Technical Note

# Medial Collateral Ligament Reconstruction: A Gracilis Tenodesis for Anteromedial Knee Instability

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**Abstract:** The main principle of the present medial collateral ligament reconstruction technique is to address anteromedial knee instability. Therefore, we describe a gracilis tenodesis with 2 functional bundles to reconstruct the deep and superficial medial collateral ligament. The proposed technique may be performed as an isolated or combined procedure with anterior cruciate ligament reconstruction. Valgus instability in extension is a contraindication.

The medial collateral ligament (MCL) is one of the most commonly injured structures of the knee.[1,2] The majority of MCL injuries are treated conservatively. However, MCL reconstruction may be indicated in symptomatic chronic instability, acute injuries with severe laceration, and multiligament injuries. Recent studies showed that persistent MCL instability results in increased load in the cruciate ligaments, which may cause early graft failure following cruciate ligament reconstruction.[3-10]

The superficial medial collateral ligament (sMCL) is the major restraint to valgus rotation and external tibial rotation in knee flexion (Fig 1A). Lately, the deep medial collateral ligament (dMCL) has attracted attention as the largest medial restraint to external tibial rotation in extension.[11-17] The anatomy of the dMCL is shown in Fig 1B. Current surgical procedures do not adequately address the dMCL and therefore may need to be adapted according to the latest biomechanical findings (Table 1).[18-23]

In 1952 Bosworth[24] described the semitendinosus tendon transfer to reconstruct the medial side of the knee. Lind et al.[19] later published a modified procedure to imitate better the course of the posterior oblique ligament (POL). Although the POL is an important restraint to internal tibial rotation and valgus rotation in extension, recent biomechanical studies have questioned its role in anteromedial instability.[11-13,15,16] Hence, in anteromedial instability grade 2 or 3 (Table 1) without valgus laxity in extension, POL reconstruction may not be indicated from a biomechanical point of view.

Therefore, we propose the gracilis tenodesis to reconstruct the dMCL and sMCL (Fig 1 A-C) in cases presenting with anteromedial instability. For this, the tibial insertion site of the gracilis tendon is preserved, and the free tendon end is rerouted via the femoral sMCL insertion site to the tibial sMCL insertion site, thus presenting 2 functional bundles restraining anteromedial rotatory instability (anterior arm) and valgus opening (posterior arm).

## Surgical Technique (With Video Illustration)

### Indication

The present technique is performed in symptomatic chronic anteromedial instability grade 2 and 3 (Table 1) or in acute injuries with a severe laceration of the

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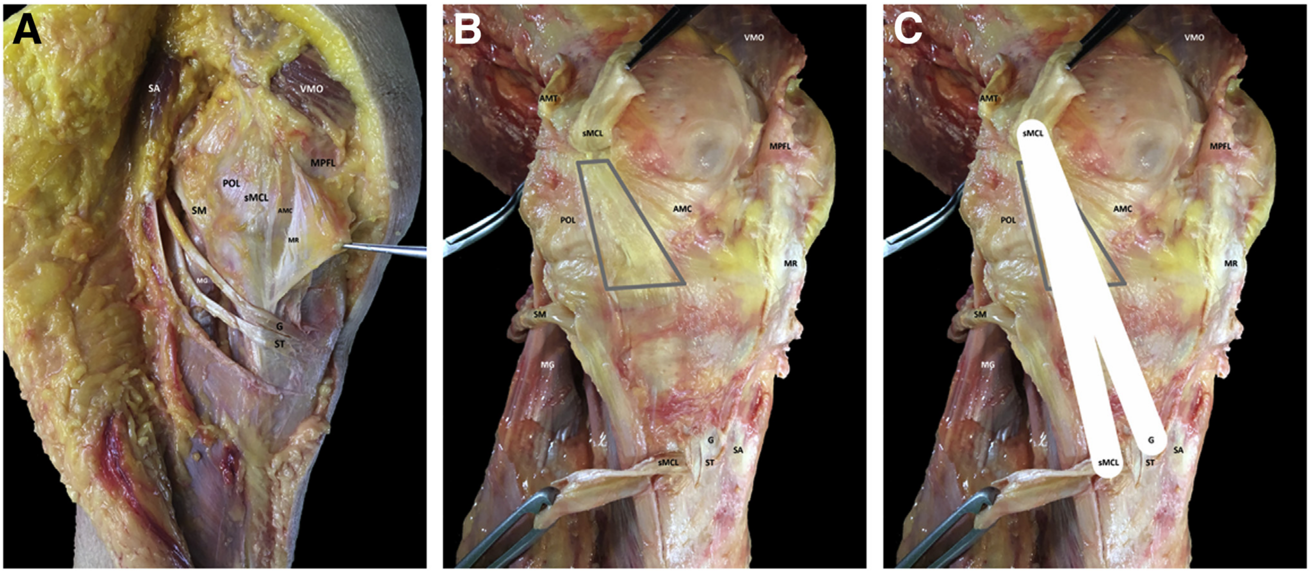


