Technical Note

Hybrid Inside-Out—Outside-In Meniscal Repair Through a Small Skin Incision

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Abstract: Although the updated generation of all-inside devices for meniscal repair is more convenient to deploy and can provide comparable clinical outcomes with those of the inside-out procedure, the latter is still a very useful technique, giving many advantages over the former. The critical drawback of the conventional inside-out technique is the need for preparation of the accessory incision to prevent the risk of soft-tissue entrapment and neurovascular injury while retrieving the exiting meniscal needles, especially at the posterior corner of the knee. To minimize the space volume of the incision, a small, bluntly dissected track guided by the first exiting meniscal needle is sufficient in our hybrid inside-out—outside-in technique. The guiding cannula for the first meniscal needle passage is a commercial inside-out device, whereas the guiding cannula for retrieval in the subsequent meniscal needle passages is a spinal needle applied in an outside-in manner via the small track. Subsequent meniscal needles can be inserted in an inside-out or outside-in manner according to the design of the suture construct.

The importance of the meniscus in maintaining normal knee biomechanics and function has been globally acknowledged.[1] When feasible, it is currently standard practice to repair a torn meniscus to restore its structure and knee kinematics to alleviate the risk of early degenerative changes.

Despite the various meniscal repair techniques, each has its benefits and drawbacks and none can serve for all situations. Many complex meniscal tear patterns might require sophisticated devices and technical mastery. Although a modern all-inside meniscal repair apparatus is generally more expensive and yields a higher risk of subsequent cyst formation than the conventional inside-out technique,[2] it is still gaining popularity in repairing tears of the meniscal body and posterior horn. An important favorable aspect of this device is its technical convenience while giving comparable clinical results with those of the inside-out approach.[3]

The inside-out technique has been considered the gold standard for meniscal repair.[4] A recent study recommended this procedure for all potentially reparable meniscal tears regardless of vascular zones, preferably in acute cases.[5] Critical disadvantages that compromise routine use of this technique include the risk of neurovascular injury and tissue entrapment under the knot tied over the capsule. The underlying problem is the technical difficulty in controlling the direction of the tiny, flexible meniscal needle while penetrating outside the joint. It should be noted that entrapment is inevitable because there must be some tissue in the span between the 2 inside-out needle tracks. Dissection to clear up space at the expected area of involvement, especially the posteromedial or posterolateral corner of the knee, is then required prior to needle passage.[6]

We describe an applied technique to minimize the invasiveness of the additional tissue dissection by hybridizing the inside-out and outside-in concepts, that is, the hybrid inside-out—outside-in (I-O) technique. Instead of the need to prepare enough space in the soft tissue, particularly at the posterior corner, to retrieve the rather scattered inside-out needles, the space volume is minimized by creating only a small, extracapsular track surrounding the first exiting

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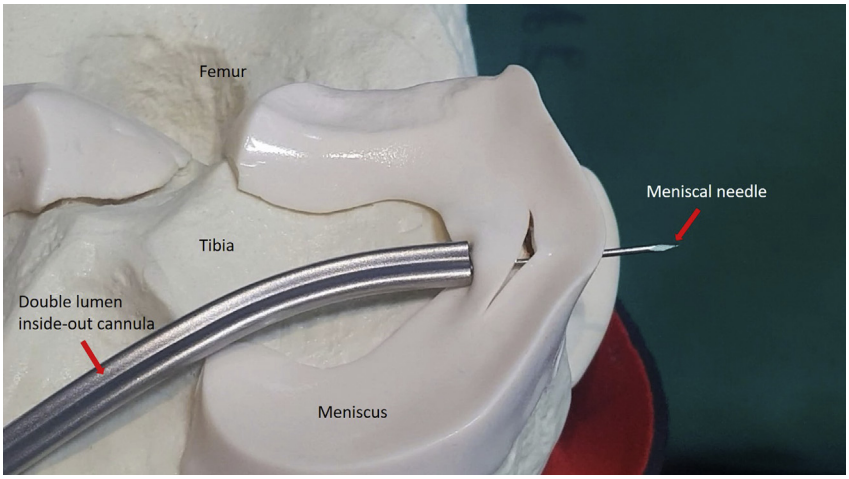

Fig 1. Teaching model showing in-out-out pattern for hybrid inside-out–outside-in repair. A curved inside-out double-lumen cannula is used to guide the meniscal needle for the first passage of the suture inside-out through the torn meniscus and capsule.

meniscal needle. The subsequent needle passages, performed in either an inside-out manner or the reverse, will be guided by an outside-in spinal needle inserted adjacent to the first needle inside this small track. The spinal needle is stiff enough to control the direction of application, and either extracapsular or intracapsular needle passages would be contained in the small vicinity near the first needle track. Moreover, this hybrid I-O technique provides greater versatility in suture constructs for different meniscal tear patterns by using interrupted or continuous inside-out and outside-in sutures.

