Technical Note

Double-Bundle Femoral-Based Reconstruction of the Deep and Superficial Medial Collateral Ligament for Anteromedial Rotatory Instability: The MAVERIK Technique

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Abstract: A technique to reconstruct both the superficial and the deep medial collateral ligaments to restore the valgus and the anteromedial knee stability is described. The semitendinosus tendon, with its tibial attachment preserved, is used as a graft to reproduce a double-bundle isometric V-shaped construct, with a single femoral tunnel and anchor-based attachments on the tibia. This technique can be performed isolated or combined with anterior and/or posterior cruciate ligament reconstruction.

Various techniques for medial collateral ligament (MCL) reconstruction have been described in the literature[1-11]; however, no consensus has been reached regarding the optimal approach.[12-15] Anatomic reconstruction techniques usually are performed with 2 strands that aim to reproduce the superficial MCL (sMCL) and the posterior oblique ligament (POL).[16] Biomechanical studies have shown that external rotation (ER) is mainly controlled by the deep MCL (dMCL).[17,18] The most recent works have highlighted the role of this ligament in controlling anteromedial rotation, suggesting that specifically addressing this ligament when performing a reconstruction surgery to fully restore ER stability, rather than focusing on POL reconstruction, is effective.[14,19] Based on those achievements, we describe a double-bundle technique using autologous semitendinosus as a graft, preserving its tibial insertion, with a single femoral tunnel, for the reconstruction of both the dMCL and sMCL, named the MAVERIK technique: Medial Autologous V-shaped Reconstruction for Rotatory Instability of the Knee.

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Surgical Technique

Indications

Indications for dMCL and sMCL reconstruction are reported in Table 1.

Patient Preparation

The patient is placed in a supine position, with a cylindrical foot support and a lateral support positioned on the lateral aspect of the thigh at the level of the padded tourniquet, allowing the knee to be flexed at 90°.

Patient Evaluation

Following the induction of anesthesia, a thorough knee examination is performed: varus and valgus stress at 0° and 30° of flexion, as well as the Lachman test, pivot-shift test, anteromedial drawer test, and posterior drawer test to detect anteromedial rotation.[20] A diagnostic arthroscopy is conducted through the standard anterolateral and anteromedial portals to identify and address any concurrent intra-articular injuries. In cases of severe medial instability, the "drive-through" sign is typically observed. The positioning of the meniscus can offer valuable insights into the location of the medial ligament damage. If there is concurrent anterior or posterior instability, arthroscopic reconstruction of the

Table 1. Indications for Deep and Superficial MCL Reconstruction

Indications
Isolated MCL lesion
• Acute or chronic grade III laxity at valgus stress at 30° and/or 0°
• Nonacute grade II laxity at valgus stress at 30° and/or 0° in high-demanding patients or symptomatic
ACL + MCL lesion
• Grade II or grade III valgus laxity and/or Slocum test positive (anteromedial drawer test)

ACL, anterior cruciate ligament; MCL, medial collateral ligament.