**Fig 1.** (A) The medial aspect of a left cadaveric knee is shown. The subcutaneous layer is reflected posteriorly. The sartorius muscle (SA), vastus medialis obliquus (VMO), and medial head of the gastrocnemius muscle (MG) are marked. The fascia (layer 1)[17] has been incised along the anterior border of the SA to the inferior tip of the tibial tuberosity to demonstrate the gracilis tendon (G), semitendinosus tendon (ST), semimembranosus tendon, and layer 2. Layer 2 includes the posterior oblique ligament (POL) as a part of the posteromedial capsule, the superficial medial collateral ligament (sMCL), and medial patellofemoral ligament (MPFL). Deep layer 3, including the anteromedial capsule (AMC) and deep MCL (Fig 1B), is seen anterior to the sMCL due to a split of layer 2. Further anterior layer 1 (held in forceps) blends with layer 2, forming the medial retinacula (MR) fibers. (B) The medial capsular layer (layer 3)[17] of a left cadaveric knee is shown. The superficial medial collateral ligament (sMCL) has been dissected intraligamentary and reflected (held in clamps) while its femoral and tibial insertion sites have been preserved. The posterior oblique ligament (POL), the deep MCL (gray box), and the anteromedial capsule (AMC) are seen. The bony tibial insertion sites of the gracilis tendon (G), semitendinosus tendon (ST), and sartorius muscle (SA) are indicated. The vastus medialis obliquus (VMO), medial patellofemoral ligament (MPFL), and medial retinacula (MR) have been released posteriorly and are reflected anteriorly. The adductor magnus tendon (AMT) is also shown. (C) The medial capsular layer of a left cadaveric knee is shown. The modified Lind procedure (white) is demonstrated. The gracilis tendon (G) is left attached to the tibia and fixed proximally at the center of the femoral superficial medial collateral ligament (sMCL) insertion. The free end of the G is then directed distally and fixed in the center of the tibial sMCL insertion. The deep MCL (gray box) and sMCL insertions are widely covered by the gracilis tenodesis (white).

dMCL and sMCL. Valgus instability in knee extension is a contraindication for the present technique.

## Positioning

The patient is placed supine on the operating table. A thigh tourniquet and lateral support are applied, as shown in Fig 2. The contralateral leg is put to lithotomy position. This allows unlimited access to the medial side of the operative knee. Clinical examination under anesthesia is performed before the leg is prepped and draped in a sterile fashion.

## Preoperative Examination

Clinical examination under anesthesia includes range of motion and stress tests. The valgus stress test is evaluated in full extension and 20° to 30° of knee flexion (Video 1). The Slocum test, i.e., anteromedial drawer, and external dial test are performed in 30° and 90° of knee flexion (Table 2; Video 1). Standard anterior/posterior drawer and Lachman tests are completed to detect complex knee instabilities, which are further differentiated by diagnostic arthroscopy.

**Table 1.** Classification of Anteromedial Instability[13]

| Grade | Anteromedial Drawer (30-90°) | External Dial Test (30-90°) | Valgus Stress Test (30°) | Injury Pattern |
|---|---|---|---|---|
| I | + | + | − | dMCL |
| II | ++ | ++ | + | dMCL + sMCL |
| III | +++ | +++ | +++ | dMCL + sMCL + ACL |

NOTE. Kinematical grading (+ 1-5, ++ 5-10, +++ >10 mm/°).
ACL, anterior cruciate ligament; dMCL, deep medial collateral ligament; sMCL, superficial medial collateral ligament.


**Fig 2.** Patient positioning, including lateral support (1) at the patient's left leg, is shown. The contralateral right leg is put to lithotomy position (2).

