Radiographic Identification of the Primary Medial Knee Structures

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Background: Radiographic landmarks for medial knee attachment sites during anatomic repairs or reconstructions are unknown. If identified, they could assist in the preoperative evaluation of structure location and allow for postoperative assessment of reconstruction tunnel placement.

Methods: Radiopaque markers were implanted into the femoral and tibial attachments of the superficial medial collateral ligament and the femoral attachments of the posterior oblique and medial patellofemoral ligaments of eleven fresh-frozen, nonpaired cadaveric knee specimens. Both anteroposterior and lateral radiographs were made. Structures were assessed within quadrants formed by the intersection of reference lines projected on the lateral radiographs. Quantitative measurements were performed by three independent examiners. Intraobserver reproducibility and interobserver reliability were determined with use of intraclass correlation coefficients.

Results: The overall intraclass correlation coefficients for intraobserver reproducibility and interobserver reliability were 0.996 and 0.994, respectively. On the anteroposterior radiographs, the attachment sites of the superficial medial collateral ligament, posterior oblique ligament, and medial patellofemoral ligament were 30.5 ± 2.4 mm, 34.8 ± 2.7 mm, and 42.3 ± 2.1 mm from the femoral joint line, respectively. On the lateral femoral radiographs, the attachment of the superficial medial collateral ligament was 6.0 ± 0.8 mm from the medial epicondyle and was located in the anterodistal quadrant. The attachment of the posterior oblique ligament was 7.7 ± 1.9 mm from the gastrocnemius tubercle and was located in the posterodistal quadrant. The attachment of the medial patellofemoral ligament was 8.9 ± 2.0 mm from the adductor tubercle and was located in the anteroproximal quadrant. On the lateral tibial radiographs, the proximal and distal tibial attachments of the superficial medial collateral ligament were 15.9 ± 5.2 and 66.1 ± 3.6 mm distal to the tibial inclination, respectively.

Conclusions: The attachment locations of the main medial knee structures can be qualitatively and quantitatively correlated to osseous landmarks and projected radiographic lines, with close agreement among examiners.

Clinical Relevance: The present study identifies medial knee structure attachment sites with use of radiographic landmarks and thus allows for reliable preoperative and postoperative assessments of surgical repairs and reconstructions of the main medial knee structures.

Injuries to the medial (tibiofemoral) knee structures, collectively called the medial collateral ligament, are the most common knee ligament injuries[1-6]. Previous studies have demonstrated that the superficial medial collateral ligament and the posterior oblique ligament are the main stabilizing structures of the medial tibiofemoral joint[7-15]. In addition, the medial patellofemoral ligament is the main medial stabilizer of the patellofemoral joint[16], and its femoral attachment is located in close proximity to the femoral attachments of the medial knee stabilizers[15].

A review of the literature provides numerous qualitative[4,8,11,17-21] and quantitative[15] gross anatomic descriptions of

