Winner of the 2010 Nicola's Foundation Young Researcher Award

Structural Properties of the Primary Medial Knee Ligaments

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Background: The structural properties of the individual components of the superficial medial collateral ligament (MCL), deep MCL, and posterior oblique ligament (POL) have not been studied in isolation. To define the necessary strength requirements for an anatomical medial knee reconstruction, knowledge of these structural properties is necessary.

Hypothesis: The components of the superficial MCL, POL, and deep MCL have significantly different structural properties.

Study Design: Controlled laboratory study.

Methods: This study used 20 fresh-frozen nonpaired cadaveric knee specimens with a mean age of 54 years (range, 27 to 68 years). These knees provided 8 samples for each tested medial knee structure, which was individually isolated and loaded to failure at 20 mm per minute. Specifically tested were the superficial MCL with intact femoral and detached proximal tibial attachments, the superficial MCL with intact femoral and detached distal tibial attachments, the central arm of the POL, and the isolated deep MCL. Load was recorded as a function of displacement. Stiffness of the ligament at failure was calculated from these measurements.

Results: The mean load at failure for the superficial MCL with the intact femoral and distal tibial attachments was 557 N. Mean load at failure was 88 N for the intact femoral and proximal tibial divisions of the superficial MCL, 256 N for the POL, and 101 N for the deep MCL. Stiffness of the ligaments just before failure was 63, 17, 38, and 27 N/mm, in the same order as above.

Conclusion: The proximal and distal tibial divisions of the superficial MCL, POL, and deep MCL produced loads of clinical importance.

Clinical Relevance: Knowledge of the structural properties of these attachment sites will assist in reconstruction graft choices, fixation method choices, and overall operative treatment of medial knee injury.

Keywords: superficial medial collateral ligament; deep medial collateral ligament; posterior oblique ligament; medial knee structures; biomechanics

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The superficial medial collateral ligament (MCL) and medial knee stabilizers are the most commonly injured structures of the knee.[10,13,20,27,30] Quantitative anatomy and biomechanical studies have recently recognized that the individual components of these structures have different functional elements.[8,9,17,34] The superficial MCL has 2 tibial attachments that effectively divide it into 2 functional units—the proximal and distal divisions (Figure 1A).[9,17,34] The posterior oblique ligament (POL) consists of superficial, central, and capsular arms, with the central arm being the main component (Figure 1A).[14,17] The deep MCL is composed of meniscofemoral and meniscotibial components (Figure 1B).[17]

Despite uncertainty about the most appropriate management of acute combined grade III medial knee injuries, surgical reconstruction is usually necessary for symptomatic chronic medial knee injuries.[5-7,14,18] The native structural strengths of the individual components of the main medial knee structures—whose function and importance has been recently quantified[8,9,34]—have not yet been well described. This information is necessary to help guide reconstruction graft and fixation method choices for anatomic medial knee reconstruction techniques.

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Presented at the annual meeting of the AOSSM, Providence, Rhode Island, July 2010.

One or more authors has declared a potential conflict of interest: This research study was supported by a Research Council of Norway grant (175047/D15), by a Health East Norway grant (10703604), and by the Sports Medicine Research Fund of the Minnesota Medical Foundation.

The American Journal of Sports Medicine, Vol. 38, No. 8
DOI: 10.1177/0363546510363465

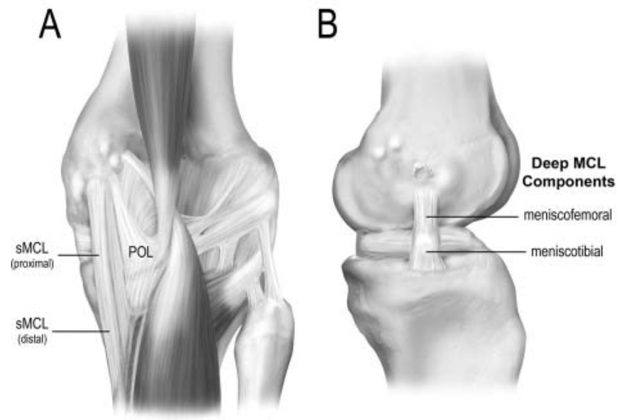

Figure 1. A, illustration of the superficial medial collateral ligament (sMCL; posteromedial aspect, right knee) and posterior oblique ligament (POL); B, illustration of the deep medial collateral ligament (MCL) components (medial view, left knee). Reprinted with permission from the *Journal of Bone Joint Surgery*, 2007;89(9).

