

Minimally Invasive Anatomical Reconstruction of Posteromedial Corner of Knee: A Cadaveric Study

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Abstract

We conducted a study to determine if a minimally invasive posteromedial reconstruction technique would return medial knee stability to its intact state. Ten cadaveric knees were tested under 3 state conditions: intact, sectioned, and reconstructed. The medial compartment opening was measured on valgus stress radiographs at full extension and at 20° of flexion with a 10-N valgus load (applied with dynamometer) to assess valgus stability in the intact, sectioned, and reconstructed states.

After posteromedial sectioning, mean medial gap was statistically significantly larger ($P = .0002$) at full extension (11 mm vs 3.3

mm) and at 20° of flexion (12.6 mm vs 3.7 mm). There was no statistically significant difference between the value of the intact state and the value after minimally invasive reconstruction at 0° ($P = .56$) or 20° ($P = .102$) of flexion. Interobserver reliability for the measurements was almost perfect ($\kappa = 0.86$).

Minimally invasive medial knee reconstruction returns medial knee stability almost to normal at full extension and at 20° of flexion. Development of minimally invasive techniques will allow medial ligament reconstruction with minimal disruption of the surrounding tissue, potentially leading to less scarring and easier restoration of knee motion after surgery.

Most injuries of the medial structures of the knee are treated conservatively.¹⁻³ In severe acute injuries and chronic symptomatic instabilities, however, surgical treatment is needed to restore knee stability and to prevent degenerative changes secondary to instability.⁴ Three structures involved in medial stability are the superficial medial collateral ligament (sMCL), which is the primary valgus restraint; the posterior oblique ligament (POL), which is the primary restraint to internal rotation and the secondary valgus restraint; and the semimembranosus.^{5,6}

Surgical techniques for posteromedial knee reconstruction include direct repair,⁷ repair with augmentation,^{8,9} advancement of the tibial insertion of the sMCL,¹⁰ and transfer of the pes anserine tendons.¹¹ In anatomical reconstruction of the posteromedial corner, which has been described before, the sMCL and the POL are reconstructed

to reproduce the native motion and stability of the knee.¹² Clinically, repair and reconstruction have similar patient-reported outcomes and medial

Take-Home Points

- Injuries to the medial knee are the most common knee ligament injuries, and often occur in the athletic population.
- Complete posteromedial corner injuries require surgical treatment to restore joint stability and biomechanics.
- Biomechanical evidence has demonstrated an important load-sharing distribution between the sMCL and the POL.
- Valgus instability caused by a medial side injury, can lead to both ACL/posterior cruciate ligament reconstruction graft failure if the medial sided injury is not concurrently repaired or reconstructed.
- Anatomic posteromedial corner reconstruction yields excellent biomechanical and patient-reported outcomes.

Authors' Disclosure Statement: The authors report no actual or potential conflict of interest in relation to this article.

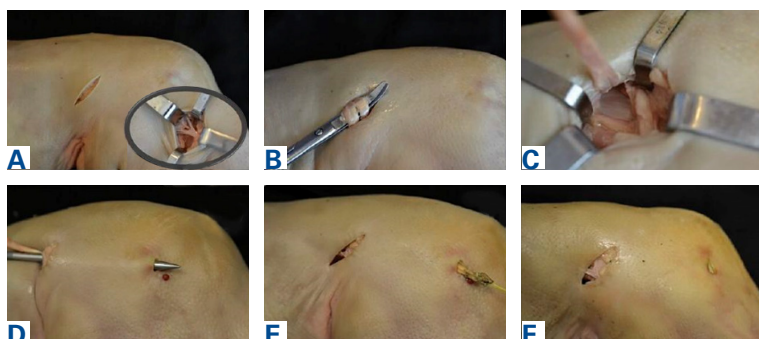


Figure 1. Sequence: (A) mini-invasive posteromedial oblique approach (round image is saphenous nerve); (B) identification of the hamstrings; (C) harvest of the semitendinosus tendon (superficial medial collateral ligament at bottom); (D) incision 10 mm posterior and 2 mm proximal to the medial epicondyle and deep passage of a blunt awl to create the path; (E) passage of the semitendinosus tendon; (F) cosmetic result of the surgery.