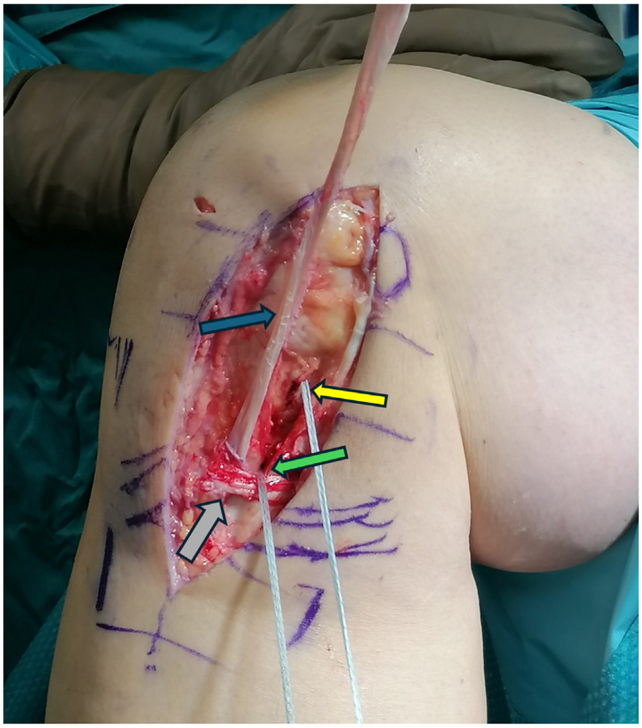

Fig 1. The harvested semitendinosus tendon (blue arrow), passing under the gracilis (gray arrow), is shown together with the distal anchor (green arrow) to redirect the graft posteriorly and the proximal anchor (yellow arrow) to reproduce the advantage of the short isometric construct (right knee), as described by Borque et al.[25]

anterior cruciate ligament (ACL) or posterior cruciate ligament can be performed simultaneously.

Surgical Steps

A longitudinal incision is made, extending from the medial epicondyle to approximately 6 cm distal to the joint line at the midpoint of the width of the native sMCL, giving a slightly oblique orientation (Video 1). The deep fascial layer is incised along the full length of the sMCL, with the pes anserinus exposed. The semitendinosus tendon (ST) is harvested using an open-ended tendon stripper, ensuring that the tibial attachment is preserved during the procedure. It is possible to arm the free end of the tendon with a No. 2 Vicryl (Ethicon) suture in a standard baseball stitch technique for secure handling. The harvested graft is then wrapped in gauze soaked in a vancomycin solution. First, a 2.8-mm double-loaded Q-Fix anchor (Smith & Nephew Endoscopy) is placed about 6 cm distally from the joint line, at the anatomic footprint of the sMCL (the midpoint of the anteroposterior distal sMCL insertion was chosen for anchor placement). Since the ST insertion is more anterior than the distal sMCL insertion, thanks to the anchor, the graft is redirected posteriorly without disrupting its attachment at the pes anserinus and fixed with 2 locking stitches and simple knots to the anchor. Subsequently, a second 2.8 mm Q-Fix anchor (Smith & Nephew Endoscopy) is positioned along the course of the MCL, about 20 mm distally from the joint line, at the same line of the previous anchor, on the anteroposterior plane (Fig 1). The graft is therefore passed under the remaining pes anserinus and fixed to the proximal anchor in the same fashion as before (Fig 2). Next, the proximal insertion of the MCL at the medial epicondyle is exposed. To determine the

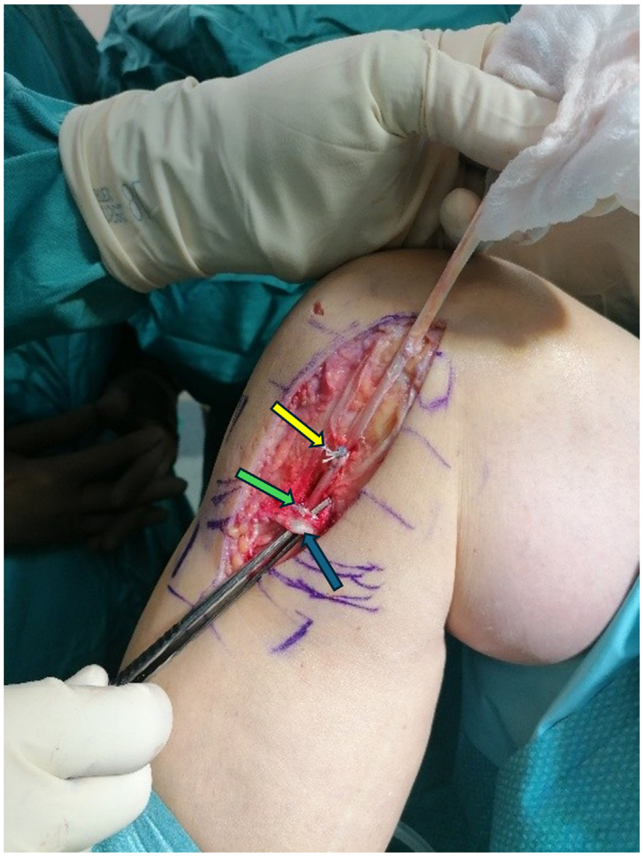

Fig 2. The semitendinosus tendon has been fixed to the distal (green arrow) and proximal (yellow) anchors after passing under the remaining pes anserinus (blue arrow indicates the gracilis tendon; right knee).

