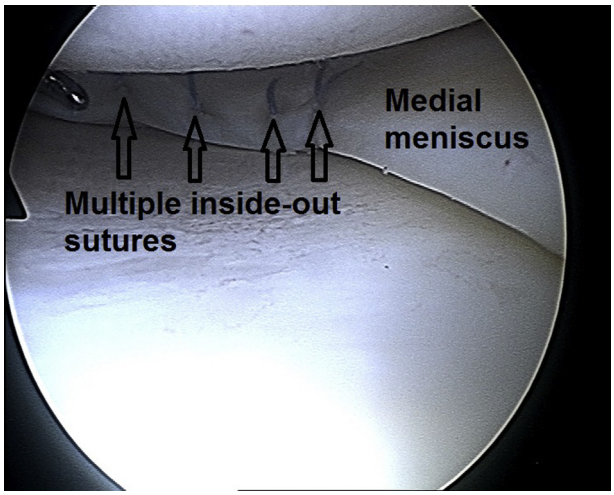

Fig 9. Arthroscopic view of a right knee using a 30° arthroscope through the anterolateral portal. Medial meniscal repair with complete stability is finalized using multiple vertical inside-out suture configurations.

cross in this area (Fig 5). The superficial MCL layer is exposed.

9. The inside-out suture needles (No. 2-0 FiberWire meniscal repair needles; Arthrex) are passed through metal cannulas (Acufex Meniscal Stitcher Set; Smith & Nephew, Andover, MA) (Fig 6). The sutures are placed consecutively from posterior to anterior, leaving a 5-mm gap between sutures. For proper needle aiming to the meniscus, the AL portal is optimal for placing posterior sutures at the posterior horn of the medial meniscus while the arthroscope is viewing from the AM portal. Using this angle for aiming the suture needles enables passing the needles from inside the knee and exiting the skin at a posteromedial location that is not too central at the back of the knee and farther from the popliteal vessels.
10. To achieve anatomic and stable reduction of the meniscal fragment, the sutures are placed in a vertical or oblique configuration, which stabilizes both the upper and lower faces of the meniscus (Fig 7).
11. Through the posteromedial safety window, the gracilis tendon is palpated overlying the posteromedial joint capsule. Because the saphenous nerve runs at the level of the aponeurosis envelope of the gracilis tendon, for the most posterior sutures, the suture knots should avoid the gracilis coverage and slide over the joint capsule, thus avoiding the nerve at this location (Fig 8).
12. Sutures are consecutively placed further anteriorly. Because the saphenous nerve passes superficial to the superficial MCL layer, the meniscal sutures are placed directly over the superficial MCL layer to avoid catching the nerve branches. Complete stability of the meniscus should finally be achieved and checked using an arthroscopic probe (Fig 9).

Fig 10. As shown in a right knee, skin markings for preparing the posterolateral safety window include (1) the lateral joint line (black line), (2) the head of the fibula (star), (3) the Gerdy tubercle (GT), and (4) a 7- to 8-cm longitudinal mark running along the posterior border of the iliotibial band from about 5 cm proximal to the joint level and distally to a midpoint between the GT and the head of the fibula.

Fig 11. As shown in a right knee, the skin and subcutis are opened and the plain between the posterior fibers of the iliotibial band (ITB) and the anterior fibers of the biceps femoris is identified and opened.

Fig 12. As shown in a right knee, the thin layer overlying the fibular collateral ligament (FCL) is identified anteriorly, and the tendon of the lateral head of the gastrocnemius (LG) is identified just posterior to the posterolateral joint capsule. (GT, Gerdy tubercle.)