Surgical Technique

The patient is placed supine, as for routine arthroscopy, and receives general or regional anesthesia (Video 1). A pneumatic thigh tourniquet is usually installed and inflated. Adequate exposure of the meniscus is the key for success. To repair the lateral meniscus, the knee is flexed 60° to 90° in a figure-of 4 position. Additional varus stress can help open the lateral compartment. To repair the medial meniscus, the knee is flexed about 20° to 30° and valgus stress is applied using a lateral post to widen the joint. Pie crusting (fenestration) of the medial collateral and posterior oblique ligaments for better exposure is optional. Correct placement of the viewing and working portals is essential, and accessory portals are often obliging for achieving optimal access to the meniscal tear. Tissues blocking visualization must be adequately shaved or cauterized. The torn meniscal fragments are carefully debrided and reduced into

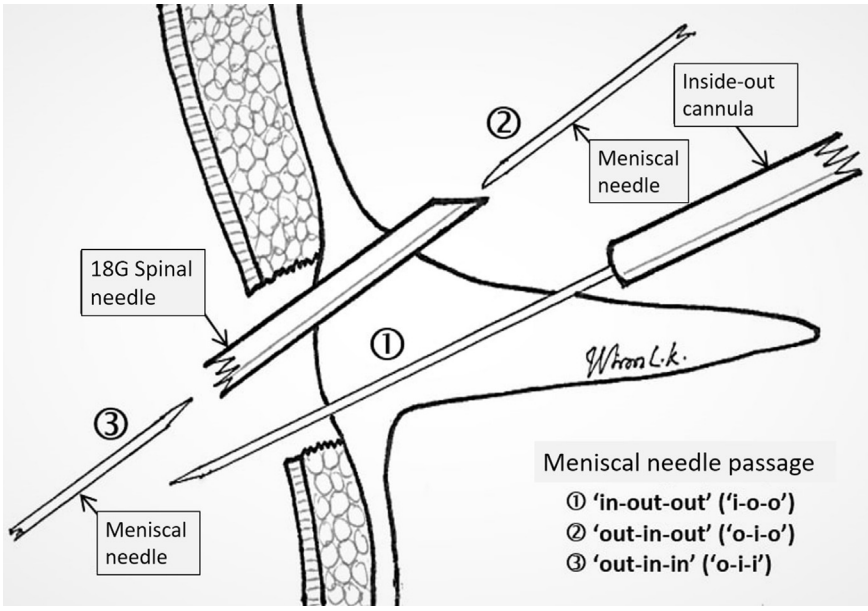

Fig 2. Three different patterns of meniscal needle passage, each described using 3 terms according to the direction of the guide (first 2 terms) and the direction of the meniscal needle tip (last term): (1) in-out-out (i-o-o), in which the commercial cannula is used as an inside-out guide and the meniscal needle passes inside-out; (2) out-in-out (o-i-o), in which the spinal needle is used as an outside-in guide and the meniscal needle passes inside-out into the spinal needle lumen; and (3) out-in-in (o-i-i), in which the spinal needle is used as an outside-in guide and the meniscal needle passes outside-in. (G, gauge.)

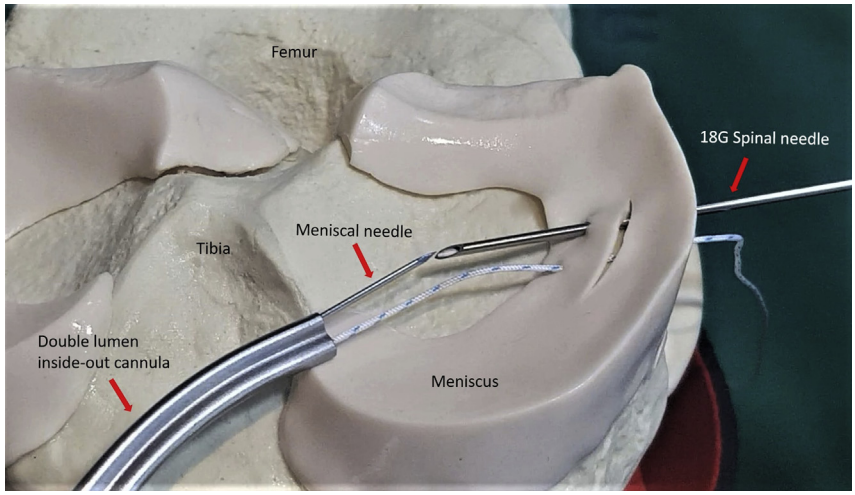

Fig 3. Teaching model showing out-in-out pattern. The 18-gauge (18G), 90-mm spinal needle is inserted outside-in through the knee capsule and torn meniscus to receive and pass the meniscal needle inside-out from the knee joint using the cannula guide. The other suture limb has been passed by the in-out-out pattern.