## Arthroscopy

Before arthroscopy, relevant landmarks are identified and marked, as shown in Fig 3. A routine arthroscopic examination is performed using standard anterolateral and anteromedial portals. The medial compartment is evaluated to detect a drive-through sign. Medial gapping under valgus stress is measured using a probe (Fig 4A). Lift-off of the medial meniscus with meniscofemoral or meniscotibial gapping (Fig 4B) and meniscocapsular injuries (Fig 4C) can be observed. Signs of anterior subluxation of the medial tibial plateau include (1) the medial meniscus squeeze sign (Fig 4D), (2) an enlarged triangle of the anteromedial capsule, and (3) extensive presentation of the anterior

**Table 2.** Pearls and Pitfalls

| Steps | Pitfalls | Pearls |
|---|---|---|
| Clinical examination | To mistake an increased external dial test for anteromedial instability in case of posterolateral instability. | Observe and palpate the medial tibial plateau during the external dial test and anteromedial drawer. |
| Graft harvesting | To injure the tibial insertion of the gracilis tendon. | Use an open tendon stripper and preserve the tibial insertion of the gracilis tendon. |
| | The dimension of the gracilis tendon is insufficient. | Harvest the semitendinosus tendon instead. |
| Femoral fixation | Abnormal graft length change pattern through knee range of motion. | Perform an isometry test before femoral graft fixation. |
| | Femoral tunnel convergence in case of combined anterior cruciate ligament reconstruction. | Orientate the medial collateral ligament tunnel proximally and anteriorly. |
| Tibial fixation | Insufficient graft length. | Fixate the free end of the gracilis tendon proximal to the tibial insertion site of the superficial medial collateral ligament. |
| Minimally invasive approach | Entrapment of the saphenous nerve and its infrapatellar branches. | Respect the medial layers and shuttle the graft deep to the fascia. |

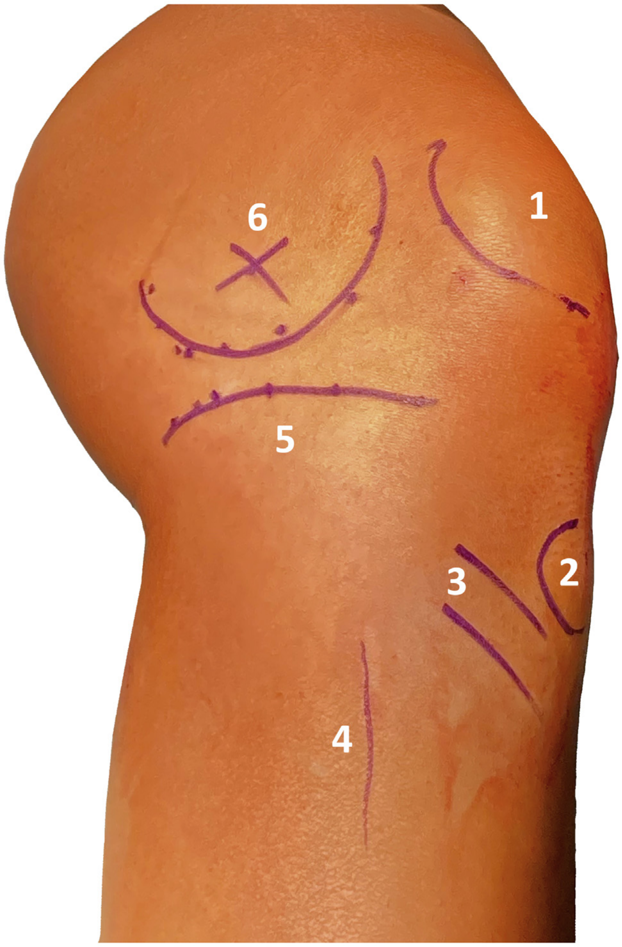


**Fig 3.** The skin markings on a left knee include the patella (1), tibial tuberosity (2), pes anserinus superficialis (3), posteromedial edge of the tibia (4), medial tibial plateau (5), and medial femoral epicondyle (6).

medial meniscus horn (Fig 4E). The medial joint line is identified using a cannula in an outside-in fashion under arthroscopic visualization (Fig 4F) before the open approach is performed.

## Minimally Invasive Approach

The minimally invasive approach to the MCL is guided by the preoperative skin markings (Fig 3) and the previously placed cannula (Fig 4F). A 2- to 3-cm longitudinal skin incision is made 2 cm medial to the tibial tuberosity. Special care should be taken to preserve the saphenous nerve and its infrapatellar branches during subcutaneous dissection (Fig 4G). Next, the sartorius fascia is incised obliquely, preserving the hamstring tendons. The gracilis tendon is identified and harvested proximally using an open tendon stripper. The tibial insertion site of the gracilis tendon is preserved at the superficial pes anserinus while the free tendon end is prepared on the graft workstation (Fig 5A).

