Technical Note

The "Figure of Four" Reconstruction of the Medial Collateral Ligaments in the Setting of Anteromedial Rotatory Knee Instability Using a Single Autograft

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Abstract: The deep medial collateral ligament plays an important role in controlling tibial external rotation and restrain anterior translation of the medial tibial plateau. Despite being the basic lesion of anteromedial knee instability as proposed by many authors, the majority of the medial side reconstructions do not restore the anatomy and the function of the deep medial collateral ligament. In this Technical Note, we describe a technique to reconstruct both the superficial and deep medial collateral ligament in the setting of anteromedial knee instability using a single peroneus longus autograft.

Anteromedial rotatory instability (AMRI) of the knee is caused mainly by an injury to both the anterior cruciate ligament (ACL) and the medial collateral ligaments (MCLs) with both superficial medial collateral ligament (sMCL) and deep medial collateral ligament (dMCL) components usually involved,[1] resulting in a coupled anterior tibial translation and external rotation (ER) causing the medial tibial plateau to subluxate anteriorly.[2] Failure to identify AMRI during ACL reconstruction may lead to residual knee laxity with subsequent greater ACL graft in situ forces and eventually failure.[3,4]

Both the sMCL and dMCL act reciprocally to restrain ER through different flexion angles. The dMCL is taught near extension, whereas the sMCL becomes more involved in deeper flexion angles.[5,6] The importance of the dMCL in controlling tibial ER and its role in AMRI was first described by Slocum and Larson,[7] who found that dMCL injury caused excessive tibial ER and was the basic lesion resulting in AMRI. This findings were later confirmed by several biomechanical studies.[5,6,8]

The dMCL fans out anterodistally from a point distal and posterior to the medial epicondyle (ME) and attaches to the medial tibial plateau with a broad footprint (Fig 1). This orientation makes it ideal to resist anterior translation of the medial tibial plateau.[9]

Despite the importance of the dMCL, the majority of the medial side reconstructions do not restore the function of the dMCL and describe only either isolated sMCL or combined sMCL and posterior oblique ligament reconstructions.[10-13] We describe our "figure of 4" technique of sMCL and dMCL reconstruction using a single peroneus longus autograft (Fig 2). A full procedural demonstration may be found in Video 1.

Surgical Technique (With Video Illustration)

Patient Positioning and Examination Under Anesthesia

The patient is positioned supine with a lateral thigh post and a footrest after induction of general anesthesia. Examination under anesthesia and fluoroscopic stress radiographs are performed to confirm preoperative diagnosis. The leg is then prepared and draped in standard fashion.

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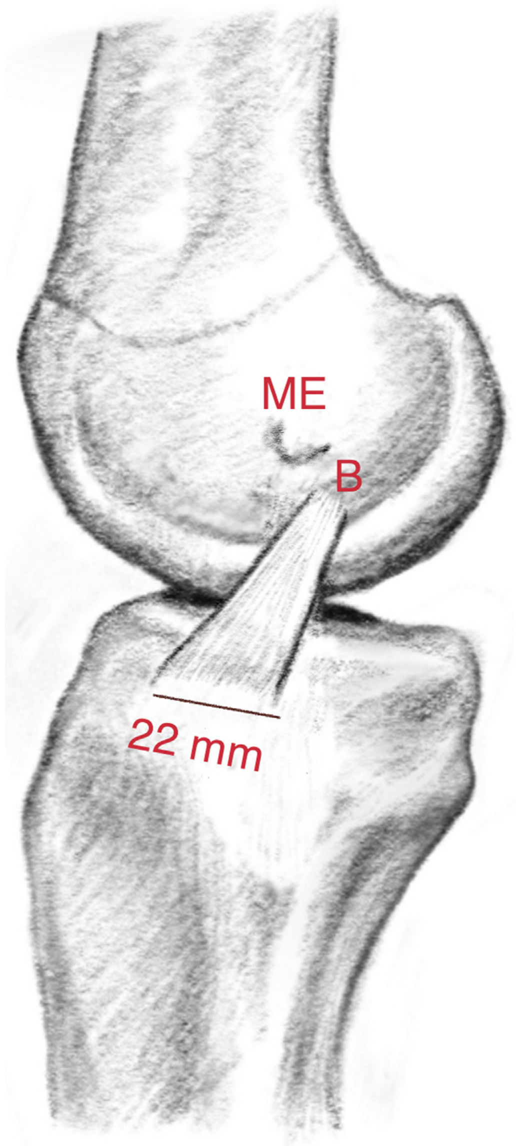