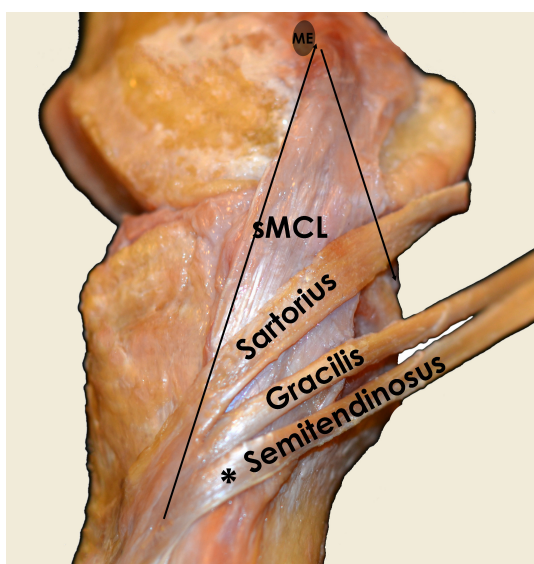


Figure 2. Cadaveric dissection shows the relationship between the superficial medial collateral ligament (sMCL) and the pes anserine. Proximal end of the semitendinosus tendon (~5 cm proximal to incision) was cleared of all muscular and fatty soft-tissue remnants and whipstitched with No. 2 Vycril suture. Afterward, radiographic guidance was used to visualize and identify the medial epicondyle and guide placement of the femoral tunnel.

opening evaluations over the short term.

These approaches require large incisions and extensive dissection of soft tissue on the medial aspect of the knee.⁵ Given these drawbacks, it is reasonable to consider less invasive options. Minimally invasive surgery has the advantages of reduced scarring and blood loss, less disruption of surrounding tissue, faster recovery, and improved aesthetics.⁴

We conducted a study of a minimally invasive technique for reconstructing the posteromedial structures of the knee. We compared medial

compartment stability measured on valgus stress radiographs in intact, sectioned, and reconstructed states in cadaveric knees. We hypothesized that a minimally invasive technique using autogenous hamstring graft in the appropriate anatomical location would return valgus stability to its nearly native state.

Materials and Methods

This study was conducted at the Buenos Aires British Hospital in Buenos Aires, Argentina, and at the University of Colorado Hospital in Aurora. Ten fresh-frozen cadaveric knees with no evidence of ligamentous injuries, osteoarthritis, or previous surgery were used. Mean donor age was 69.4 years (range, 45-87 years). Each specimen was maintained at room temperature for 24 hours before use. The femur was sectioned 20 cm proximal to the knee joint. The tibia was sectioned 12.5 cm distal to the knee joint.

Identification and Sectioning of Posteromedial Structures

Anatomical insertion sites of the sMCL, the deep MCL (dMCL), and the POL were identified on the tibia through an oblique 3-cm incision on the posteromedial aspect of the knee (**Figures 1A-1C**). A valgus stress radiograph with medial compartment gap measurement was obtained for each of the 10 knees before sectioning the medial stabilizing structures.

After intact-state evaluation, each knee's sMCL, dMCL, and POL were sectioned at their tibial insertion. Valgus stress radiograph was repeated and medial compartment gap was remeasured for comparison of the sectioned state with the intact and reconstructed states.

Anatomical Reconstruction With Mini-Invasive Technique

After sectioning of medial stabilizing structures, minimally invasive reconstruction was performed through 2 small incisions on the medial aspect of each of the 10 knees, as follows. First, the semitendinosus tendon was identified through the oblique incision that had been used for sectioning. Then, an open-ended tendon stripper was placed around the circumference of the semitendinosus and was passed proximomedially, transecting the tendon at its musculotendinous junction. While the tendon stripper was being passed, care was taken to maintain the nearby tibial insertion of the sartorius fascia (**Figures 1D-1F**).

The proximal end of the semitendinosus tendon (~5 cm proximal to incision) was then cleared of all muscular and fatty soft-tissue remnants and whipstitched with No. 2 Vycril suture (**Figure 2**). Then, the medial epicondyle was visualized and identified under radiographic guidance. A 1-cm incision was made 10 mm posterior and 2 mm proximal to the epicondyle (midpoint of femoral attachment of sMCL and POL).¹² A 1.8-mm Kirschner wire was inserted into the femur at this location. A blunt awl was used for deep (under sartorius fascia) passage of the semitendinosus tendon, from distal to proximal, and the tendon was looped over the top of the wire and brought through the incision.

With the semitendinosus tendon looped around the wire, isometricity was tested by pulling the suture within the tendon and moving the knee through a full range of motion. The isometric point was confirmed by tendon migration of <2 mm.¹³ Migration was measured by marking the graft 2 mm from its insertion; the graft was then pulled to ensure correct isometric point position. An 18-mm cannulated spiked screw and washer (Arthrex) were then passed over the wire and partially secured to the femur—the attachment point for the proximal sMCL portion of the semitendinosus graft. The semitendinosus tendon was then secured beneath the spiked washer with the knee in 20° of flexion with neutral rotation, recreating the sMCL.