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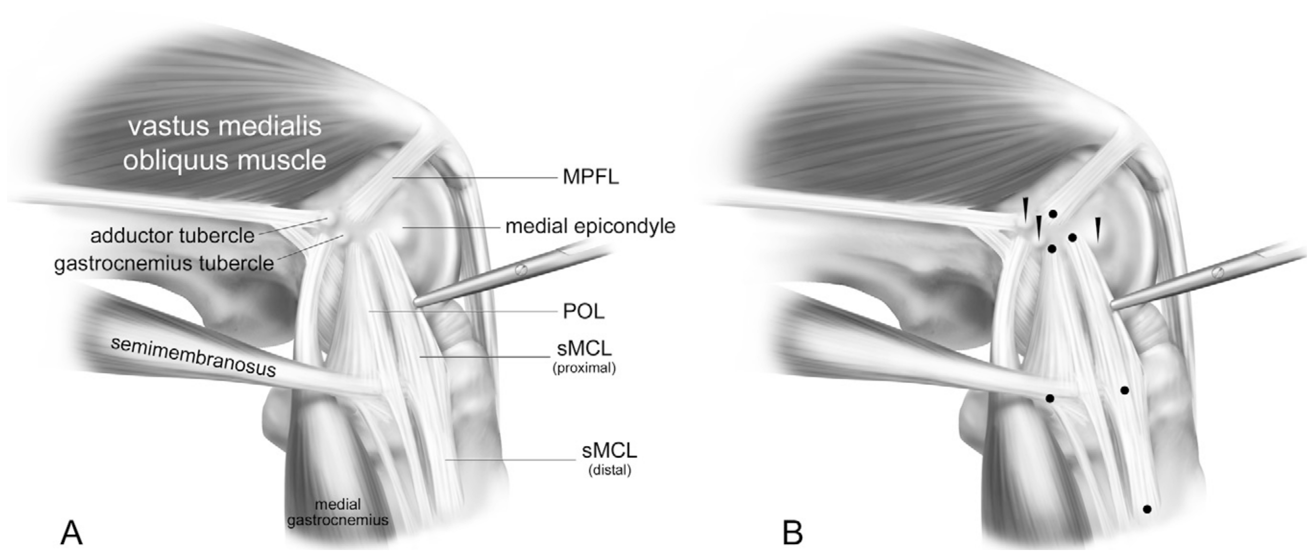

Fig. 1

A and *B:* Illustrations demonstrating the placement of radiopaque markers for the medial knee structure attachment sites (spheres at attachment sites and cut T-pins at osseous landmarks). MPFL = medial patellofemoral ligament, POL = posterior oblique ligament, and sMCL = superficial medial collateral ligament.

these medial knee structures; however, there is a lack of established and validated radiographic descriptions of the medial knee anatomy. Understanding both the gross and radiographic anatomy is important for the surgical treatment of medial knee injuries. In revision surgery cases, the frequent presence of heterotopic ossification after injury[22] or obliteration of the normal osseous anatomy by previous surgical hardware or tunnels can make identification of the normal medial knee attachment sites very difficult, and radiographic guidelines could assist with the interpretation of medial structure location on these radiographs. In addition, quantitative assessment of the radiographic location of structures would assist in the evaluation of postoperative placement of these structures. Thus, radiographic orientation should be an important adjunct to utilize for the preoperative planning and postoperative assessment of repairs or reconstructions of medial knee structures.