## Femoral Fixation

An additional 2- to 3-cm longitudinal skin incision is made at the medial femoral epicondyle (Fig 5A). The fascia is incised longitudinally, and a beath pin is drilled in the center of the femoral insertion of the sMCL through the lateral cortex (Fig 5B). Pin position can be controlled using intraoperative fluoroscopic imaging, according to Athwal et al.[25] Next, the gracilis tendon is shuttled proximally deep to the fascia. The tendon is wrapped around the femoral beath pin, and any relevant length change pattern while taking the knee through the full range of motion is evaluated. Hence, a so-called “isometry testing” is performed. If it gets tight in flexion, an insertion point more posterior should be chosen.[26] The tendon is tensioned again in 20° of knee flexion, marked at the level of the femoral beath pin, and folded 15 to 20 mm proximally from there. The folded end is whipstitched using a nonabsorbable suture no. 2 (FiberWire; Arthrex, Naples, FL), and the graft diameter is checked, which is typically 5 to 7 mm. Then the femoral beath pin is overdrilled according to

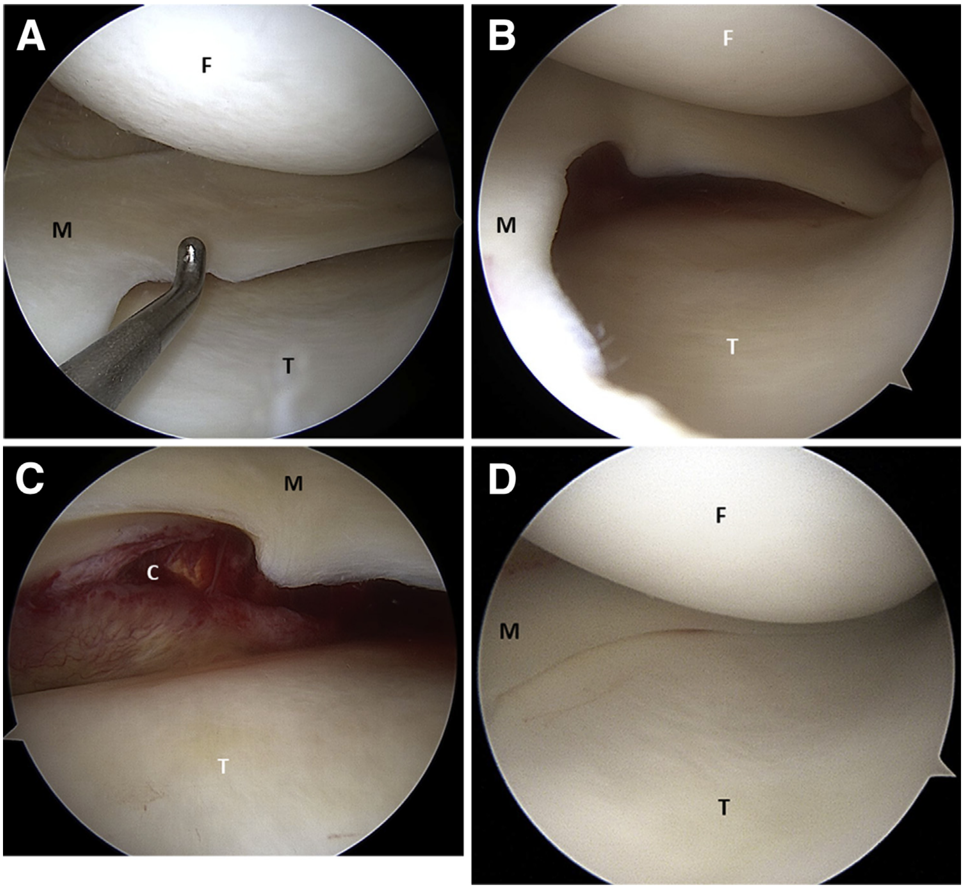


**Fig 4.** (A) An arthroscopic view of a left knee's medial compartment, including the medial femoral condyle (F), medial tibial plateau (T), and medial meniscus (M) is shown. Medial gapping under valgus stress is measured using a probe. (B) An arthroscopic view of a left knee's medial compartment, including the medial femoral condyle (F) and medial tibial plateau (T), is shown. The medial meniscus (M) shows a lift-off with meniscotibial gapping. (C) An arthroscopic view of a left knee's medial compartment, including the medial meniscus (M) and medial tibial plateau (T), is shown. Meniscotibial gapping and a meniscocapsular rupture (C) are observed. (D) An arthroscopic view of a left knee's medial compartment, including the medial femoral condyle (F) and medial tibial plateau (T), is shown. Due to anterior subluxation