Fig 1. Artist's impression of the deep medial collateral ligament (dMCL) anatomical orientation. The dMCL fans out anterodistally as it originates from a point (B) slightly distal and posterior to the medial epicondyle (ME) and broadly attaches to the tibia nearly 1 cm distal to the joint line.[9]

Diagnostic Arthroscopy and Concomitant Pathology

ACL reconstruction is routinely preformed first using an ipsilateral autologous quadriceps tendon graft. Meniscal and chondral lesions are addressed at this point before extraarticular reconstruction.

Graft Harvest and Preparation

The ipsilateral peroneus longus (PL) tendon is harvested, prepared, and both ends are whipstitched by no. 2 nonabsorbable suture.

Technique

An anteromedial skin incision is made starting proximally midway between the adductor tubercle and the medial border of the patella extending distally across the joint line midway between the anterior and posterior tibial borders to the level of the pes anserinus 6 to 7 cm distal to the joint line. Full-thickness skin flaps are developed, with special attention not to injure the saphenous nerve.

On the femoral side, we start by identifying the adductor magnus tendon. The tendon is followed toward its insertion point at the adductor tubercle, which serves as an important landmark to locate the ME, which is located approximately 12.6 mm distal and 8.3 mm anterior to the adductor tubercle.[14] The native sMCL envelopes and attach directly to the ME, whereas the dMCL femoral footprint is located 6 mm distal and 5 mm posterior to the ME.[9] The femoral insertion is exposed by making a longitudinal incision over the ME down to the crural fascia. For creation of the dMCL femoral socket, an eyelet pin is placed slightly distal and posterior to the ME at the femoral attachment site of the dMCL from medial to lateral aiming slightly anterior and proximal (Fig 3), then a 7 × 25-mm socket is reamed over the guide pin and a passing suture is placed.

Attention now is directed distally to create the tibial attachment sites for both the sMCL and dMCL. To create the dMCL tibial attachment site, 2 slightly convergent tunnels are created 20 mm apart to a depth of 15 mm at the mid-third of the anteroposterior diameter of the medial tibial plateau 1 cm distal to the joint line using a 5-mm drill. Care must be taken not to break the medial tibial cortex to avoid tunnel blow out. A shuttling suture with a large curved needle is used to pass a suture loop through the tibial transosseous tunnel saved for later graft passage (Fig 4).

The tubular part of the graft (distal end of the PL tendon graft) is docked first into the dMCL femoral socket and secured with a 7 × 25-mm bioabsorbable interference screw (Inion, Tampere, Finland) (Fig 5). The graft is then shuttled through the convergent tibial tunnels from posterior to anterior using the passing sutures previously left in place creating the dMCL tibial footprint (Fig 6). The free end of the graft (sheet-like