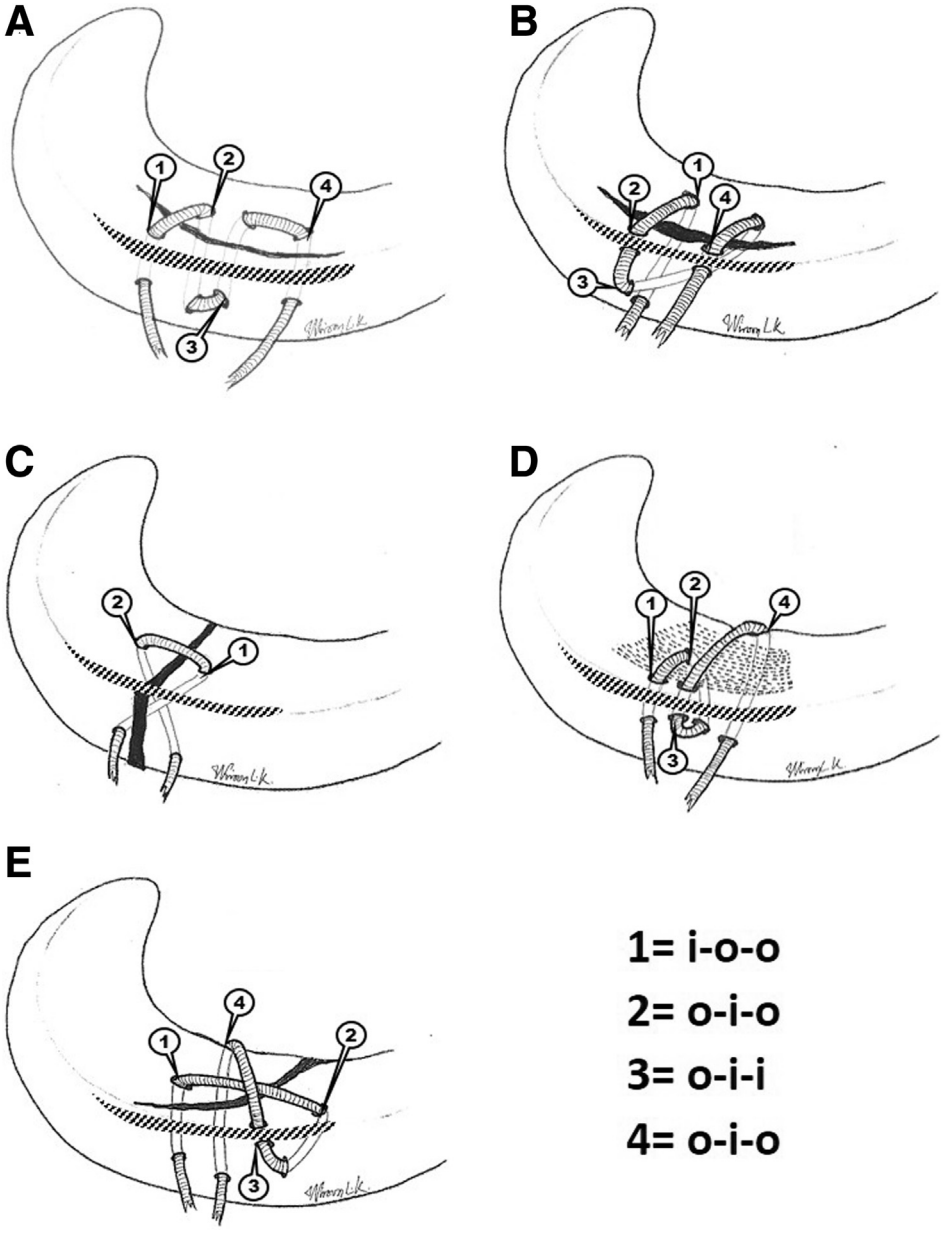

Fig 4. Different suture constructs proposed for some meniscal tear patterns. (A) Continuous vertical and horizontal mattress sutures for longitudinal tear. (B) Continuous double vertical mattress sutures for longitudinal tear. (C) Figure-of-8 suture for radial tear. (D) Continuous double vertical mattress sutures for horizontal tear. (E) Figure-of-8 mattress suture for oblique tear. Numbers indicate patterns of meniscal needle passage: in-out-out (1), out-in-out (2), out-in-in (3), and out-in-out (4).

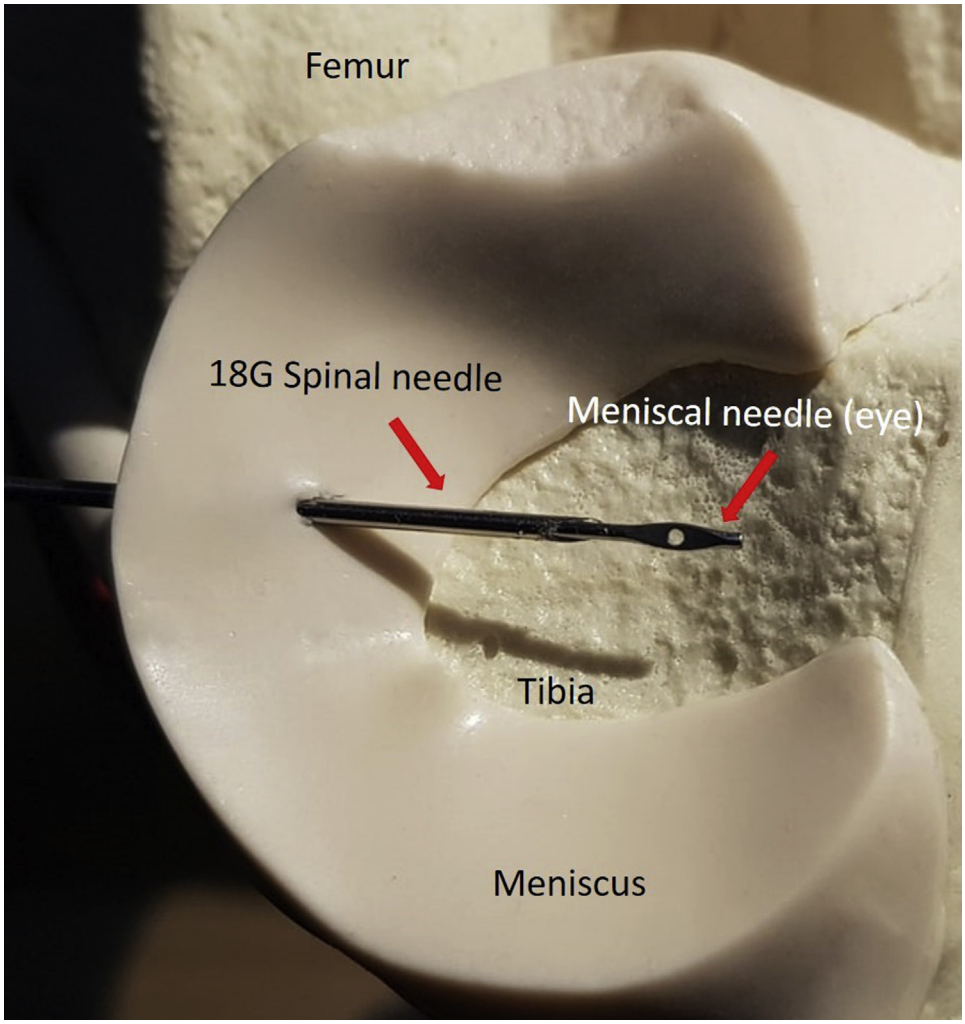

Fig 5. Teaching model. Owing to its slight enlargement, the meniscal needle eye could be too bulky to pass through the 18-gauge (18G) spinal needle lumen.

place. The tear surface is refreshed by rasping, trephining, or shaving to enhance healing.