13. For repair of the lateral meniscus, relevant skin markings for preparing the posterolateral safety window include (1) the lateral joint line, (2) the head of the fibula, (3) the Gerdy tubercle, and (4) a 7- to 8-cm longitudinal mark running along the posterior border of the iliotibial band from about 5 cm proximal to the joint level and distally to a midpoint between the Gerdy tubercle and the head of the fibula (Fig 10).
14. The skin and subcutis are opened. A split is performed, separating between the posterior fibers of the iliotibial band and the anterior fibers of the biceps femoris (Fig 11).
15. The thin layer overlying the fibular collateral ligament is identified anteriorly, and the tendon of the lateral head of the gastrocnemius is identified just posterior to the posterolateral joint capsule (Fig 12). This tendon is a key landmark for properly placing sutures over the joint capsule for repair of the posterior horn of the lateral meniscus.
16. The tendon of the lateral head of the gastrocnemius is peeled off of the joint capsule posteriorly, and the capsule and joint line can easily be palpated. This completes the safety window for properly placing the posterolateral inside-out sutures (Fig 13).
17. With the knee in a figure-of-4 position, the inside-out sutures are placed from a posterior to anterior direction through the AM portal.
18. A flexible flat retractor is placed through the posterolateral safety window anterior to the lateral head of the gastrocnemius and posterior to the joint capsule (Fig 14).
19. To achieve stability of the posterior horn of the lateral meniscus, 2 or 3 sutures are placed medial to the popliteus tendon (Fig 15). Care is taken to avoid suture placement through the center of the popliteus tendon itself.
20. The suture needles are caught and pulled out through the posterolateral window anterior to the retractor using a needle holder. This allows one to avoid penetration of the needles in the areas posterior to the biceps femoris and potential harm to the common peroneal nerve.
21. Suture is placed just lateral to the popliteus tendon, avoiding tethering the meniscus to the popliteus tendon itself (Fig 16).
22. Sutures are placed further anteriorly with gaps of 5 mm between them until complete meniscal stability is achieved (Fig 17).

The postoperative protocol includes wearing a T Scope knee brace (Breg, Carlsbad, CA) with range of

Fig 13. As shown in a right knee, the tendon of the lateral head of the gastrocnemius (LG) is peeled off of the posterolateral joint capsule posteriorly. This opens the posterolateral safety window (black rectangle) through which the inside-out suture needles will be pulled. (FCL, fibular collateral ligament.)

Fig 14. As shown in a right knee, a flexible flat retractor is placed through the posterolateral window anterior to the lateral head of the gastrocnemius and posterior to the joint capsule. (FCL, fibular collateral ligament.)

motion of 0° to 60° during the first 2 weeks and 0° to 90° during the third and fourth weeks; thereafter, a gradual increase in range of motion is encouraged. Partial weight bearing with the use of crutches and the T Scope brace is advised for 5 weeks. Crutches are used

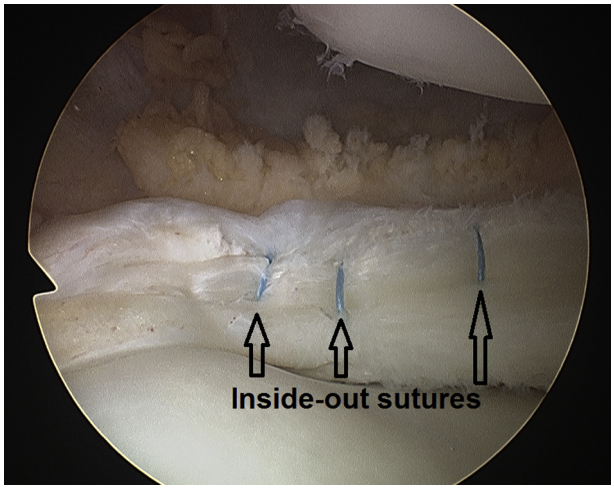

Fig 15. Arthroscopic view of a left knee using a 30° arthroscope through the anterolateral portal. Three vertical inside-out sutures (No. 2-0 Ti-Cron suture meniscal repair needles) are placed medial to the popliteus tendon.