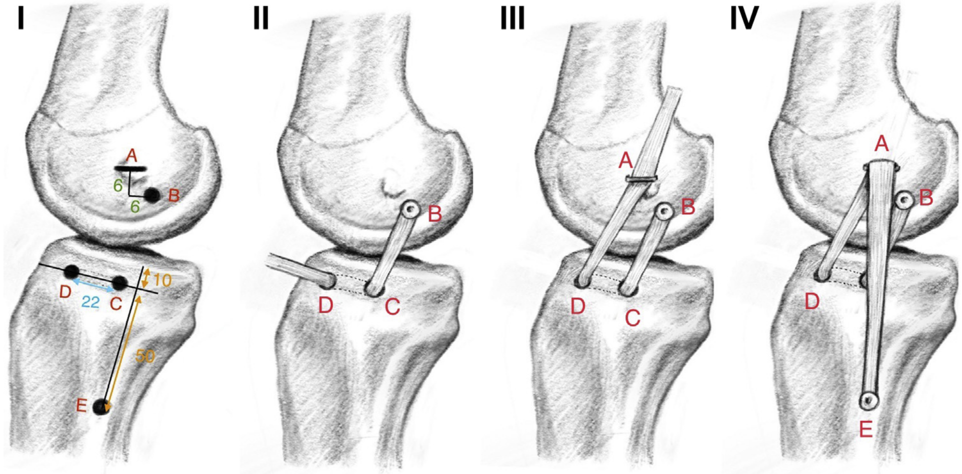

Fig 2. The figure of 4 reconstruction of the superficial (sMCL) and deep (dMCL) medial collateral ligaments. (I) Anatomical landmarks. (A) medial epicondyle (ME), which is the femoral insertion point for the sMCL. (B) dMCL femoral insertion point nearly 6 mm distal and 6 mm posterior to the ME. (C) and (D) 2 convergent tunnels drilled 22 mm apart and 10 mm distal to the joint line to create a transosseous tunnel for the dMCL tibial fixation. (E) sMCL tibial insertion point 60 mm distal to the joint line at the posterior border of the native ligament. (II) The graft is docked first and fixed in a 7 × 25-mm tunnel created at point B and then shuttled through the transosseous tibial tunnel from posterior (C) to anterior (D) to create the dMCL tibial footprint. (III) The graft is brought back proximally and fixed at the ME with a titanium staple (Arthrex, Naples, FL) at 20° of flexion, neutral rotation and slight varus force is applies. (IV) The graft is folded, pulled back distally and shuttled through a 7 × 25-mm tunnel created at point E to complete the sMCL reconstruction, the graft is then fixed by an interference screw (Inion, Tampere, Finland) at 20° of flexion, neutral rotation and slight varus force being applied.

proximal end of the PL graft) is then brought back proximally and fixed to the ME by a thorny titanium staple (Arthrex, Naples, FL) with the knee at 20° of flexion, neutral rotation, and slight varus force being applied (Fig 7).

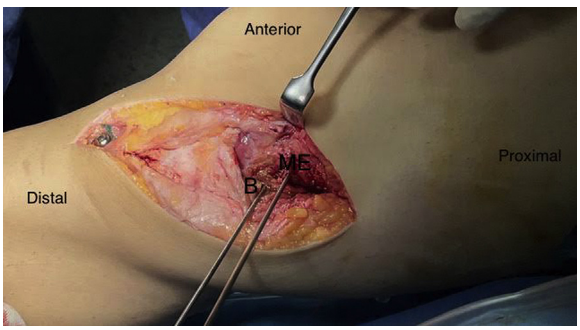

Fig 3. Right knee, the patient is lying supine with the leg extended (the patient's head is to the right side of the picture). A guide pin is inserted in the center of the medial epicondyle (ME) for orientation, and a second guide pin is inserted slightly distal and posterior at the deep medial collateral ligament femoral insertion point (B) then reamed to create a 7 × 25-mm socket.

For sMCL tibial tunnel creation, the superior border of the pes anserinus is retracted distally, an eyelet pin is placed 6 cm distal to the joint line at the posterior border of the native sMCL and reamed creating a 7-mm tunnel (Fig 8). The graft is folded, brought back distally, and pulled into the tibial tunnel. The graft is the tensioned, cycled multiple times, and fixed using a bioabsorbable interference screw (Inion) with the knee held in 20° of flexion, neutral rotation and a varus force being applied (Fig 9). To create the proximal tibial attachment of the sMCL, the sMCL portion of the graft is sutured to dMCL portion 1 cm below the joint line at the level of the dMCL tibial tunnels. Pearls and pitfalls of this technique are summarized in Table 1.

Postoperative Protocol

The specific rehabilitation protocol is tailored according to the concomitant procedures performed along with the MCL reconstruction. The knee is kept in