An inside-out cannula (Acufex single or double lumen; Smith & Nephew, Andover, MA) is used to guide the meniscal needle for the first passage of suture inside-out through the meniscus or capsular ligament. This step can be described as an "in-out-out" pattern (Fig 1), in which the first 2 terms indicate the direction of the guide (commercial cannula or spinal needle) whereas the third term indicates the direction of the meniscal needle tip (Fig 2).

The subsequent suture passages are guided by the lumen of an outside-in 18-gauge, 90-mm spinal needle (Terumo, Somerset, NJ) (Fig 3); we selected this caliber because it can accommodate the size of the meniscal needle shaft. The suture attached to the meniscal needle is shuttled inside-out (out-in-out pattern) or outside-in (out-in-in pattern) through the spinal needle lumen depending on the suture construct (Fig 4).

If the meniscal needle eye is too bulky to pass through the spinal needle lumen (Fig 5), the beveled opening of the spinal needle will serve as a receptacle for the meniscal needle that then passes through the joint, together with retraction of the spinal needle, for the out-in-out pattern. For the out-in-in pattern under this same condition (antegrade meniscal needle in the spinal needle lumen obstructed at the meniscal needle eye), passage of the meniscal needle should be modified by first inserting the meniscal needle butt into the outside-in spinal needle's beveled opening (as the receptacle) in the joint. The meniscal needle is then passed in a retrograde manner by following retraction of the outside-in spinal needle until the butt is outside the joint. The spinal needle is removed. To finish the process, the suture is attached and the meniscal needle is passed in an antegrade outside-in manner (tip forward) (Fig 6).

Because it can be difficult to control the exact direction of the first in-out-out exiting meniscal needle