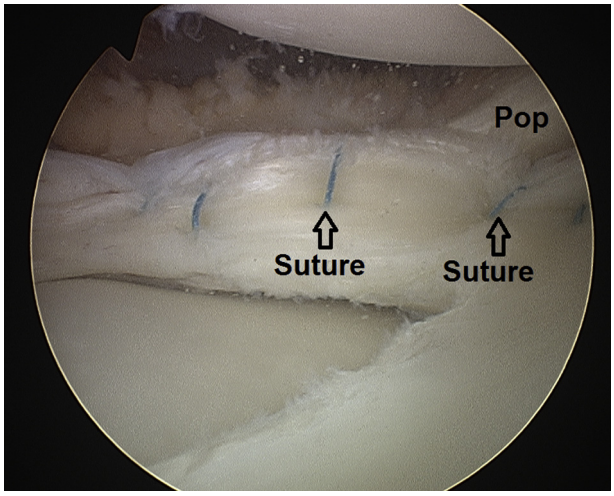

Fig 16. Arthroscopic view of a left knee using a 30° arthroscope through the anterolateral portal. The inside-out sutures are placed medial and lateral to the popliteus tendon (Pop).

until the gait pattern is normalized. Closed and open kinetic chain exercises are encouraged during rehabilitation. Running is allowed at 5 months postoperatively.

Table 1 summarizes tips and pitfalls for performing the described operation. Table 2 summarizes advantages and disadvantages of the technique.

Discussion

This article describes in detail how to properly use posteromedial and posterolateral safety windows to avoid iatrogenic lesions to the neurovascular bundles during implementation of the inside-out meniscal repair technique for extensive meniscal tears. On the

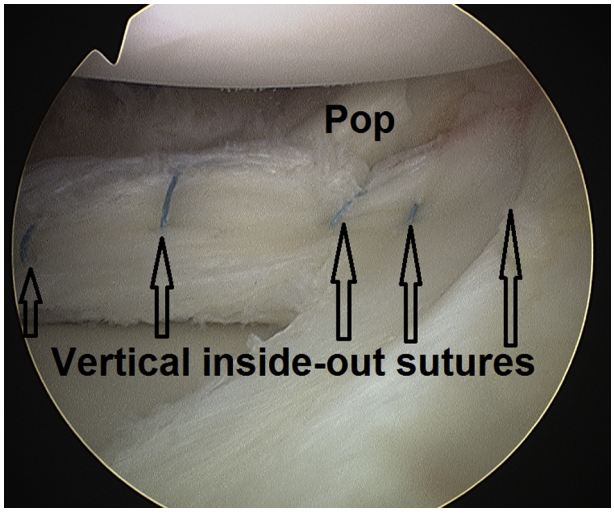

Fig 17. Arthroscopic view of a left knee using a 30° arthroscope through the anterolateral portal. Sutures are placed in a vertical configuration further lateral and anterior to the popliteus tendon (Pop) until complete meniscal stability is achieved.

Table 1. Tips and Pitfalls During Inside-out Repair of Extensive Meniscal Tears Using Posteromedial and Posterolateral Protective Windows