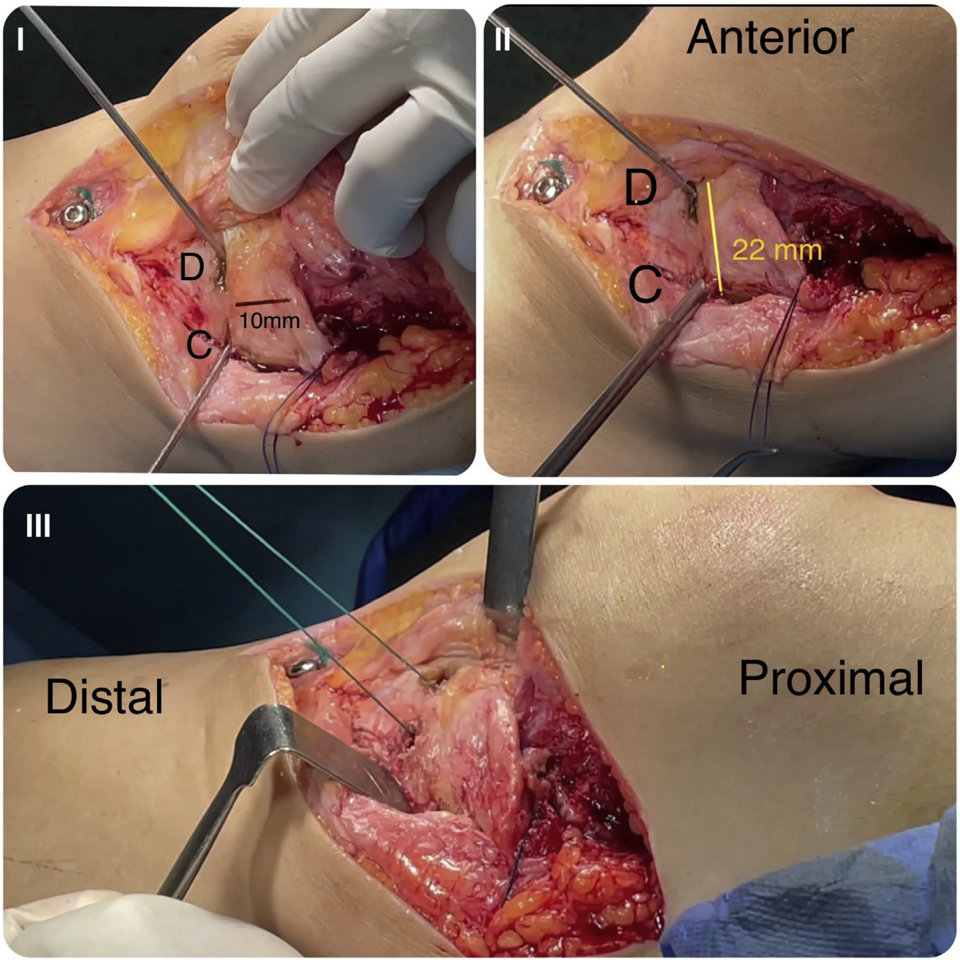

Fig 4. Right knee, the patient is lying supine with the leg extended (the patient's head is to the right side of the picture). Drilling of tibial transosseous tunnel for deep medial collateral ligament tibial footprint creation; 2 guide pins are drilled slightly convergent to a depth of 15 mm at points (C) and (D) at the middle third of the anteroposterior diameter of the medial tibial plateau, nearly 1 cm distal to the joint line and 22 mm apart. The guide pins are reamed to the desired diameter and a shuttling suture is passed for later graft passage.

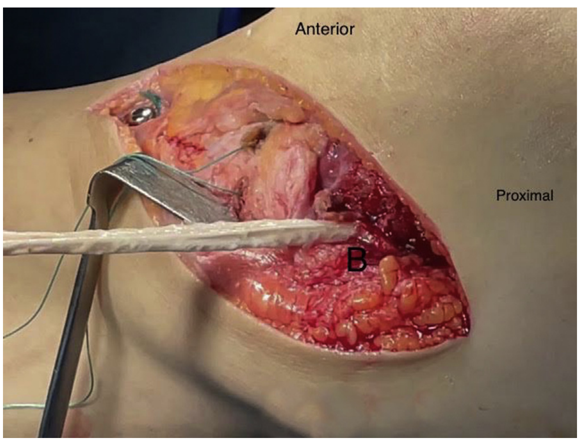

Fig 5. Right knee, the patient is lying supine with the leg extended (the patient's head is to the right side of the picture). The tubular part of the graft is docked first and fixed at the deep medial collateral ligament femoral socket (B) using a 7 × 25-mm interference screw (Inion, Tampere, Finland).