No previous study has measured the maximum mechanical load tolerated by the proximal and distal tibial attachments of the superficial MCL, the central arm of the POL, and the deep MCL in isolation. The purpose of our study was to define the structural properties (strength and stiffness) of the individual components of the 3 main medial knee structures and therefore provide guidance toward reconstruction graft choices and surgical fixation technique for medial knee reconstructions. We tested the superficial MCL with an intact femoral and detached proximal tibial attachments, the superficial MCL with an intact femoral and detached distal tibial attachments, the central arm of the POL, and the isolated deep MCL. During failure testing, we investigated the structure-specific failure loads, displacements at failure, and linear stiffness.

MATERIALS AND METHODS

Specimen Preparation

In this study, we used 20 fresh-frozen nonpaired cadaveric knee specimens with a mean age of 54 years (range, 27 to 68 years). These knees provided 8 samples for each tested medial knee structure. Table 1 denotes these ligamentous structures and numerically identifies their respective specimens. The knees were maintained at –20°C and thawed at room temperature before structure isolation. All ligamentous structures were isolated with a scalpel. Each ligament had a tibial- and femoral-side attachment, which was isolated via a reciprocating bone saw (ConMed Linvatec Hall, Largo, Florida) to provide enough bone stock to facilitate embedding in polymethylmethacrylate (PMMA; Dentsply, York, Pennsylvania) (Figure 2). Two drywall screws were fixed into opposing sides of the isolated bone, with approximately 1 cm of the screw remaining outside the cortex to ensure static fixation in the PMMA. Each end was then placed inside a metal cylinder (6 × 5 cm) and filled with PMMA.

Ligamentous Structures of the Medial Knee

Superficial MCL. The anterior border of the superficial MCL was identified and followed proximally to its femoral attachment. The posterior border of the femoral superficial MCL was then separated from the anterior aspect of the POL by fine dissection according to a previously described technique.[17] The superficial MCL and deep MCL were separated by running a fine-tipped hemostat between the superficial MCL and the meniscofemoral and meniscotibial deep MCL components. The superficial MCL was then dissected from other underlying structures to its distal tibial attachment. For biomechanical testing of each individual superficial MCL division, the individual tibial attachments of the superficial MCL were isolated. The distal tibial division was transected proximal to its bony attachment to isolate the proximal superficial MCL tibial attachment for testing (Figure 3). To isolate the distal tibial superficial MCL attachment, the proximal tibial attachment of the superficial MCL was bluntly dissected off the tibia.

Posterior Oblique Ligament. The tibial POL attachment was identified by locating its attachment to the anterior and direct arms of the semimembranosus tendon. The posterior border of the POL was then identified by incising away the portion of the posteromedial capsule that did not course toward the POL femoral attachment. In effect, this isolated out its thicker anterior oblique fibers, the central arm of the POL.[14,17] As described previously, the anterior margin of the POL was identified by its fiber orientation relative to the superficial MCL longitudinal fibers. To isolate the POL from the superficial MCL, the anterior aspect of the POL was incised away from the posterior margin of the superficial MCL, proximal to distal (Figure 2).

Deep MCL. The anterior border of the deep MCL was identified by separating it from the anteromedial capsule and incising it vertically to the level of the medial meniscus. Meticulous blunt dissection from anterior to posterior was performed to separate the deep and superficial MCL. The meniscal attachment of the deep MCL was retained during isolation (Figure 4).

Mechanical Testing

All soft tissues were kept moist with normal saline throughout ligament harvesting, PMMA embedding, and biomechanical testing, and care was taken to preserve the bony attachment for each ligament tested. Embedded PMMA cylinders were locked in an Instron 5865 (Instron Systems, Norwood, Massachusetts), with the fibers oriented along the axis of the applied force vector (Figure 3). Specimens were preconditioned from 10 N to 50 N at 0.1 Hz for 10 cycles. They were then immediately subjected to failure loading at 20 mm per minute until failure, and the mechanism of failure was subsequently recorded. Our overall purpose was to guide strength requirements

TABLE 1
Failure Loading Biomechanical Results for the Medial Knee Structures[a]