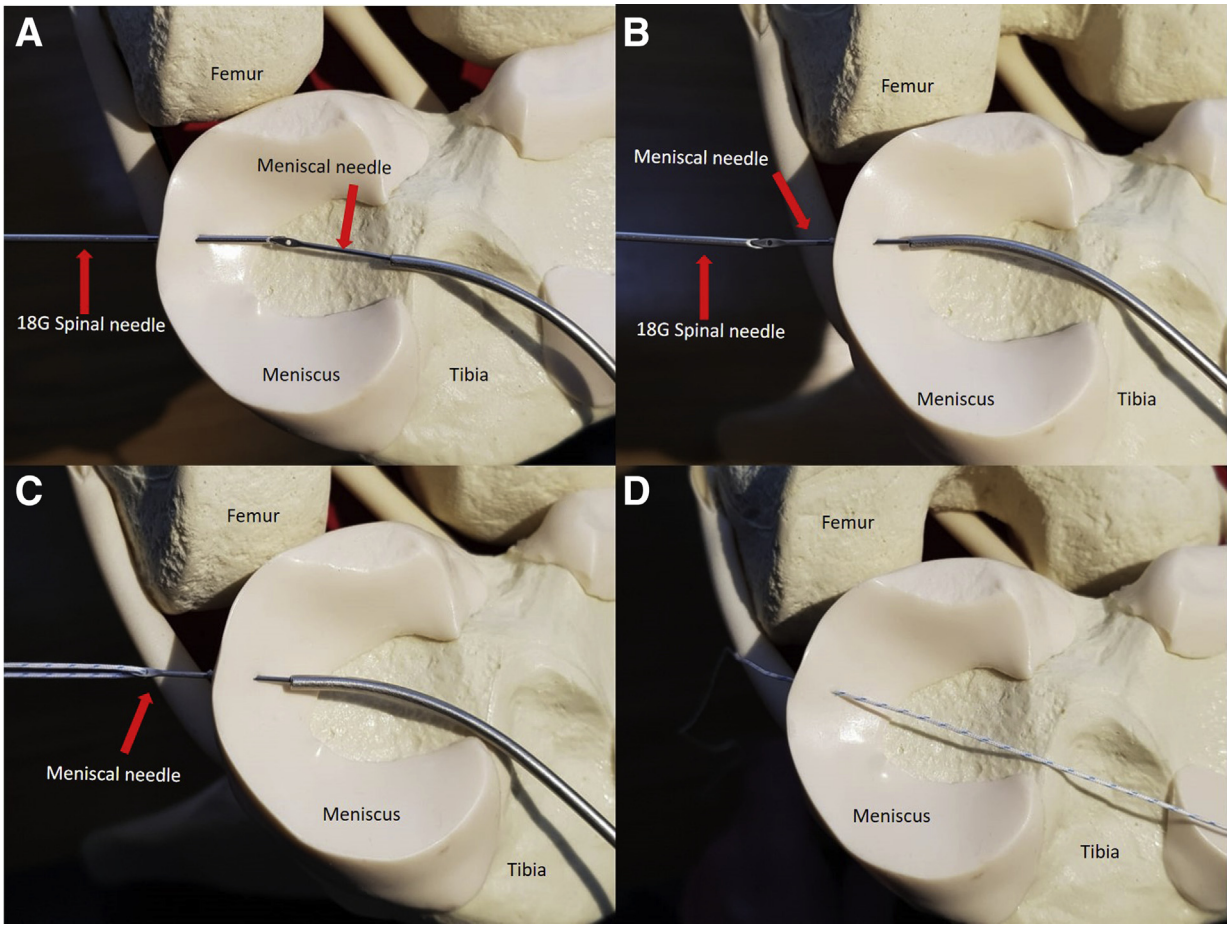

Fig 6. Teaching model showing out-in-in pattern. If the meniscal needle is obstructed by the bulky eye portion while passing outside-in, the process should be modified as follows: (A) The meniscal needle butt is inserted into the outside-in spinal needle bevel in the joint. (B) The meniscal needle butt is passed in a retrograde manner along with retraction of the outside-in spinal needle until the meniscal needle butt is outside the joint. (C) The spinal needle is removed, and the suture is attached to the meniscal needle. (D) The meniscal needle is passed in an antegrade outside-in manner to finish the process. (G, gauge.)

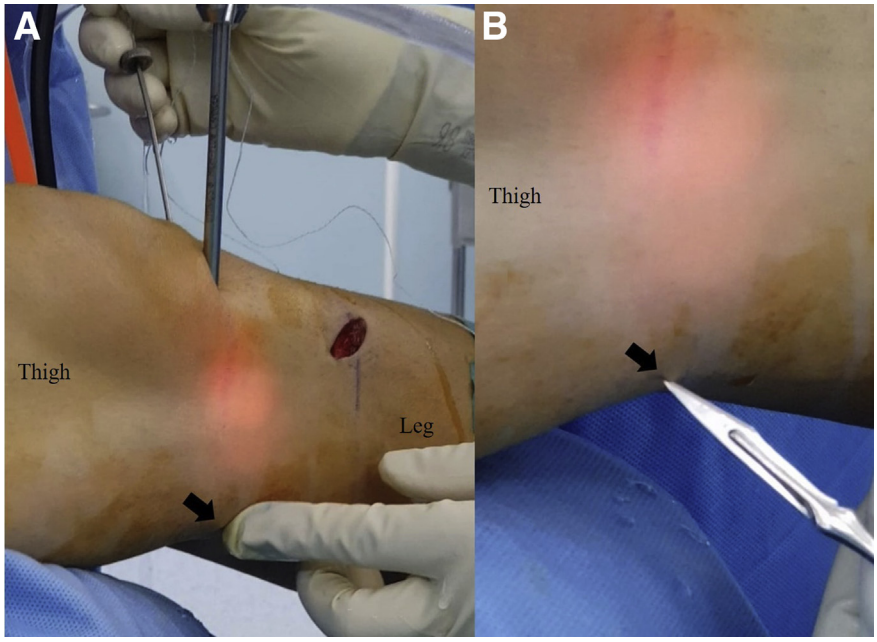

Fig 7. (A) Left lower extremity in the supine position showing the in-out-out pattern during repair of the medial meniscus by inserting the meniscal needle through the inside-out single-lumen cannula (in the anterolateral portal). (B) The skin tenting over the meniscal needle tip (arrow) before penetration is the landmark where a small incision is made.

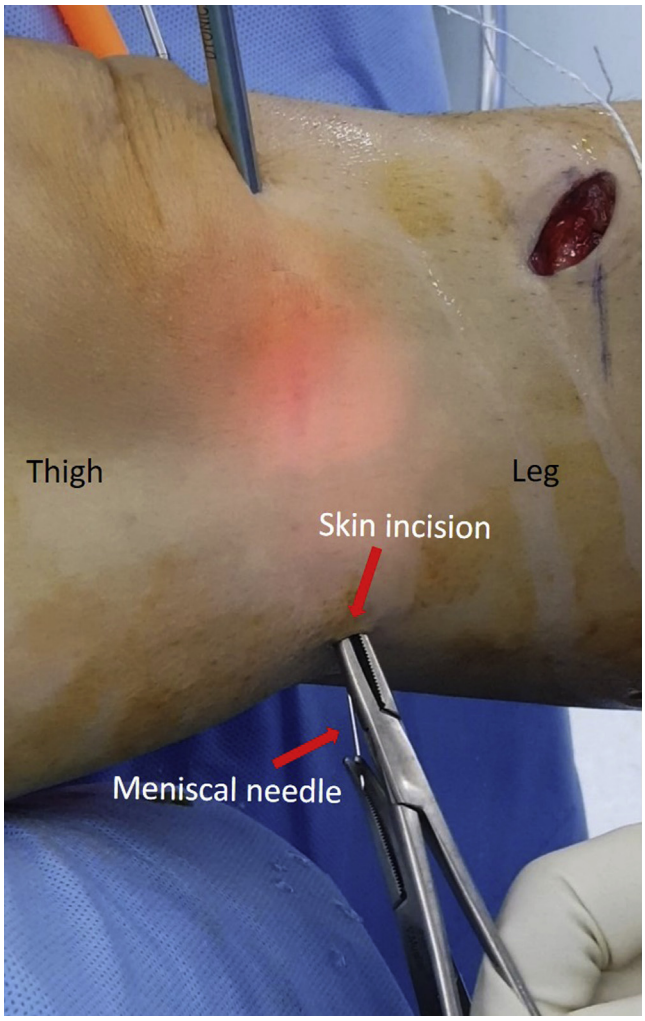

Fig 8. Left lower extremity in the supine position undergoing repair of the medial meniscus. The extracapsular inside-out meniscal needle track at the posteromedial corner of the knee is traced back along the needle toward the capsule using blunt dissection. The meniscal needle tip is held by the clamp to prevent accidental staff injury.

outside the capsule, we do not recommend using this technique if the initial needle is expected to point toward the popliteal neurovascular structures. The safe zone should exclude about 2 cm at the terminal curve of the posterior horn of the medial meniscus, as well as the part of the lateral meniscus medial to the popliteal tendon. Owing to limitations from knee flexion positions under valgus or varus stress, surgical procedures outside the joint are relatively more convenient on the medial side than on the lateral side. A skillful assistant can be very helpful.