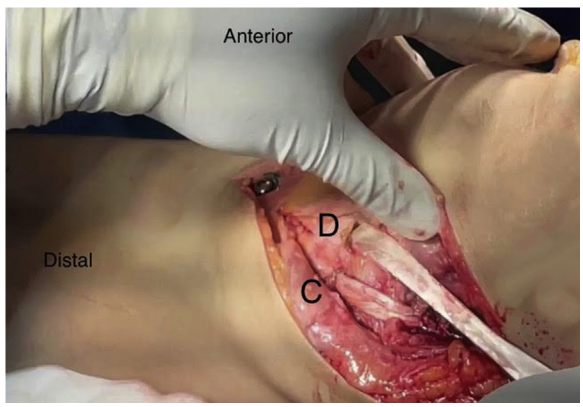

Fig 6. Right knee, the patient is lying supine with the leg extended (the patient's head is to the right side of the picture). The free end of the graft (the proximal sheet-like end of the peroneus longus graft) is shuttled through the tibial transosseous tunnel from posterior (C) to anterior (D) creating the deep medial collateral ligament tibial footprint.

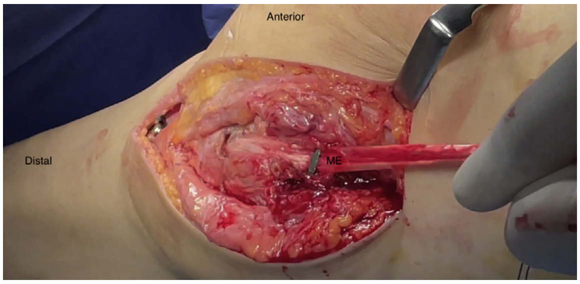

Fig 7. Right knee, the patient is lying supine with the leg extended (the patient's head is to the right side of the picture). The graft is brought back proximally and fixed to the medial epicondyle (ME) using a titanium staple (Arthrex, Naples, FL) at 20° of flexion, neutral rotation and slight varus force being applied.

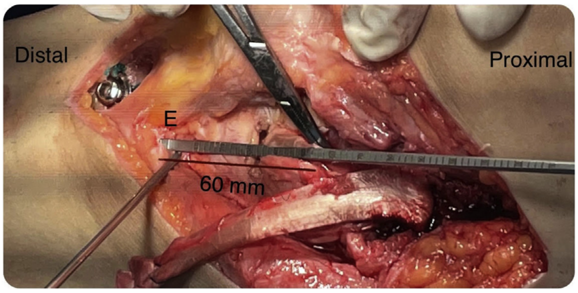

Fig 8. Right knee, the patient is lying supine with the leg extended (the patient's head is to the right side of the picture). Creation of the superficial medial collateral ligament tibial tunnel; the forceps points to the level of the joint line, a guide pin is inserted at a point 6 cm distal to the joint line at the posterior border of the native ligament (E) and reamed to the desired diameter.

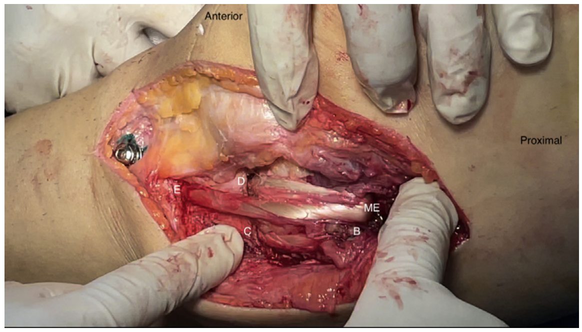

Fig 9. Right knee, the patient is lying supine with the leg extended (the patient's head is to the right side of the picture). The final shape of our reconstruction that resembles the Latin number 4 after shuttling the free end of the graft into the tibial tunnel of the superficial medial collateral ligament and fixing the graft. (B) dMCL femoral socket. (C) and (D) inlet and exit for the dMCL tibial transosseous tunnel. (E) sMCL tibial tunnel. (dMCL, deep medial collateral ligament; ME, medial epicondyle; sMCL, superficial medial collateral ligament.)

extension for the first 2 weeks followed by gradual increase of the flexion range. The patient is allowed to partially bear weight while the knee is locked in extension for 6 weeks followed by progression to full weight bearing. Return to most activities by 4 to 6 months.

Discussion

Combined ACL and MCL injuries are one of the most common knee injuries.[15] Slocum and Larson[7] first described the term AMRI as an excessive valgus motion coupled with ER of the knee in which the anteromedial tibial plateau subluxate anterior to the corresponding femoral condyle.[7] Failure to identify this instability pattern during ACL reconstruction increases the risk of ACL graft failures and revisions.[3,4]

Recent biomechanical studies[1,5,6] highlighted the importance of the dMCL in controlling the tibial external rotation and that it was the major restraint against ER in extension and early flexion angle, while the sMCL was dominant in deeper flexion angles besides being the major restraint against valgus forces across the whole range of motion, thus minimizing the role of the posterior oblique ligament in controlling ER. A recent anatomical study[9] described the dMCL as an oblique fan-shaped structure running anterodistally from a small femoral attachment distal and posterior to the ME to a broad tibial attachment. This orientation causes the dMCL to tighten with ER, thus resisting AMRI.