Ligamentous Structure / Specimen No.	Load at Failure N	Displacement at Failure mm	Stiffness at Failure N/mm	Failure Location
Intact distal sMCL				
1	631.8	8.3	74.8	Femur
2	462.9	6.1	69.9	Femur
3	519.5	8.5	56.5	Midsubstance
4	577.7	8.3	65.1	Midsubstance
5	599.1	8.4	68.8	Femur
6	513.1	7.1	67.2	Femur
7	595.8	13.2	48.2	Femur
8	557.2	9.8	54.7	Midsubstance
	557.1 ± 55.4	8.7 ± 2.1	63.1 ± 9.1	
Intact proximal sMCL				
14	80.1	3.8	19.3	Proximal tibia
13	142.7	3.8	26.2	Proximal tibia
15	71.6	3.4	21.5	Proximal tibia
16	140.9	2.9	34.5	Proximal tibia
17	54.6	8.6	10.2	Proximal tibia
18	53.4	12.1	4.6	Proximal tibia
19	62.6	15.6	3.5	Proximal tibia
20	95.2	7.6	21.5	Proximal tibia
	87.6 ± 36.1	7.2 ± 4.7	17.6 ± 10.7	
POL				
1	292.6	5.9	48.7	Femur
3	292.9	9.2	25.7	Midsubstance
12	247.6	4.3	47.7	Femur
4	260.9	9.5	23.1	Midsubstance
13	235.1	11.3	17.1	Tibia
5	276.8	5.2	47.6	Tibia
10	229.0	2.9	64.1	Midsubstance
9	214.8	4.9	35.1	Midsubstance
	256.2 ± 29.5	6.6 ± 2.9	38.6 ± 16.0	
Deep MCL				
3	95.3	2.7	21.5	Meniscotibial
4	107.8	1.9	32.3	Meniscotibial
5	89.8	1.7	25.6	Femur
6	91.3	1.4	35.3	Meniscofemoral
9	99.8	2.2	24.5	Meniscofemoral
10	121.7	2.5	30.8	Meniscotibial
11	101.1	2.1	28.5	Meniscofemoral
7	97.5	2.3	22.1	Meniscofemoral
	100.5 ± 10.3	2.1 ± 0.4	27.6 ± 5.0	

[a] sMCL, superficial medial collateral ligament; POL, posterior oblique ligament; MCL, medial collateral ligament.

for operative fixation of these medial knee structures. Therefore, a rate was chosen on the basis of prior literature, using this rate to maximize the stress on the studied ligamentous attachment site instead of the stress within the graft.[4,25,31,32] Load and displacement data were recorded at 100 Hz by Instron Bluehill software (version 1.1, Instron Systems). Failure was defined as the point at which a change in displacement no longer exhibited concomitant load increases (Figure 5). The displacement at failure was determined as the load at failure point. The stiffness was computed as the slope of the linear region just before failure on the force-versus-displacement curve, corresponding to the steepest straight-line tangent to the curve. Measurements were plotted and analyzed with Microsoft Excel.

Statistical Analysis

Statistical analysis was performed with SAS 9.1.3 (SAS Institute, Cary, North Carolina). We compared the failure load, displacement at failure, and stiffness data for each ligamentous structure using a 2-way analysis of variance. Post hoc Tukey tests were conducted to assess whether there was a significant difference between parameters. Significant difference was set at $P < .05$.

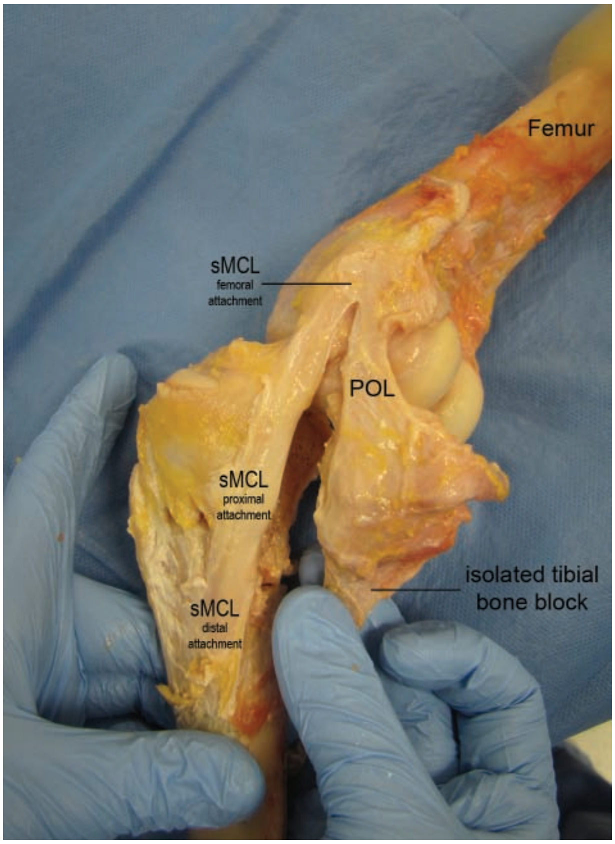

Figure 2. Preparatory photograph demonstrating the intact femoral and distal tibial attachments of the superficial medial collateral ligament (sMCL) before biomechanial testing. The posterior oblique ligament (POL) was isolated by carefully cutting a tibial bone block from the tibia with a reciprocating surgical saw. The tibial bone block was then embedded with polymethylmethacrylate in similar fashion to the femoral side.

RESULTS

The proximal and distal attachments of the superficial MCL, the central arm of the POL, and the deep MCL were identified and isolated. Table 1 reports the biomechanical testing results.