Posteriorly, the distal insertion site of the POL was identified at the posteromedial aspect of the tibia through the oblique incision previously described. A 7-mm tunnel was drilled starting posteromedial (10 mm under tibial articular surface) and exiting just distal and medial to the Gerdy tubercle. The graft was passed subcutaneously and below the sartorius fascia from posterior to anterior and was secured with a 7-mm × 23-mm cannulated titanium screw. Fixation was performed at full extension with neutral rotation (**Figures 3A-3C, 4**).

After final fixation, the medial knee was openly dissected to assess the inverted-V ligament reconstruction for anatomical placement and avoidance of crucial structures.

Stability Testing

Per International Knee Documentation Committee guidelines for stressing the medial compartment,¹⁴ valgus stress radiographs were obtained for all specimens at 0° and 20° of flexion in intact, sectioned, and reconstructed states. For all radiographs, performed by Dr. Chahla, a 10-N valgus force (measured by dynamometer) was applied to an intramedullary



Figure 3. Minimally invasive reconstruction of the posteromedial corner of the knee. (A) Proximal fixation with a spiked washer used as the attachment point for the semitendinosus tendon. (B) Spiked washer in the superior window and posterior fixation of the posterior oblique ligament. (C) Knee dissected to expose the posteromedial reconstruction: superficial medial collateral ligament and posterior oblique ligament. Note the tightness of the superficial medial collateral ligament and the posterior oblique ligament graft in 60° of flexion.

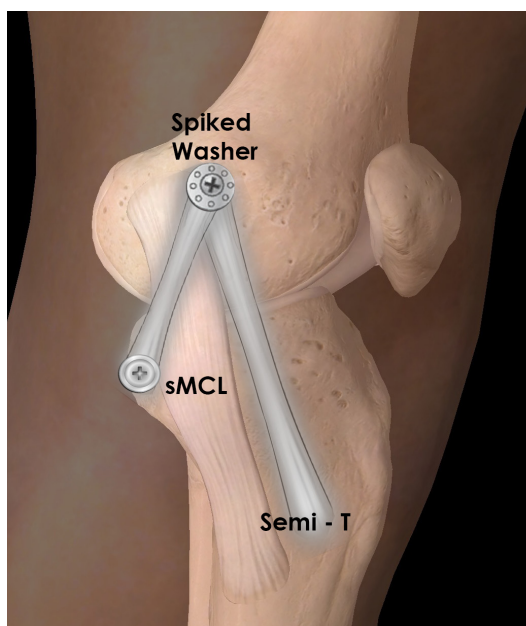


Figure 4. Schematic of a left knee shows the final result of the minimally invasive posteromedial reconstruction.

Abbreviations: semi-T, semitendinosus; sMCL, superficial medial collateral ligament.

rod placed in the femur while the tibia was firmly attached to a specially designed base¹⁵ (**Figures 5A-5C**). A situation of 1 *df* was recreated to allow only varus/valgus motion during testing.

The medial gap formed by the femoral condyle and its corresponding tibial plateau (at site of maximal separation) was tested in all 3 state conditions (intact, sectioned, reconstructed). Distances were digitally measured with a picture archiving and communication system viewer (Imagecast; IDX Systems Corporation). Medial gap was measured by taking the shortest distance between the subchondral bone surface of the most distal aspect of the medial femoral condyle and the corresponding



Figure 5. Extension valgus stress radiographs show (A) intact state, (B) sectioned state (with valgus instability evident), and (C) reconstructed state.

Table. Mean Medial Gap at Full Extension and at 20° of Flexion With Posteromedial Corner of Knee in Intact, Sectioned, and Reconstructed States According to 3 Readers^a

Knee	State, mm					
	Intact		Sectioned		Reconstructed	
	0°	20°	0°	20°	0°	20°
1	3.1	3.4	11.2	13.5	3.3	3.7
2	3.5	3.9	12.0	14.1	4.1	5.8
3	3.0	3.8	10.9	12.1	3.4	4.8
4	3.7	3.9	9.9	11.0	2.7	3.1
5	2.9	3.6	10.2	11.6	2.6	3.1
6	3.6	3.8	11.3	13.2	3.4	3.7
7	3.4	3.8	10.1	12.3	3.1	3.4
8	3.4	3.9	11.6	12.7	3.8	5.3
9	3.3	3.8	11.5	12.5	3.9	5.2
10	3.4	3.9	11.6	12.7	4.0	5.3
Mean	3.3	3.78	11.0	12.57	3.4	4.3

^a $P < .05$, $\kappa = 0.86$.

medial tibial plateau. Three independent examiners took all the measurements; each examiner was blinded to the others' measurements.

Statistics

Paired Student *t* tests were used to compare the 3 conditions, and the Shapiro-Wilk test was used to check for a normally distributed population. Statistical significance was set at $P < .05$. Statistical analyses were performed with GraphPad software.