The advantage of this technique (Table 2) is that it reproduces the orientation and the broad attachment of the dMCL on the tibia, thus providing better control for ER. An additional benefit of this technique is the use of a single autograft to reconstruct both components of the MCL, which may be useful in the setting of multiligament knee injuries. The use of the peroneus longus

Table 1. Pearls and Pitfalls

	Pearls	Pitfalls
Preoperative planning	Use stress radiographs to confirm the direction of the coronal plane instability When preforming a dial test, it is important to differentiate between AMRI and PLRI injuries	A positive dial test could be falsely interpreted as posterolateral corner injury; anterior subluxation of the medial tibial plateau is the key for AMRI diagnosis
Concomitant ACL reconstruction	Ipsilateral quadriceps or BTB autografts are better used ACL graft should be tensioned and fixed first before MCL reconstruction	It's better to avoid using ipsilateral hamstring tendon, as they may provide dynamic stability against valgus forces
Skin incisions	An anteromedial incision with full-thickness flaps is useful in case of combined ACL and MCL reconstruction	Avoid posterior skin incisions, as it may cause iatrogenic saphenous nerve injury
Femoral fixation	Locating the adductor tubercle facilitates femoral insertion points identification Using a surface fixation method to fix the graft to the ME will save some graft length	Avoid tunnel coalition in multiligament reconstructions by aiming the guide pins slightly anterior and proximally
Tibial tunnel creation	Use a 5-mm drill to create 2 slightly convergent 15-mm deep sockets. Maintain at least 20 mm between the 2 tunnels. a guide pin and 5-mm cannulated drill can be used to facilitate tibial socket orientation Use a braided suture with a large curved needle to pass the suture loop through the tibial transosseous tunnel	If the 2 tunnels are too close, the bony bridge between them can collapse, sMCL tibial tunnel should be tapped to avoid breakage of the interference screw as it advances in hard cortical bone
Graft tensioning	Both graft components should be fixed in 20° of flexion with neutral rotation and slight varus force applied	Fixation of the dMCL component in internal rotation could capture the knee.
Peroneus longus graft harvesting	The graft should be at least 25 mm long	With inappropriate harvest technique or in short individuals, graft length could be insufficient and 2 separate grafts should be used
Concomitant POL injury	In the case of grade III injuries with a positive stress valgus test in extension, repair or reefing of posterior oblique ligament—posteromedial capsule complex is done, and the sutures are tied in full extension	Stress valgus test should be done in full extension after ACL reconstruction to exclude POL injury. Failure to address posteromedial instability may lead to failure of the other reconstructions

ACL, anterior cruciate ligament; AMRI, anteromedial rotatory knee instability, BTB, bone—tendon—bone; dMCL, deep medial collateral ligament; MCL, medial collateral ligament; ME, medial epicondyle; PLRI, posterolateral rotatory knee instability; POL, posterior oblique ligament; sMCL, superficial medial collateral ligament.

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
Creating both superficial and deep components of the medial collateral ligament Creating the broad tibial footprint of the deep medial collateral ligament helps in better rotational control Use of a single autograft is helpful especially in multiligament injuries	Requires at least 25 mm graft length, which is not reproducible in all cases

autograft in knee ligament reconstruction has recently been popularized with great outcomes and negligible drawbacks.[16] In our opinion, the use of the peroneus longus carry some advantages; it provides a long graft with sufficient length to perform this technique in addition that the graft is broader than the hamstrings with a sheet-like proximal end, which better mimics the native sMCL. The main disadvantage of this technique is the need for a long graft (25 cm or more), which is not reproducible in all cases. We recommend the use of 2 separate grafts in short individuals or insufficient graft length.

In summary, our technique to reconstruct both the sMCL and dMCL using a single autograft can closely reproduce the native anatomy of the MCL and could restore normal rotational laxity in the setting of AMRI.

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