of T the posterior horn of the medial meniscus (M) gets squeezed between F and T, the so-called "meniscus squeeze" sign. (E) An arthroscopic view of a left knee's medial compartment, including the medial femoral condyle (F) and medial tibial plateau (T), is shown. Due to anterior subluxation of T an enlarged triangle of the anteromedial capsule (C) and extensive presentation of the anterior medial meniscus horn (M) is observed. (F) An arthroscopic view of a left knee's medial compartment, including the medial femoral condyle (F), medial tibial plateau (T), and medial meniscus (M), is shown. A cannula is placed outside-in to identify the meniscotibial gapping and guide the subsequent open approach to the medial collateral ligament. (G) An intraoperative view of an open medial approach to the left knee is shown. An infrapatellar branch of the nervus saphenous (N) superficial to the sartorius fascia (SA) is demonstrated. The cannula indicates the medial joint line (see Fig 4G).

the measured diameter of the double-looped tendon until it contacts the opposite cortex. The Beath pin is used to pull the sutures laterally and shuttle the folded end of the gracilis tendon into the femoral tunnel. The knee is cycled through full range of motion while the tendon is pulled into the femoral socket. Femoral fixation is performed with an absorbable interference screw matching the tunnel diameter. The screw is inserted over a nitinol wire in 20° of knee flexion and neutral rotation.

## Tibial Fixation

The free end of the gracilis tendon is whipstitched with a nonabsorbable suture no. 2 (FiberWire; Arthrex) and retrieved distally deep to the fascia (Fig 5C). Tibial fixation is performed with a 4.5-mm SwiveLock anchor (Arthrex) in the center of the distal tibial insertion of the sMCL (Fig 5D). Fixation is performed in 20° of knee flexion and neutral rotation.

Alternatively, the gracilis tendon can be incised and flattened to mimic the flat MCL anatomy (Fig 1 A and