Superficial MCL With Intact Femoral and Distal Tibial Attachments

The mean load at failure for the superficial MCL with intact femoral and distal tibial attachments, with the proximal tibial attachment detached, was 557.1 ± 55.4 N (Figure 6). The mean stiffness was 63.1 ± 9.1 N/mm (Figure 7). Both load-at-failure and stiffness parameters were significantly higher than those of the other tested structures ($P < .05$). The mean displacement at failure was 8.7 ± 2.1 mm. Five failures occurred at the femoral attachment; the remaining 3 occurred with a midsubstance rupture.

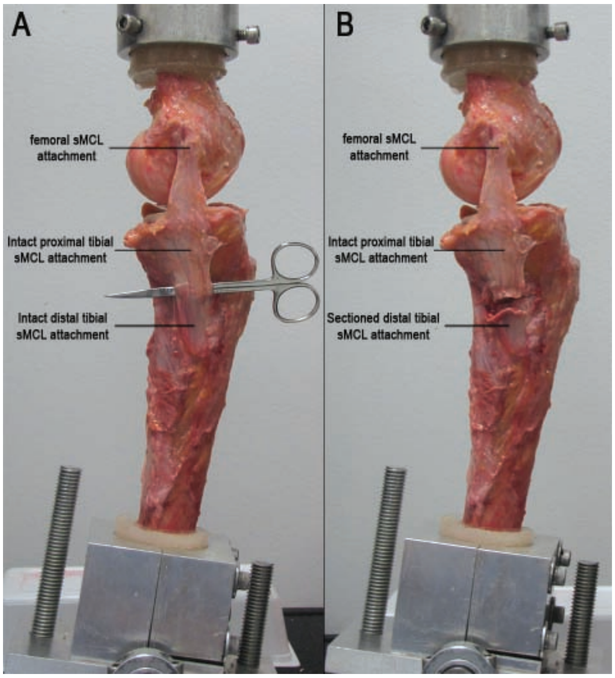

Figure 3. Testing setup for the superficial medial collateral ligament (sMCL) with intact femoral and proximal tibial attachments before biomechanical testing. The distal and proximal tibial attachments are identified (A), followed by sectioning of the distal division to isolate the proximal division (B). Note that the posterior oblique ligament was removed but not tested from this knee specimen.

Superficial MCL With Intact Femoral and Proximal Tibial Attachments

The mean load at failure for the superficial MCL with intact femoral and proximal tibial attachments was 87.6 ± 36.1 N (Figure 6). The mean stiffness was 17.6 ± 10.7 N/mm (Figure 7). Both load-at-failure and stiffness parameters were significantly lower than those of the superficial MCL with intact femoral and distal tibial attachments and the POL ($P < .05$). The mean displacement at failure was 7.2 ± 4.7 mm, which was significantly higher than that of the deep MCL (2.1 mm; $P < .05$). All failures occurred at the proximal tibial superficial MCL attachment site.

Central Arm of the POL

The mean load at failure for the central arm of the POL was 256.2 ± 29.5 N (Figure 6). The mean stiffness was 38.6 ± 16.0 N/mm (Figure 7). Both load-at-failure and stiffness parameters were significantly lower than those of the superficial MCL with intact femoral and distal tibial attachments and significantly higher than both the superficial MCL with intact femoral and proximal tibial attachments and the deep MCL ($P < .05$). The mean displacement at failure for the POL attachment was 6.6 ± 2.9 mm, which was significantly higher than the deep MCL (2.1 mm;

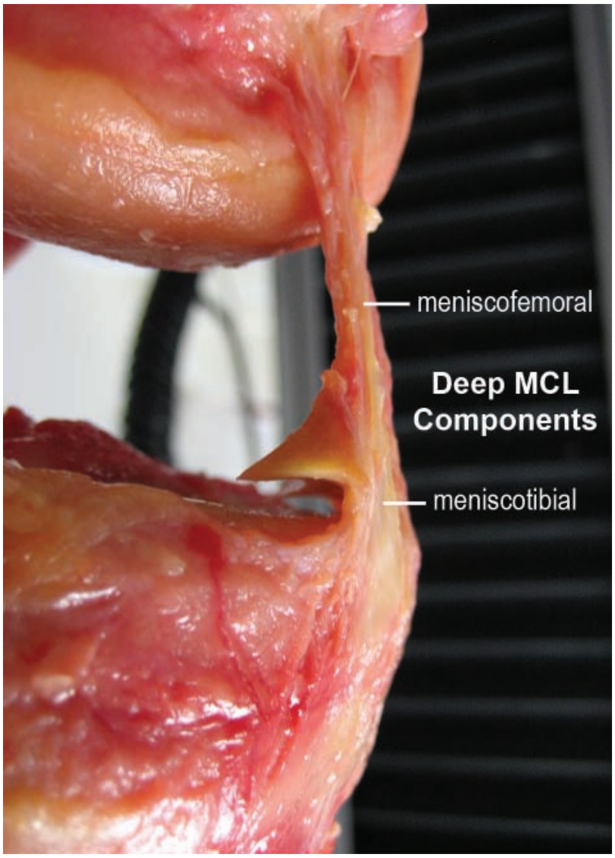

Figure 4. Posttesting photograph for the deep medial collateral ligament (MCL) components of a right knee specimen. The attached medial meniscus was retained throughout testing.