Fig 3. A Beath pin (blue arrow) is passed through the femur on the medial epicondyle, after having confirmed the isometric point by testing the graft throughout the full range of motion (right knee). The green arrow indicates the distal anchor, and the yellow arrow indicates the proximal anchor.

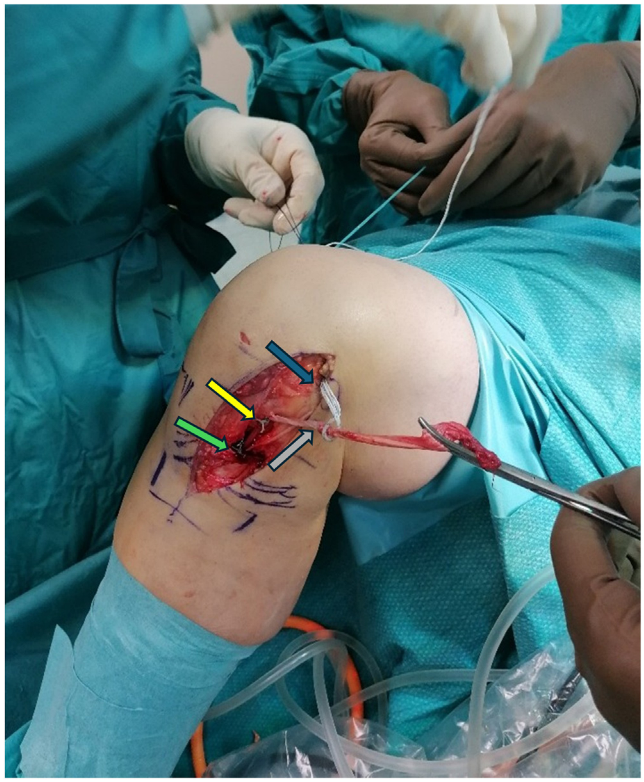

Fig 4. A bicortical tunnel is created using a 4.5-mm drill. Subsequently, a half-tunnel is drilled to the same diameter as the graft, to a depth of 25 mm (right knee). The graft (gray arrow) is then passed through the loop of an UltraButton (Smith & Nephew Endoscopy) (blue arrow) and inserted into the femoral tunnel. (The green arrow indicates the distal anchor, and the yellow arrow indicates the proximal anchor.)

isometric point, a K-wire is placed on the medial epicondyle, and the free end of the graft is wrapped around the K-wire while the knee is flexed to the full range of motion. Once the isometric point is identified and confirmed, a Beath pin is placed (Fig 3), followed by the creation of a bicortical tunnel using a 4.5-mm drill. Subsequently, a half-tunnel is drilled to the same diameter as the graft, to a depth of 25 mm. The graft is then passed through the loop of an UltraButton (Smith & Nephew Endoscopy) and inserted into the femoral tunnel (Fig 4), fixed in suspension with the knee held at 30° of flexion and slight varus. Finally, the distal footprint of the dMCL on the tibia is identified, aiming at a point placed anterodistally at a 25° angle from the previous bundle, approximately 10 mm distal to the joint line. The third 2.8-mm Q-Fix anchor (Smith & Nephew Endoscopy) is then deployed, and the graft is fixed at the tibia in a neutral rotation with 30° of flexion, making eventually a V-shaped construct (Fig 5 A and B). The final construct is checked, and if some extra-tension of the graft is needed, the adjustable loop of the button can be further pulled in full extension to prevent knee stiffness (Fig 6). Pearls and pitfalls of the surgical technique are reported in Table 2, while advantages and disadvantages of the procedure are presented in Table 3.