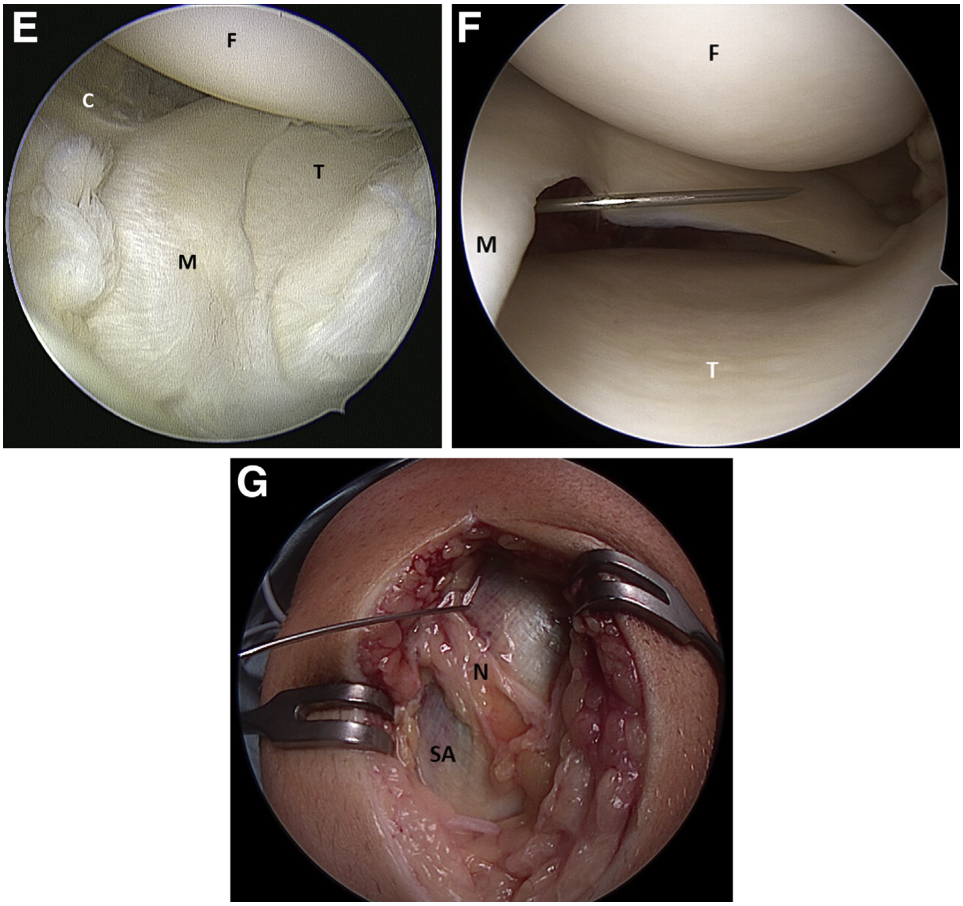


**Fig 4.** Continued

B).[27] In this case, the distal ends of the graft are fixed with 2 separate anchors.[28]

## Open Approach

The open approach is an alternative, especially in acute cases. A longitudinal skin incision is made from the medial epicondyle to the superficial pes anserinus. Next, the sartorius fascia is incised (Fig 6A), preserving the hamstring tendons. Ligament remnants of the medial ligament complex are identified and prepared using whipstitches for refixation. The gracilis tendon (Fig 6B) is harvested proximally with an open tendon stripper and prepared as described above. The tendon is wrapped around the femoral beath pin while taking the knee through the full range of motion for isometry testing (Fig 6C). As described for the minimally invasive approach, femoral and tibial fixation is performed (Fig 6 D and E). In the present case, a chronic distal avulsion injury of the sMCL is shown, which is refixed at the distal tibial insertion in combination with the gracilis tenodesis.

## Postoperative Rehabilitation

Postoperative care is depended on additional injuries, leg axis, and patient compliance. In simple cases, a hinged knee brace limiting the range of motion is applied for 6 weeks. Passive and active mobilization with the aid of a physical therapist is allowed through the full range of motion according to patient comfort, knee swelling, and pain.

Mobilization starts with partial weight-bearing of 15 to 20 kg for 2 weeks and is continued with full weight-bearing after that as tolerated. Physical therapy is recommended 2 to 3 times per week until a free range of motion and adequate muscular rehabilitation is achieved.

# Discussion

In a recent expert consensus statement,[18] there was a 100 % agreement that medial reconstructions should address the anatomic deficiency based on clinical examination and imaging findings. The experts also