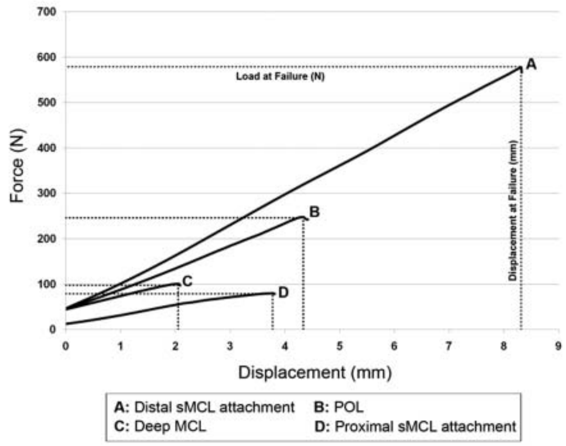

Figure 5. Representative load-displacement curves used to determine load at failure (N), displacement at failure (mm), and stiffness (N/mm). Failure was defined as the point at which a change in displacement no longer exhibited concomitant load increases. The displacement at failure was determined to be present at the load at failure point. The stiffness was computed as the slope of the linear region just before failure on the force-versus-displacement curve, corresponding to the steepest straight-line tangent to the curve. sMCL, superficial medial collateral ligament; POL, posterior oblique ligament; MCL, medial collateral ligament.

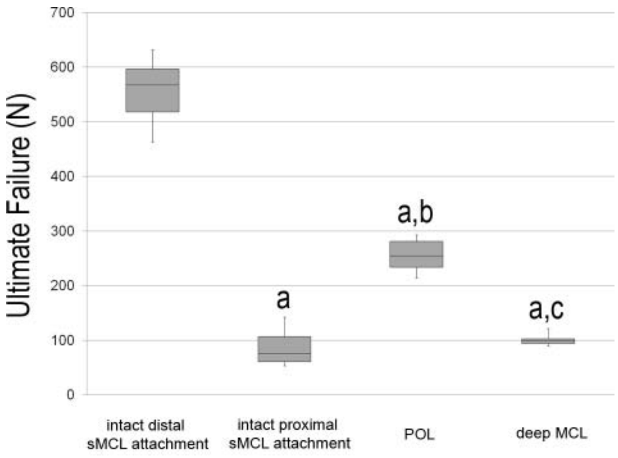

Figure 6. Box plot representing ultimate failure load of the tested structures. The horizontal line indicates the median, the box extends from the 25th percentile to the 75th, and the bars indicate the largest and smallest observed values. Statistical significance is denoted in the figures where the structure is different from the intact distal superficial medial collateral ligament (sMCL) attachment (a), from the intact proximal sMCL attachment (b), and from the posterior oblique ligament (POL) (c). MCL, medial collateral ligament.

$P < .05$). Failures occurred most commonly midsubstance (n, 4), followed by the femoral (n, 2) and tibial (n, 2) attachment sites.

Deep MCL

The mean load at failure for the deep MCL was 100.5 ± 10.3 N (Figure 6). The mean stiffness was 27.6 ± 5.0 N/mm (Figure 7). Both load-at-failure and stiffness parameters were significantly lower than those of the superficial MCL with intact femoral and distal tibial attachments and the central arm of the POL ($P < .05$). The mean displacement at failure was 2.1 ± 0.4 mm, which was significantly lower than that of both the superficial MCL with femoral and proximal attachments intact (7.2 mm) and the POL (6.6 mm; $P < .05$). Of the 8 failures, 7 occurred midsubstance (4 in the meniscofemoral portion and 3 in the meniscotibial portion) and 1 failed at the femoral attachment site.

DISCUSSION

Identification of the maximum structural loads tolerated by the proximal and distal tibial attachments of the superficial MCL, the central arm of the POL, and the deep MCL in isolation is necessary to guide strength requirements for fixation and reconstruction of these structures for operative management of medial knee injury.