Tips
Prior to preparing the neurovascular protective window, the surgeon should palpate and mark on the skin all important anatomic landmarks. These include the medial epicondyle, joint line, and posteromedial proximal tibial ridge for the posteromedial window and the Gerdy tubercle, fibula head, and posterior border of the ITB for the posterolateral window.
For the posteromedial window, the surgeon should be sure to identify the thin fascia (i.e., layer 1). The surgeon should make sure all sutures are tied deep to this layer to avoid the saphenous nerve and branches.
To properly aim the most posteromedial suture needles for the medial meniscus, the surgeon should introduce the metal cannula of the suture needles in the anterolateral arthroscopic portal. This will prevent the suture needle from exiting the skin too posteriorly and too close to the popliteal neurovascular bundle.
When tying the most posterior medial meniscal suture, the surgeon should make sure the knots are placed deep to the gracilis tendon and aponeurosis to avoid catching the saphenous nerve.
For the posterolateral window, a key landmark is the lateral gastrocnemius tendon just posterior to the joint capsule. It is crucial to peel this tendon posteriorly away from the posterolateral joint capsule to properly open the window, allowing the suture knots to be tied just over the joint capsule.
The popliteus tendon and hiatus should remain intact without sutures passing through the tendon because this is a normal structure of the knee.
Pitfalls
If full extension is lacking and there is a suspicion that the posterior horn of the lateral meniscus is flipped anteriorly in a bucket-handle dislocated configuration, the surgeon should take extra care while establishing the anterolateral arthroscopic knee portal. In this case, the surgeon should use a No. 11 blade to make a skin and subcutis cut while penetrating the capsule only bluntly. This will avoid an inadvertent radial split of the posterior horn of the meniscus, which is overlying the anterior horn in this situation.
The surgeon should always check the sensory and motor function of the limb immediately after surgery. If one performs overzealous dissection and does not adhere to the anatomic landmarks and layers as described, the potential exists for catching the saphenous or peroneal nerve branches. This can be a devastating complication and is difficult to treat once a suture is tied around a nerve. If sensory loss or motor loss is diagnosed immediately after surgery in the awakened patient corresponding to the specific nerves at risk, the corresponding suture should be immediately removed.

ITB, iliotibial band.

posteromedial side of the knee, the saphenous nerve courses within the thin aponeurosis that covers the gracilis tendon. It then runs medially superficial to the layer of the superficial MCL.[5,6] By creating the posteromedial safety window as described, it becomes relatively straightforward to slide the most posterior knots posteromedially deep to the gracilis tendon and over the joint capsule and then to slide the more medial knots just on top of the superficial MCL layer and deep to the thin fascia (i.e., layer 1). By doing so, multiple inside-out suture repairs of the medial meniscus can be safely performed, respecting the layered anatomy and the course of the saphenous nerve as described over 4 decades ago.[5] On the posterolateral side of the knee, the common peroneal nerve is at risk because of its proximity to the posterolateral joint capsule.[7] Retracting the lateral gastrocnemius tendon posteriorly away from the posterolateral knee capsule opens the posterolateral safety window and enables the nerve to be avoided as described. On this side of the knee, to restore the normal anatomy as much as possible, it is desirable to place the sutures medial and lateral to the popliteus tendon, thus avoiding tethering of the tendon mass itself to the meniscus and preserving the intact popliteus hiatus with sutures nearly following the course of the superior and inferior popliteomeniscal fascicles.[8] In the case of both the medial meniscus and lateral meniscus, creating a vertical suture configuration is preferable to a horizontal configuration because it results in superior load-to-failure values[9] and enables anatomic reduction of the displaced meniscal fragments. This approach of repairing extensive meniscal tears using the inside-out technique and multiple vertical sutures has also been reported recently as the recommended approach for such challenging meniscal tears, achieving improved outcomes and low failure rates.[10]

In summary, using the posteromedial and posterolateral safety windows to safely perform multiple inside-out suture repairs of extensive meniscal tears as described relies on a sound anatomic basis, and it is particularly valuable for challenging meniscal tears such as chronically

Table 2. Advantages and Disadvantages of Inside-out Repair of Extensive Meniscal Tears Using Posteromedial and Posterolateral Protective Windows

Advantages
The failure rate is low.
The smallest-diameter suture needles among all meniscal suture devices are used, which are therefore almost atraumatic to meniscal tissue. This enables anatomic repair of challenging meniscal tissue without iatrogenic tearing of the meniscus.
No meniscal-repair hardware devices are deployed on the outer side of the capsule, which might migrate into the knee joint.
Disadvantages
The technique is time-consuming compared with all-inside techniques.
There is a risk of neurovascular injury compared with all-inside techniques.

deformed lesions that may still be amenable to repair. Moreover, this technique can be of value in other procedures that require extensive repair of suboptimal tissue in terms of biological qualities, such as meniscal allograft transplantation.

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