As an example, if we use a simple mattress suture, the first in-out-out passage of the meniscal needle is guided by the inside-out commercial cannula for meniscal repair. When the leading meniscal needle tip is tenting under the skin, a small (10- to 15-mm) incision is made over this point (Fig 7). The meniscal needle is further advanced through this incision but still kept in the path as a landmark. The surgeon should beware to retrieve the meniscal needle tip to prevent accidental staff injury. The extracapsular needle track is traced back toward the capsule using blunt dissection (Fig 8). A small space surrounding the exiting meniscal needle is then ready for the introduction of the outside-in spinal needle void of substantial extracapsular tissues risking entrapment. While the soft tissues are being cleared, if the meniscal needle has penetrated through substantial structures (e.g., the lateral collateral ligament or popliteal tendon), the meniscal needle should be reapplied to avoid injuring such structures. The inside-out meniscal needle can now be pulled out with the attached suture to complete the first (in-out-out) suture passage or just remain there as a direction guide for the next step.

The surgeon applies an 18-gauge, 90-mm spinal needle (with its stylus in place) in an outside-in

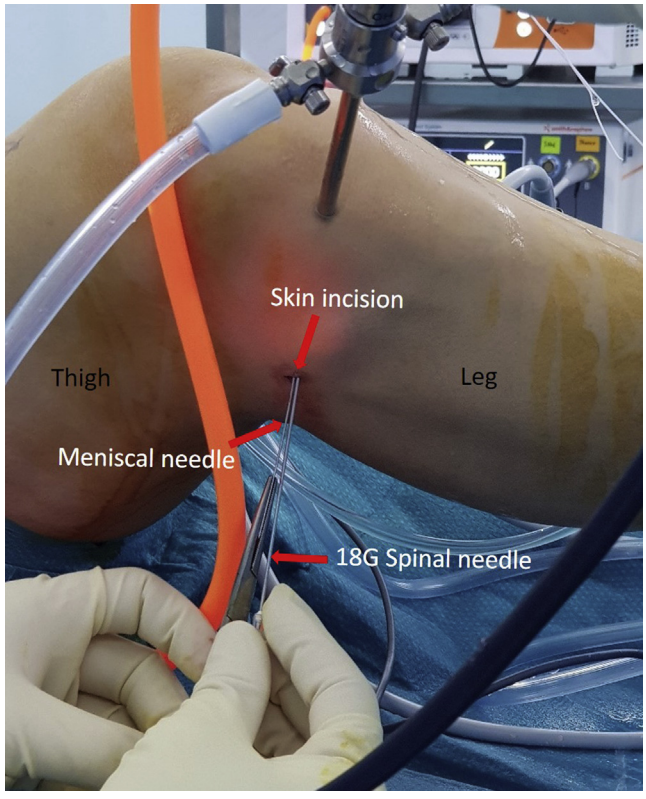

Fig 9. Right lower extremity in the supine figure-of-4 position undergoing repair of the lateral meniscus. The arthroscope is applied through the anterolateral portal. The outside-in spinal needle is introduced into the small dissected space surrounding the exiting meniscal needle (applied via the anteromedial portal) at the posterolateral corner of the knee. The meniscal needle tip is held by the clamp to prevent accidental staff injury. (G, gauge.)