Results

In all 10 specimens, the sMCL, the dMCL, and the POL were successfully identified and sectioned

through a medial oblique incision over the distal insertion of the structures.

During all valgus testing states, there was no loss of graft fixation, and there was no gross graft slippage. In addition, all grafts remained in continuity with no evidence of failure, and there were no failures or breakages of the proximal or distal screw.

After posteromedial sectioning, mean medial gap was statistically significantly larger ($P = .0002$) at full extension (11 mm vs 3.3 mm) and at 20° of flexion (12.6 mm vs 3.8 mm). There was no statistically significant difference between the value of the intact state and the value after minimally invasive reconstruction at 0° ($P = .56$) or 20° ($P = .102$) of flexion. Each knee had a notable endpoint in valgus stress noted on clinical examination after reconstruction. All individual results are listed in the **Table**. Interobserver reliability for the measurements was almost perfect¹⁶ ($\kappa = 0.86$).

Discussion

In this article, we describe a minimally invasive technique for anatomical posteromedial reconstruction of the knee in a cadaveric model. This technique restores the knee's native valgus stability without causing extensive damage to the surrounding soft tissues and thereby potentially prevents scar formation and reduces blood loss.

Superficial MCL injury, one of the most common knee ligament injuries, is often associated with POL injury.⁷ Although most sMCL injuries are treated nonoperatively, with good results,³ surgical treatment is needed for severe (grade III) instabilities, symptomatic chronic instabilities, and knee dislocations.^{12,17} Most posteromedial reconstruction techniques require an extensive approach that causes damage to surrounding soft tissue,^{6,7,9,10} which in turn may compromise healing and positive patient outcomes. Surgical techniques include direct repair with sutures or anchors,¹⁸ capsular procedures,¹⁹ augmentations,⁹ internal bracing,⁶ and complete reconstruction of the posteromedial corner.²⁰

LaPrade and Wijdicks¹² have previously described anatomical reconstruction of the posteromedial corner. In their technique, a split semitendinosus autograft is used to reconstruct the sMCL and the POL separately, using 4 implants and reproducing each ligament's anatomical attachment site. In this proposed technique, the distal attachment of the semitendinosus insertion is left intact, and uses 1 attachment point on the distal femur and 1 on the proximal tibia, allowing use of only 2 implants. In addition, it is performed with a

minimally invasive approach, reduces cost, limits surgical exposure, and with experience may shorten operative time. To reduce the graft failure rate, the technique of LaPrade and Wijdicks¹² positions the sMCL tibial attachment as posterior as possible, which can be performed with this minimally invasive approach as well.

To reduce the graft failure rate, the technique of LaPrade and Wijdicks¹² positions the sMCL as posterior as possible. Despite the potential for increased graft stress with an anterior position, as in our modified technique, our group of 10 knees had no graft fixation failures in isolated valgus stress testing in either extension or flexion. Our minimally invasive posteromedial knee reconstruction significantly improved knee stability over the sectioned state as well as medial compartment gapping with valgus stress. There was no significant difference in medial compartment gapping between the intact and reconstructed states.

Our technique was built on open procedures (described by Kim and colleagues¹³) that carefully identify the isometric point of the graft. In addition, it adopted the modification (proposed by Lind and colleagues²¹) in which a fixation point is added at the distal insertion of the POL instead of being sutured to the direct arm of the semitendinosus tendon.

Furthermore, our technique, despite being similar to those described by Dong and colleagues²² and Borden and colleagues,²³ has the advantages of minimally invasive surgery and reduced disruption of soft tissues. Dong and colleagues²² reported on 64 patients with a mean follow-up of 34 months; patients' medial opening measurements were significantly decreased at follow-up and fell within the normal range.

The present study had several limitations. First, the age of our specimens was higher than the mean age of patients with knee ligament injury, potentially leading to firmer or more fibrotic tendons less susceptible to elongation. Second, we did not evaluate the knees' rotational stability, and anterior cruciate ligaments (ACLs) were intact. As most posteromedial injuries co-occur with ACL injuries, a more realistic situation would have been reproduced by assessing rotational stability while performing both ACL reconstruction and the proposed posteromedial reconstruction. Third, static specimen measurements do not reflect the dynamic function of the posteromedial corner. Prospective clinical studies are needed to assess the true effectiveness of the posteromedial corner in the clinical scenario.

Knowledge of the anatomy of the medial aspect of the knee is vital to reconstruction of the medial side of the knee. Our results suggest that a minimally invasive technique can restore valgus stability without the need for extensive dissection and disruption of surrounding soft tissues. More research is needed to determine the results of this technique in vivo.

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