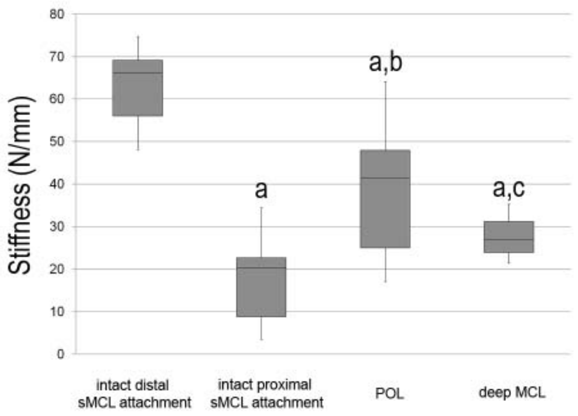

Figure 7. Box plot representing linear stiffness of the tested structures. The horizontal line indicates the median, the box extends from the 25th percentile to the 75th, and the bars indicate the largest and smallest observed values. Each box denotes when it is statistically different from the intact distal superficial medial collateral ligament (sMCL) attachment (a) and from the intact proximal sMCL attachment (b).

These physical characteristics are of interest because these ligamentous structures have been implicated as the primary medial knee stabilizers for their intact and injured states.[8,9,17,34] Thus, we biomechanically tested the clinically relevant medial knee structures and observed their failure loads and stiffness. The superficial MCL with intact femoral and distal tibial attachments, with the proximal tibial attachment detached, failed at a mean load of 557 N. The superficial MCL with intact femoral and proximal tibial attachments, with the distal division detached, failed at a mean load of 88 N. The central arm of the POL, a thickening of the posteromedial capsule, failed at 256 N. The deep MCL failed at 101 N.

These results require a close comparison with a prior biomechanical study by Robinson et al,[28] who measured the native strengths of the superficial MCL (excluding its proximal tibial attachment), the deep MCL, and the entire posteromedial capsule utilizing a total of 8 nonpaired cadaveric knees (mean age, 77 years; range, 72 to 89 years). Their testing protocol tested the ligaments by harvesting bony blocks from either end of each ligamentous structure and testing them to failure. As a result, the superficial MCL was tested as the entire span of the ligament but devoid of its proximal tibial attachment. The researchers noted the mean load at failure for the superficial MCL to be 534 N. Their study found that the superficial MCL mean load at failure was comparable with our superficial MCL test results of 557 N, with the femoral and distal tibial attachments intact. The femoral attachment of the superficial MCL was observed to fail in 5 of 8 specimens in both the Robinson et al study and our own. The deep MCL withstood 194 N of force in the Robinson et al study, which was higher than our finding of 101 N for the deep MCL yet comparable when considering the standard deviation of their study. The failure locations for the deep MCL were also comparable between studies in that it more commonly failed in the meniscofemoral portion. A major methodological difference between the Robinson et al study and our own was the isolation of the posteromedial capsule versus our isolated central arm of the POL. We isolated and tested the central arm of the POL because it has been described as the main portion of the POL amenable to being reconstructed.[5,9,17] Robinson et al noted larger loads of 425 N for the posteromedial capsule, including but not limited to the central arm of the POL, which we noted to have a failure strength of 256 N. In both the Robinson et al study and our study, a frequent midsubstance point of failure was noted for this structure. Given that only more traditional ligamentous structures are suitable for surgical reconstruction, our testing focused on the thicker anterior portion of the posteromedial capsule, defined as the central arm of the POL.[5,7,17,18]

With the trend toward more anatomical medial knee reconstructions,[3,5,7,18] it is important to understand the function and differences between the individual components of these medial knee-stabilizing structures. A medial knee reconstruction was recently described that incorporated all 3 attachments of the superficial MCL, as well as the central arm of the POL.[5] Prior literature has focused on the more robust, distal tibial superficial MCL attachment.[1,10,12,15,26] With the use of buckle transducers, current studies have elucidated the role of the proximal division as a primary medial knee stabilizer to valgus stress.[8,34] The implications of these observations are that although the superficial MCL has been biomechanically tested and surgically reconstructed under the assumption that the superficial MCL was a continuous structure,[||] the 2 divisions of the superficial MCL actually function as 2 conjoined but distinct structures.[8,9,34] A recent biomechanical study by Feeley et al[7] reported that anatomic double-strand medial knee reconstructions that reconstituted the proximal tibial superficial MCL attachment function provided stabilization against valgus and external rotational applied loads.