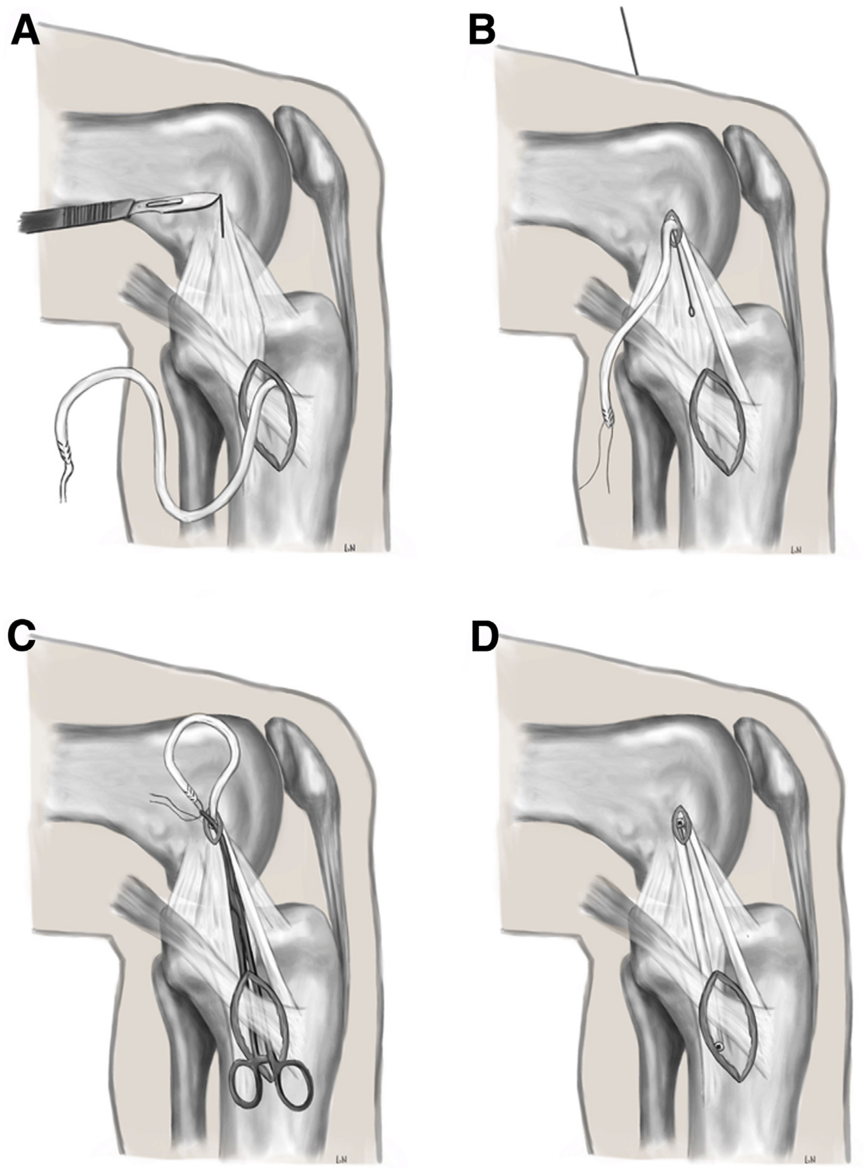


**Fig 5.** (A) An illustration of the medial aspect of a left knee is shown. The gracilis tendon has been harvested proximally via an approach at the superficial pes anserinus. The free tendon end has been whipstitched using a nonabsorbable suture while the tibial insertion site is preserved. An additional longitudinal skin incision at the medial femoral epicondyle is indicated. (B) An illustration of the medial aspect of a left knee is shown. The gracilis tendon has been harvested proximally while the tibial insertion site is preserved. The free tendon end has been whipstitched and shuttled proximally deep to the fascial layer. A beath pin has been placed in the center of the femoral insertion of the superficial medial collateral ligament to perform isometry testing. (C) An illustration of the medial aspect of a left knee is shown. The gracilis tendon has been harvested proximally while the tibial insertion site is preserved. Femoral fixation of the folded end of the gracilis tendon has been performed, and the free tendon end is retrieved distally deep to the sartorius fascia using a clamp. (D) An illustration of the medial aspect of a left knee, including the gracilis tenodesis is shown. The gracilis tendon has been harvested proximally while the tibial insertion site is preserved. Femoral fixation of the folded end of the gracilis tendon has been performed while the free tendon end has been fixed in the center of the distal tibial insertion of the superficial medial collateral ligament.

agreed to avoid reconstructing structures that are not damaged or lax. Therefore, we propose the modified Lind procedure as an isolated procedure in anteromedial instability grade 2 or combined with ACL reconstruction in anteromedial instability grade 3 (Table 1) with no valgus laxity in extension.

The anterior bundle of the modified Lind procedure reconstructs the obliquity of the anterior fibers of the dMCL restraining external tibial rotation, as shown in Fig 1 B and C. However, the anterior bundle is nonanatomical because the tibial insertion site of the gracilis tendon is distal to the native tibial insertion site of the dMCL. Abermann et al.[28] recently described a flat tendon graft to reconstruct the wide insertion sites of the dMCL and sMCL in severe cases. Although this technique is more anatomic than the present technique, it is also more time-consuming and expensive due to the complex graft preparation and fixation.

The posterior bundle of the modified Lind procedure reconstructs the middle fibers of the sMCL, which are a major restraint to valgus laxity and external tibial rotation. Kittl et al.[26] showed that a single point-to-point reconstruction could not imitate the complex behavior of the native MCL, and that small changes in the femoral MCL graft attachment position significantly effect graft length change patterns. Hence, further studies are needed to investigate biomechanical and clinical results of various MCL reconstructions techniques[23,28-33] in anteromedial instability. Advantages and disadvantages and pearls and pitfalls of the present technique are listed in Tables 2 and 3, respectively.