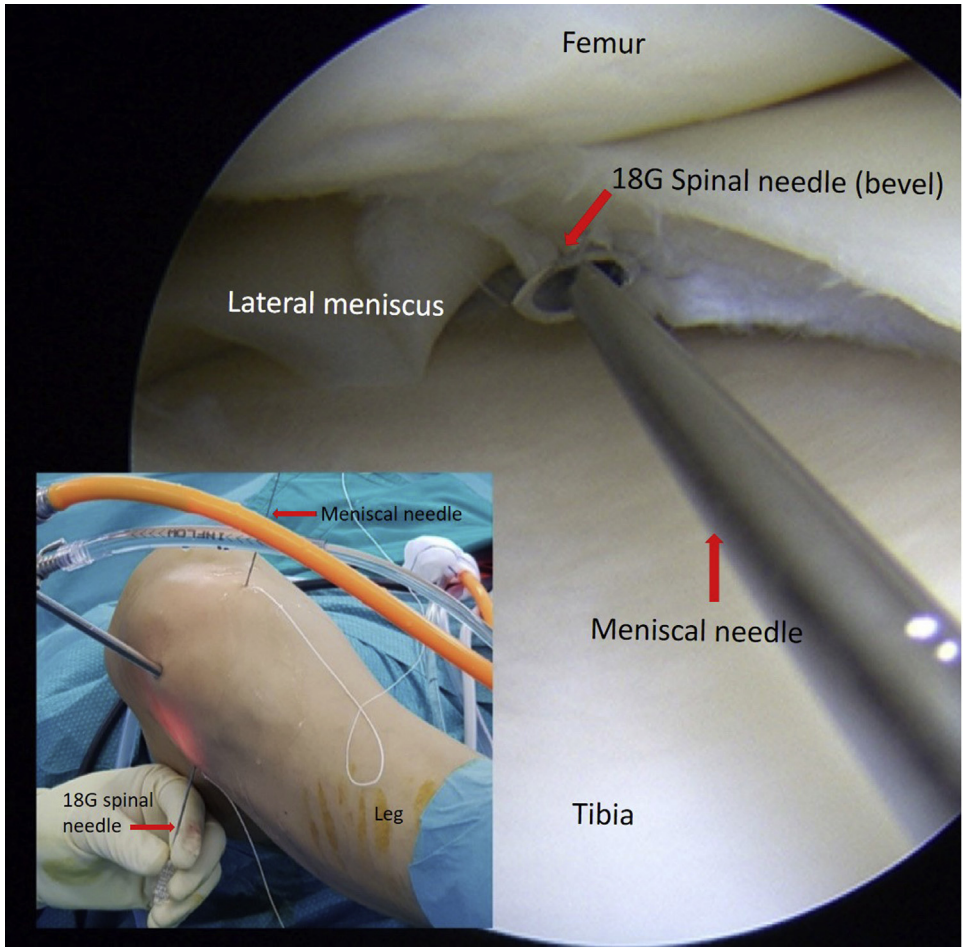

Fig 10. Right lower extremity in supine figure-of-4 position, viewing arthroscopically from anterolateral portal. The site of entry of the outside-in spinal needle in the meniscus is monitored by the arthroscope, and the meniscal needle is then passed inside-out with the retracting spinal needle (inset). (G, gauge.)

manner at the capsule adjacent to the initial exiting repair suture or the remaining first meniscal needle, keeping a small soft-tissue bridge between the 2 sites (Fig 9). If the dissected extracapsular tissue track is deep, a small tubular instrument such as a drill sleeve can be used as both a retractor and a guide for inserting the spinal needle. The determined site of the entering spinal needle is monitored by the arthroscope (Fig 10). If the initial meniscal needle remains in the path, it can now be pulled out while leaving the cannula inside the knee joint. The spinal needle stylus is removed, and the next inside-out meniscal needle (directed by the inside-out cannula) is inserted into the spinal needle's beveled opening. The other suture end is attached to the meniscal needle butt, which is then advanced through the cannula and pulled out to complete the second out-in-out suture passage for the mattress suture.

Now that the suture is looped over the torn meniscal tissues with both suture ends having exited the joint through the small skin incision, comparable to ordinary inside-out repair, the ends can be tied over the capsular bridge with a knot (Fig 11). If additional passages are desired for different suture constructs using continuous stitches, the next outside-in spinal needle is applied and the sutures are passed in an out-in-in pattern, followed by an out-in-out pattern, and so on, according to the principle elucidated earlier.

Discussion

We propose the hybrid I-O technique as an alternative approach by combining the benefits of the inside-out and outside-in techniques while solving certain disadvantages of these techniques. It is technically simple and requires only basic instruments available in most orthopaedic operating theaters. The fundamental idea is applied from the concept of "outside-in meniscal repair through a needle hole,"[7] in that a small incision is sufficient to control the extracapsular process of the meniscal repair. In this scenario, using an outside-in spinal needle helps control the direction of the inside-out meniscal needle and minimize the risk of soft-tissue entrapment. Needle passages in both directions allow the creation of continuous stitches (mattress, figure of 8, modified Mason-Allen, and so on), with ensuing better concealment and coaptation of the meniscal fragments. This could be helpful for the

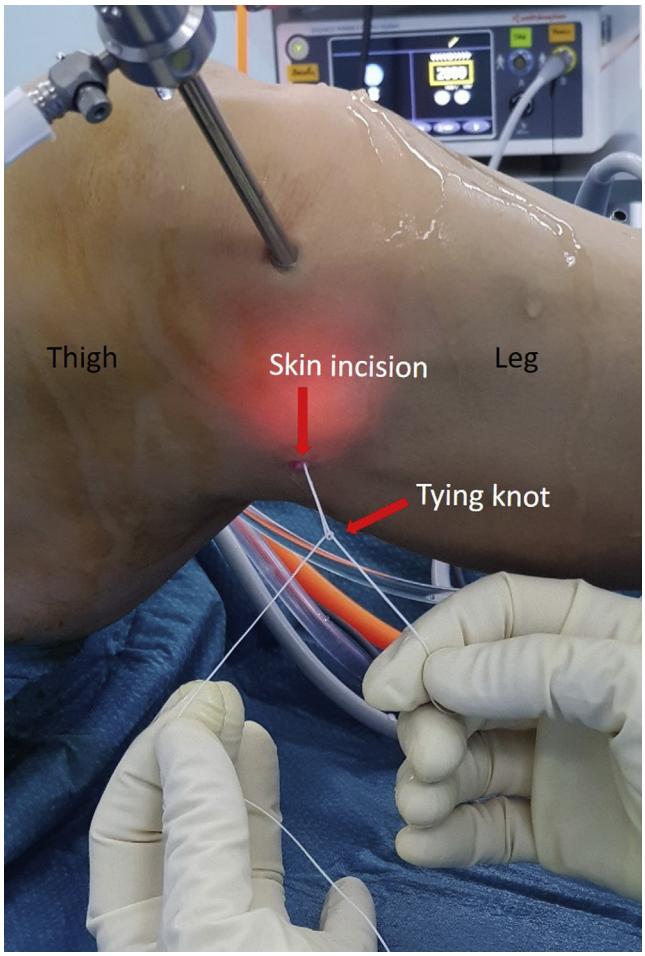

Fig 11. Lateral side of right lower extremity in supine figure-of-4 position. The suture ends are tied with a knot over the capsular bridge inside the small skin incision made at the posterolateral corner of the knee.

surgeon to accomplish meniscal repair more efficiently by designing suture constructs appropriate for different tear patterns.