Rehabilitation

Rehabilitation can be modified according to the associated procedures; in case of isolated MCL reconstruction, a hinged brace is worn for 6 weeks. For the first 2 weeks, patients are advised to use crutches, with toe-touch weightbearing and then weightbearing as tolerated for the next 4 weeks. Passive and active mobilization throughout full range of motion is encouraged early to prevent stiffness. Isometric quadriceps exercises begin immediately. Crutches are discontinued once the knee is unswollen, pain is fully resolved, and muscle tone improves. Low-impact water and muscle rehabilitation are emphasized during the successive 3 months. Afterward, gym exercises with weights are introduced. Running is permitted at 4 months, with a full return to sports after 9 months.

Discussion

We describe a technique for the reconstruction of both the sMCL and dMCL using the autologous ipsilateral ST. Conventional single-strand sMCL reconstructions fail to restore either translational or

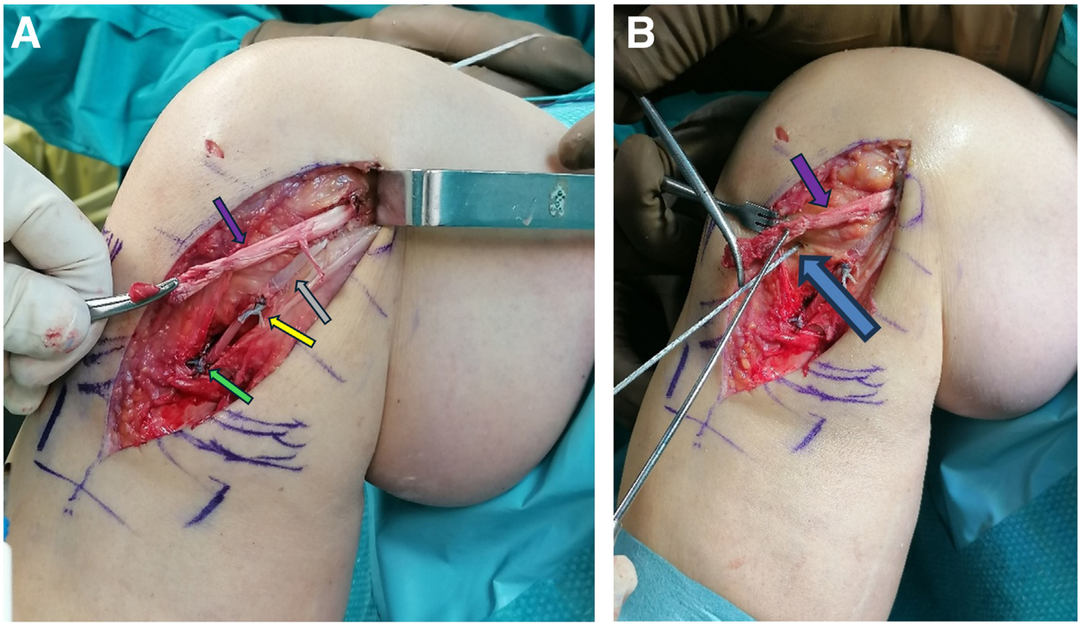

Fig 5. (A, B) After having fixed the loop of the semitendinosus graft into the femoral tunnel using the UltraButton (Smith & Nephew Endoscopy), the remaining free end of the graft (purple arrow) is directed anterodistally at a 25° angle from the previous bundle (gray arrow). At this point, about 10 mm distal to the joint line, a third anchor (blue arrow) is deployed, and the graft is fixed at the tibia, creating the anterior arm of the construct, which mimics the deep medial collateral ligament (right knee). (The green arrow indicates the distal anchor, and the yellow arrow indicates the proximal anchor.)