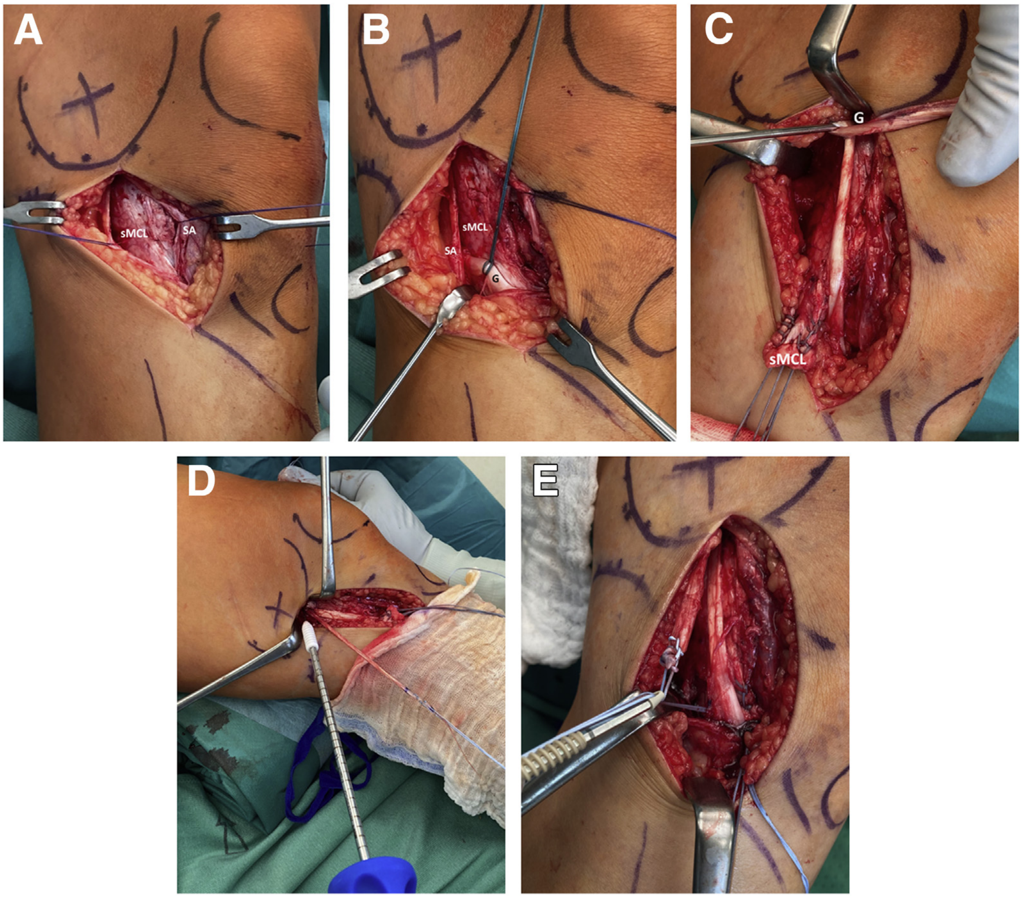


**Fig 6.** (A) An intraoperative view of an open medial approach to the left knee is shown. The sartorius fascia (SA) is incised and optionally armed with sutures. The superficial medial collateral ligament (sMCL) is identified deep to the SA. (B) An intraoperative view of an open medial approach to the left knee is shown. The SA is retracted posterior and inferior to identify the gracilis tendon (G), which runs across the sMCL. (C) An intraoperative view of an open medial approach to the left knee is shown. Isometry testing is performed by wrapping the gracilis tendon (G) around a femoral beath pin. The pin has been placed in the center of the femoral insertion of the superficial medial collateral ligament (sMCL). In addition, the distal sMCL has been armed with nonabsorbable sutures for subsequent refixation in case of a chronic distal avulsion injury. (D) An intraoperative view of an open medial approach to the left knee is shown. Femoral fixation of the folded end of the gracilis tendon into a femoral socket using an absorbable interference screw is demonstrated. The free tendon end is whipstitched with a nonabsorbable suture for subsequent tibial fixation. (E) An intraoperative view of an open medial approach to the left knee is shown. Tibial fixation of the free gracilis tendon end using a 4.75-mm SwiveLock anchor in the center of the distal tibial insertion of the superficial medial collateral ligament (sMCL) is demonstrated. In the present case of a chronic distal avulsion injury of the sMCL, the sMCL has been armed with nonabsorbable sutures and refixed with an additional anchor.

**Table 3.** Advantages and Disadvantages

| |
|---|
| Advantages |
| Straightforward technique |
| Open and minimally invasive approach |
| The deep and superficial medial collateral ligament is addressed |
| The same tibial approach in combined anterior cruciate ligament reconstruction |
| No need for allograft |
| Disadvantages |
| Nonanatomic reconstruction of the deep medial collateral ligament |
| Autograft harvest required |
| Cost of implants |
| Limited data |

## Conclusions

The modified Lind procedure addresses recent biomechanical findings in anteromedial knee instability.

## Acknowledgment

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