Another study reported that external rotation torques in knees having had all other medial knee structures sectioned resulted in a decreased load on the proximal attachment of the superficial MCL.[34] Thus, these biomechanical studies suggest that operative repair or reconstruction of the superficial MCL should strive to reconstruct the distinct functions of both divisions by reconstitution of the 2 tibial attachments in an attempt to mimic the native anatomical function of the superficial MCL complex.[9,34] Compared with the number of studies on the function of the superficial MCL, fewer studies have reported on the isolated function of the deep MCL. The previous sequential sectioning studies that evaluated the function of the deep MCL described it as a secondary restraint to valgus loads.[8,29,34]

The POL is a reinforcement of the posteromedial capsule, which courses off the distal aspect of the semimembranosus tendon.[13,14,17] Studies have reported that the entire posteromedial capsule does not lend itself to anatomic

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[||] References 10, 11, 15, 16, 19, 22, 23, 36.

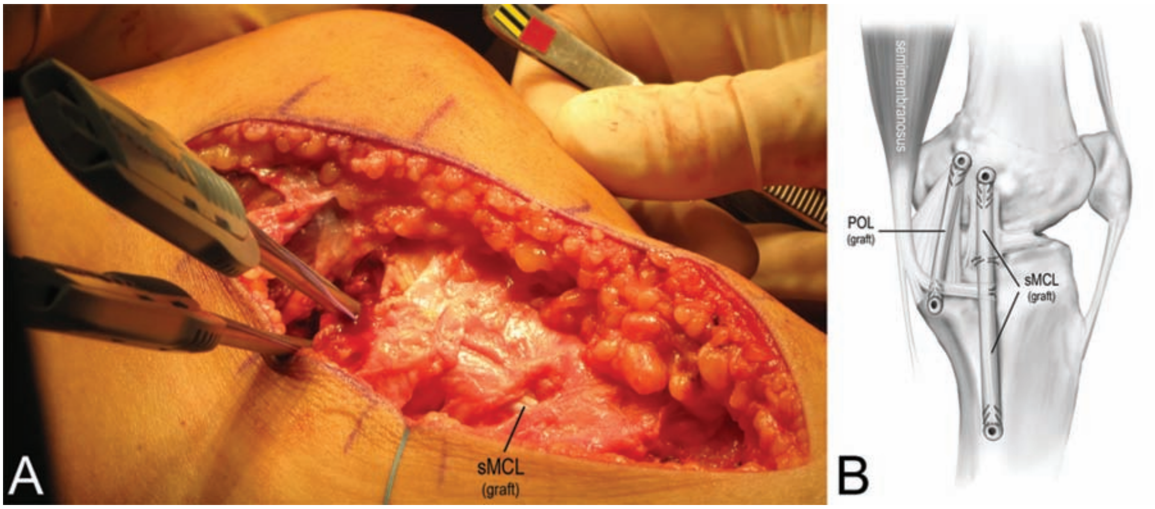

Figure 8. A, intraoperative photograph demonstrating a single anteromedial incision performed on a left knee. The superficial medial collateral ligament (sMCL) and posterior oblique ligament (POL) grafts have been passed along their natural courses under the sartorius facia and fixed into their reconstruction tunnels. The proximal suture anchor (left) is placed to secure the deep medial collateral ligament to its tibial attachment site; likewise, the distal suture anchor (right) is placed to secure the proximal tibial attachment of the sMCL to its tibial attachment site. The suture on the posterior border of the incision was placed to tag the sartorial branch of the saphenous nerve.[35] B, illustration of a medial knee reconstruction procedure demonstrating the reconstructed sMCL and PO,L which consists of a reconstruction of these structures using 2 separate grafts with 4 reconstruction tunnels (medial view, left knee). Reprinted with permission from Coobs et al, *Am J Sports Med*.[5]

reconstruction, because it is not a consistent structure.[5,17] However, an anterior thickening of the capsule, the central arm of the POL, was found to be a significant medial knee stabilizer that has potential for reconstruction.[8,9,34] From a biomechanical perspective, the POL functions as an internal rotation and valgus stabilizer at between 0° and 30° of knee flexion.[8-11,13,19,22,34] As a static structure in the uninjured knee, the central arm of the POL functions as a primary stabilizer against internal rotation and a secondary stabilizer against a valgus moment.[8] In knees with all other medial knee stabilizers sectioned, the POL experienced a significant load increase with an applied valgus and external rotation moment, particularly when the knee was in full extension.[34] These results demonstrate that injuries to the individual components of the medial knee alter the intricate load-sharing relationships that exist between all the medial knee structures, which, if left untreated, could increase the risk for further injury.[2,34]

A complete understanding of medial knee mechanical properties is valuable to assess which structures should be repaired or reconstructed when the injury requires operative management. The properties we described for these primary medial knee stabilizers can be used in review of the adequacy of reconstruction graft materials. With the limitations of cadaveric testing in mind, several graft sources are appropriate for medial knee reconstructions based on the length of the graft required, the material properties of the graft, and the desire to be minimally invasive.[5] A single-looped semitendinosus tendon (1216 N) or gracilis tendon (838 N) satisfy all 3 criteria as well as exceed the reported loads at failure in the present study.[24]