rotational knee kinematics.[21] Similarly, the "anatomic" techniques aiming to reproduce the sMCL and the POL may not provide enough ER stability[19] since the anteromedially oriented fibers of the dMCL are not restored. It has been shown that a 2-strand reconstruction (dMCL + sMCL) achieves better valgus and axial stability.[12] In the current technique, the sMCL was reconstructed using a shared femoral footprint with the dMCL. The sMCL has a broad insertion of about 7 mm centered on the medial epicondyle.[22] The native dMCL inserts approximately 6 mm distal and posterior to the medial epicondyle.[22] This close anatomic proximity suggests that creating separate graft tunnels for the sMCL and dMCL may be unnecessary, and drilling the tunnel on the medial epicondyle will provide an isometric construct. Our findings support this approach, as it avoids the risk of tunnel convergence and reduces the need for additional fixation devices, eliminating the need for further grafts and thereby streamlining the procedure. The sMCL was reconstructed using a proximal and a distal anchor plus the tibial attachment to the pes anserinus, as previously described by Lind.[23] This has a few advantages: first, preserving the tibial insertion provides better biological support and stronger mechanical support.[24] Second, using a dual-fixation construct with anchors allows for incorporating both the long isolated sMCL and the short sMCL construct,[12] reproducing the biomechanical advantages of the short isometric construct as described by Borque et al.[25] In addition, the distal anchor allows for anatomic placement of the graft (the anatomic footprint of the sMCL is reproduced by redirecting posteriorly the ST[20]), enhancing the stability and providing a more anatomically accurate reconstruction.

Lind and Kittl[26] have recently described a modification of the original Lind technique[23] for MCL reconstruction. The authors used, as well, a semitendinosus-based 2-arm construct to reproduce the native dMCL and the sMCL. However, their technique starts from the anterior arm (dMCL) reconstruction and creates the femoral tunnel before fixing the sMCL on the tibia. Our technique instead prioritizes identifying the isometric point for the sMCL. However, it is unknown if this translates into a clinical difference. In addition, potential advantages include the potential to avoid tibial tunnels (which can be advantageous, especially if a combined ACL or posterior cruciate ligament is performed) and the adjustable button, which allows for fine-tuning of the tension. Lastly, the femoral tunnel is performed after the sMCL graft has been fixed to the tibia, allowing for an accurate check of graft isometry before definitive fixation. A potential critique could stem from the use of suture anchors instead of bone tunnels. Although the use of suture anchors has not been shown to impair the graft's integration potential,[27]

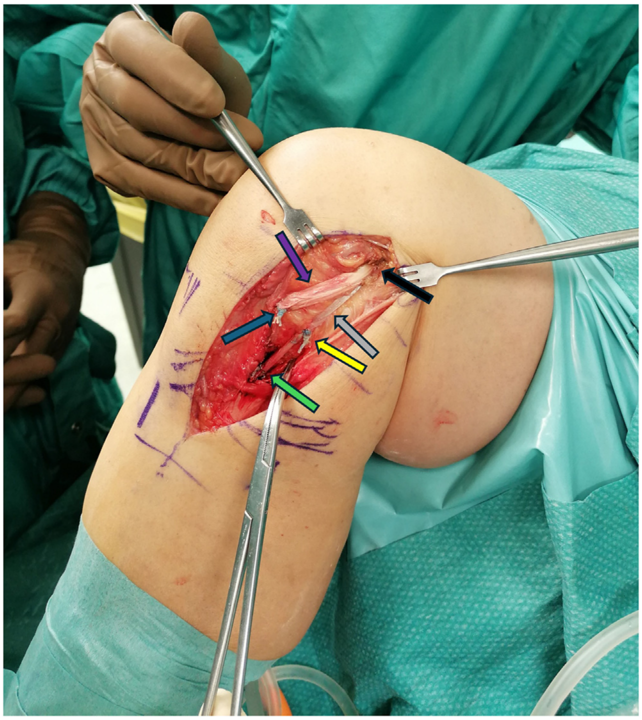

Fig 6. The final construct is shown (right knee). The 2 arms are identifiable, the anterior one (purple arrow) mimicking the deep medial collateral ligament and the posterior one (gray arrow) mimicking the superficial medial collateral ligament. Proximally, the continuous loop of the graft, from which the 2 arms originate, is fixed into a femoral tunnel at the isometric point of the medial epicondyle (black arrow). The posterior arm is then fixed on the tibia with a distal anchor (green arrow) to redirect the graft posteriorly from its native insertion and with a proximal anchor (yellow arrow) to reproduce the short isometric construct, as described by Borque et al.[25] The anterior arm is fixed anterodistally at the proximal tibia with a third anchor (blue arrow).