The hybrid I-O technique would best be applied to a meniscal tear involving the body segment or its junction with the posterior horn, where the extracapsular structures are simple and thin. It would be more difficult for the parts beyond, especially at the posterior segment, where the extracapsular structures are complex and thick, and the operation is performed while the knee is flexed. For the anterior horn, using a curved cannula is helpful in passing the first needle, while simply using outside-in technique is more comfortable. In general, the inside-out cannula is useful for reduction of loose meniscal parts that might have been deformed in chronic cases. Furthermore, the direction of the first meniscal needle offers good guidance to properly pass subsequent needles via the outside-in spinal needle, rather than blind application as in conventional techniques.

The knee position during the operation is quite influential. For the medial meniscus, it is more convenient for the assistant surgeon to approach the operated knee when flexed 20° to 30°. However, for the lateral meniscus, with the operated knee in the figure-of-4 position, it is more difficult to work at the posterolateral aspect.

The risk of neurovascular injury is essentially related to the initial inside-out needle passage but is relatively negligible during outside-in blunt dissection. Most of the posteromedial structures are relatively safe. The small saphenous vein and nerve lie posteromedial to the semitendinosus tendon. The risk of injury to these structures can be visually avoided using a transillumination technique. At the posterolateral corner, the initial meniscal needle passage through the posterior horn could harm the common peroneal nerve if the meniscal needle exits medial to the biceps femoris.

Although the initial meniscal needle passage using the commercial cannula is classically described as "inside-out" in this hybrid I-O technique, it could alternately be started with an outside-in spinal needle where the torn meniscal segment is not too posterior. The concept of "outside-in meniscal repair through a needle hole"[7] mentioned earlier could be applied to minimize the skin incision. The commercial cannula is

Table 1. Advantages, Disadvantages, and Limitations

Advantages
The small accessory incision created by blunt dissection produces lower tissue injury, less postoperative pain, and milder scarring.
Different suture constructs composed of uninterrupted shuttling suture passages could be designed according to various meniscal tear patterns.
Generally, the required equipment is less pricey than commercial all-inside meniscal repair kits, especially when many stitches are required.
For the displaced meniscal tear fragment, the inside-out cannula can serve as a meniscal tissue reduction tool and improve precision during the first meniscal needle passage.
Disadvantages and limitations
The initial meniscal needle might have some risk of passing into the neurovascular structures, especially at the posterolateral corner medial to the biceps femoris insertion.
It could be unsafe to repair the posterior horn of the lateral meniscus located medial to the popliteal tendon or posterior horn of the medial meniscus at a segment of the terminal curve measuring about 2 cm.
Passing the meniscal needle through the bevel of the 18-gauge spinal needle (out-in-out) at the middle meniscal body or in a more anterior lesion might be difficult; a curved cannula is helpful.
Owing to the figure-of-4 position during repair of the lateral meniscal lesion, it might be difficult to control the direction of the meniscal needle and 18-gauge spinal needle for in-out-out and out-in-out repair; a skillful assistant is helpful.
For constructs composed of continuous sutures, suture thread of previous passages could be accidentally damaged by subsequent passages of either the spinal or meniscal needle.

Table 2. Tips and Pearls

Blunt dissection should always be used alongside the path of the initial in-out-out meniscal needle to avoid injury to important nearby structures.
The technique is most appropriate for meniscal tears located in the body segment and around the corner approaching the posterior horn, whereas an anterior-horn tear requires the use of a curved cannula or, simply, the outside-in technique.
For classical hybrid I-O repair, the first and second meniscal needle patterns in the simple horizontal or vertical mattress construct are always in-out-out and out-in-out, respectively.
If more meniscal needle passages are designed for classical hybrid I-O repair, the continuous suture patterns will be out-in-in and out-in-out alternately; the last pattern is always out-in-out before the knot is tied over the tissue bridge.
The commercial cannula is helpful as a reduction tool for torn or deformed meniscal fragments.
The direction of the first in-out-out meniscal needle guides correct placement of the outside-in spinal needle.
Pulling the first inside-out loop counters the pressure of the outside-in spinal needle and facilitates needle insertion.
The slightly enlarged portion at the meniscal needle eye might block passage through the 18-gauge spinal needle lumen. This could be solved by the technical modification described in the "Surgical Technique" section.
It is more convenient to use a double-lumen cannula than a single-lumen cannula for complex suture constructs, given that the larger double-lumen space can accommodate both the meniscal needle and previous suture thread; this will prevent suture entrapment in the arthroscopic portal.
The single-lumen cannula can contain both suture thread and the meniscal needle shaft at the same time in an out-in-out pattern to prevent suture entrapment in the arthroscopic portal.
The spinal needle should always be inserted with the stylet to prevent accidental needle bending or tissue entrapment in the needle lumen during insertion.

I-O, inside-out—outside-in.

used for meniscal tissue reduction and counteraction of the outside-in needle, and the meniscal needle is used for suture passage.

In summary, the hybrid I-O technique can be applied to almost every part of a meniscal tear, except the short segment near the root area of the posterior horn, where using all-inside instruments or conventional inside-out repair with larger safety incisions is more comfortable to practice. Advantages, disadvantages, and limitations of this technique are presented in Table 1, and tips and pearls are presented in Table 2.

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