Current graft fixation techniques for operative management predominantly use interference screws alone for fixation of a soft tissue graft in medial knee reconstructions.[3,5,7,18] With the demonstrated supportive role of the proximal tibial attachment of the superficial MCL, current surgical techniques advise to adequately secure reconstruction grafts to their respective attachment sites (Figure 8).[5] A follow-up to the described surgical technique by Coobs et al[5] and the structural properties in the present study evaluated a distal tibial superficial MCL graft fixation technique using an interference screw and optimization with a cortical button: This study protocol[33] consisted of testing the superficial MCL knee reconstruction graft in isolation, using bovine extensor tendons and bone mineral density–controlled porcine tibias. The study used cyclic loading to simulate a rigorous rehabilitation protocol and measure how the initial fixation performed. The study found that using poly-L-lactide interference screws provided adequate graft load-carrying capacity for the distal tibial superficial MCL (445.0 ± 72.2 N), as compared with the respective structural results of the present study (557.1 ± 55.4); however, our testing protocol replicates loading indicative of a worst-case scenario, not necessarily representative of the forces experienced by the native structure during rehabilitation. As described by Coobs et al, the POL is secured in a similar fashion as the distal tibial superficial MCL attachment using an interference screw, and the data by Wijdicks et al provide the POL with enough strength (445.0 ± 72.2 N) compared with its native ligament strength (256.2 ± 29.5 N). In regard to fixating the proximal tibial superficial MCL attachment, a suture plus bony anchor has been reported to withstand a higher load (142 N); furthermore, if we assume that the proximal tibial attachment of the superficial MCL were to provide loading characteristics similar to those of the present study (87.6 N), then it should provide a larger margin of security for the proximal superficial MCL graft fixation.[21]

One of the limitations of the present study was the use of cadaveric specimens. Our observations were based on the testing and measurement of postmortem knees, which may not have been as strong as those seen in younger, active patients who require medial knee reconstructions. However, a prior study[28] used the same model, comprising an older group of cadaveric knees (mean, 72 years; range, 72 to 89 years) compared with ours (mean, 54 years; range, 27 to 68 years). We wanted to obtain an age range below that of 70 years. Also, because of the proximity of femoral and tibial attachment sites, we compared the properties of ligaments harvested from separate knees, which introduced interspecimen variability; however, our specimens had low standard deviations (Table 1).

Note that the superficial MCL femoral attachment was observed to fail in 5 of 8 specimens both in the Robinson et al study and in our own, despite a slower rate in our study (20 mm per minute) versus theirs (1000 mm per minute).[28] We can therefore extrapolate that the strongest part of the superficial MCL was the distal tibial attachment. That being said, a fixation technique should take this into consideration and attempt to exceed the load to failure of the superficial MCL with intact femoral and distal tibial attachments, which we noted to be 534 N. Note also that we tested the structures in isolation and that the observed loads were directly related to the structural properties, thereby representing a worst-case scenario not necessarily representative of an in vivo situation. This notation is made in light of studies demonstrating that, via buckle transducers, intact and reconstructed medial knee structures distribute the observed load among the primary medial knee structures.[5,8,9,34] In cases in which surgical reconstruction is indicated, consideration should be given to reconstructing all injured medial knee structures to restore the native load-sharing relationships.[5,34] A future study that validates and optimizes currently used soft tissue interference screw fixation strengths would add to the literature and potentially add benefit to the treatment of patients with medial knee injury requiring operative management. Finally, medial knee structures—particularly, the proximal attachment of the superficial MCL and the POL—can be difficult to isolate without disturbing the native anatomy or material properties of the structure. We were careful to follow the same dissection techniques reported for isolation of these structures from a previous quantitative anatomy study.[17]

We conclude that, despite being of vastly different strengths, the 2 tibial attachments of the superficial MCL sustain clinically important loads, as do the central arm of the POL and the deep MCL. Anatomic medial knee reconstructions may take these results into account and so require a proximal tibial superficial MCL attachment consisting of a suture plus bony anchor or a strong suture to secure the superficial MCL reconstruction graft to adjacent soft tissues to allow tissue integration and full ligament functionality during load bearing. In severe medial knee injuries, the robust capsular arm of the POL should be considered for consequent surgical reconstruction using a graft of suitable strength.

ACKNOWLEDGMENT

This research study was supported by a Research Council of Norway grant (175047/D15), by a Health East Norway grant (10703604), and by the Sports Medicine Research Fund of the Minnesota Medical Foundation. We acknowledge Conrad Lindquist for his work on preparing the testing fixture. We also mention Paul Lender for his statistical expertise.

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