our technique could be performed in a slightly different way. In fact, during the development of the technique, the first author (S.V.) performed a few cases in which the dMCL was fixed using a tibial tunnel in the very proximal metaphysis. However, this was really challenging when performing a simultaneous ACL reconstruction due to the risk of tunnel convergence. Therefore, the author opted for a third anchor for dMCL fixation.

Disclosures

All authors (S.V., P.Z., R.P.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 2. Pearls and Pitfalls of the Surgical Technique

Steps	Pitfalls	Pearls
Graft harvest	To avoid damaging the tibial insertion of the gracilis tendon or inadvertently cutting the semitendinosus tendon prematurely during the procedure	When harvesting the semitendinosus tendon, it is essential to use a right-angled clamp or tendon hook to carefully extract the tendon from the wound. Under direct visualization, all fascial expansions should be meticulously released before employing the tendon stripper. This step is critical to ensure sufficient tendon length for graft preparation, as inadequate harvesting may compromise the graft diameter, rendering it unsuitable.
Graft tension	Avoid overconstraint	Follow the surgical technique step by step by fixing the sMCL and the dMCL at 20° to 30° of knee flexion with the tibia in neutral rotation; a slight stress in varus is accepted.
Graft preparation	To reduce the risk of infection	Following its preparation, the graft is immersed in a vancomycin solution (1 mg/mL) for approximately 5 minutes.
Isometric point	Failure to find the correct footprints causes the graft to work nonisometrically, altering its tension and thus the kinematics of the medial compartment.	When a portion of the semitendinosus tendon is anchored on the tibia with an anchor, a K-wire can be inserted at the suspected isometric point. The free end of the graft is then looped around the K-wire and marked, the knee is taken through its full ROM, and any displacement of the marks relative to the K-wire indicates a nonisometric point. Alternatively, the free end of the graft is clamped with a Kelly clamp and positioned at the presumed isometric point. The ROM is then tested, and any loss of tension in the graft suggests a nonisometric point; this approach allows for quick adjustments without drilling into the bone, making it less invasive and time-consuming.
dMCL tibial fixation	Misplacing the ligament insertion	The tibial insertion of the dMCL has a broad surface area, which makes it difficult to detect. The anterior fibers play a crucial role in resisting external rotation in cases of anteromedial instability. As a result, it is essential to position the suture anchors in front of the sMCL near the joint line.
Femoral shared fixation	Ensuring stability	A femoral screw can be added to the femoral insertion to ensure a double fixation.

dMCL, deep medial collateral ligament; ROM, range of motion; sMCL, superficial medial collateral ligament.

Table 3. Advantages and Disadvantages of the Procedure

Technical Aspect	Advantages	Disadvantages
Open medial access with wide incision	Excellent visualization of anatomic footprints	Surgical invasiveness, poor cosmetics, risk of saphenous nerve injury
Use of anchors	Easy and fast technical execution, no risk of tunnel convergence	Higher costs
Use of hamstrings as a graft	Easy biological integration, no extra costs, easy availability, low complication rate	Risk of inadequate length, risk of destabilizing the medial compartment between 0° and 30°
Double tibial fixation for sMCL	Exploits the biomechanical advantages of double fixation and thus of both long and short sMCL reconstruction	Higher costs because of an extra anchor
Shared femoral fixation with UltraButton	There is no requirement for 2 tunnels, eliminating the risk of tunnel convergence. Additionally, only a single fixation system and 1 graft are necessary. The technique also allows for the possibility of retensioning the graft, using a pulley mechanism in the event of graft detensioning.	Higher costs compared to interference screws

sMCL, superficial medial collateral ligament.

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