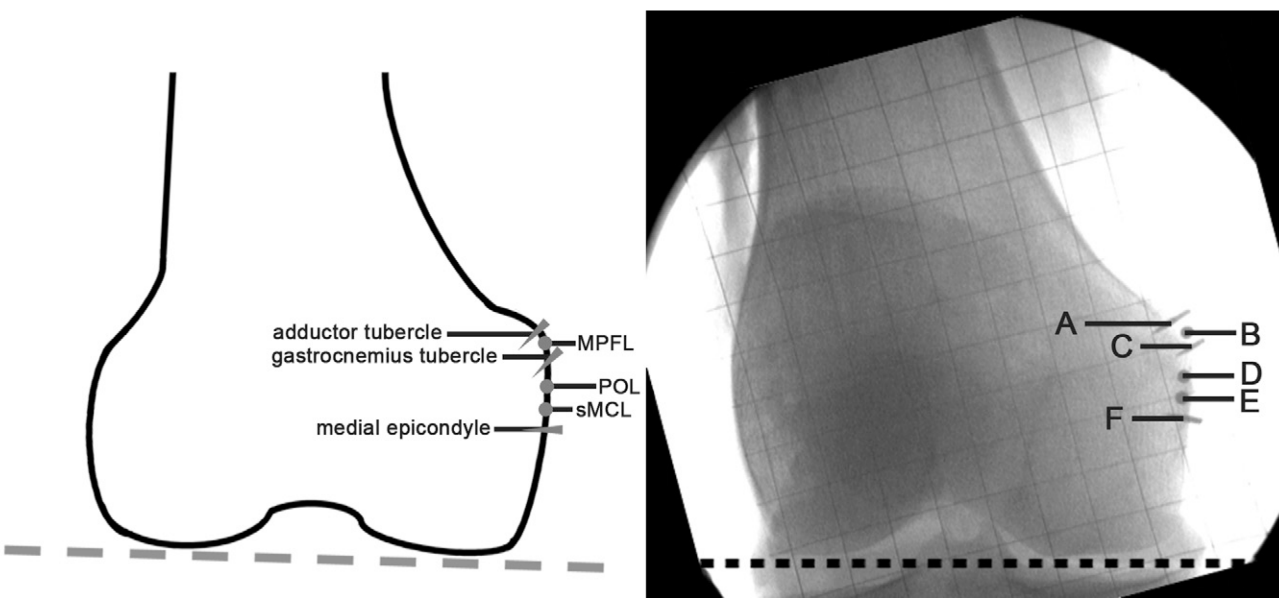

Fig. 2

Illustration (left) and anteroposterior knee radiograph (right) demonstrating the placement of the reference line intersecting the distalmost points of the lateral and medial femoral condyles. A = adductor tubercle, B = medial patellofemoral ligament (MPFL) attachment, C = gastrocnemius tubercle, D = posterior oblique ligament (POL) attachment, E = superficial medial collateral ligament (sMCL) attachment, and F = medial epicondyle.

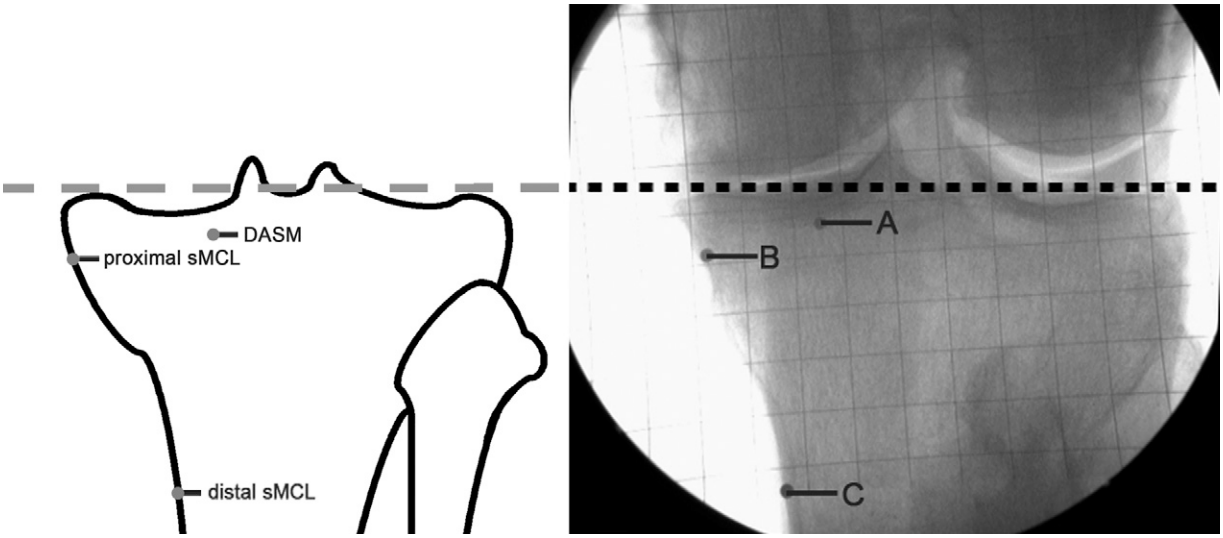

Fig. 3

Illustration (left) and anteroposterior knee radiograph (right) demonstrating the placement of a reference line crossing the most proximal aspects of the lateral and medial tibial plateaus. A = direct arm of semimembranosus muscle (DASM) attachment, B = proximal tibial superficial medial collateral ligament (sMCL) attachment, and C = distal tibial superficial medial collateral ligament attachment.

The purpose of the present study was to qualitatively and quantitatively define radiographic landmarks for the locations of the femoral and tibial attachments of the superficial medial collateral ligament and the femoral attachment sites of the medial patellofemoral ligament and posterior oblique ligament. Our hypothesis was that a standardized radiographic mea-

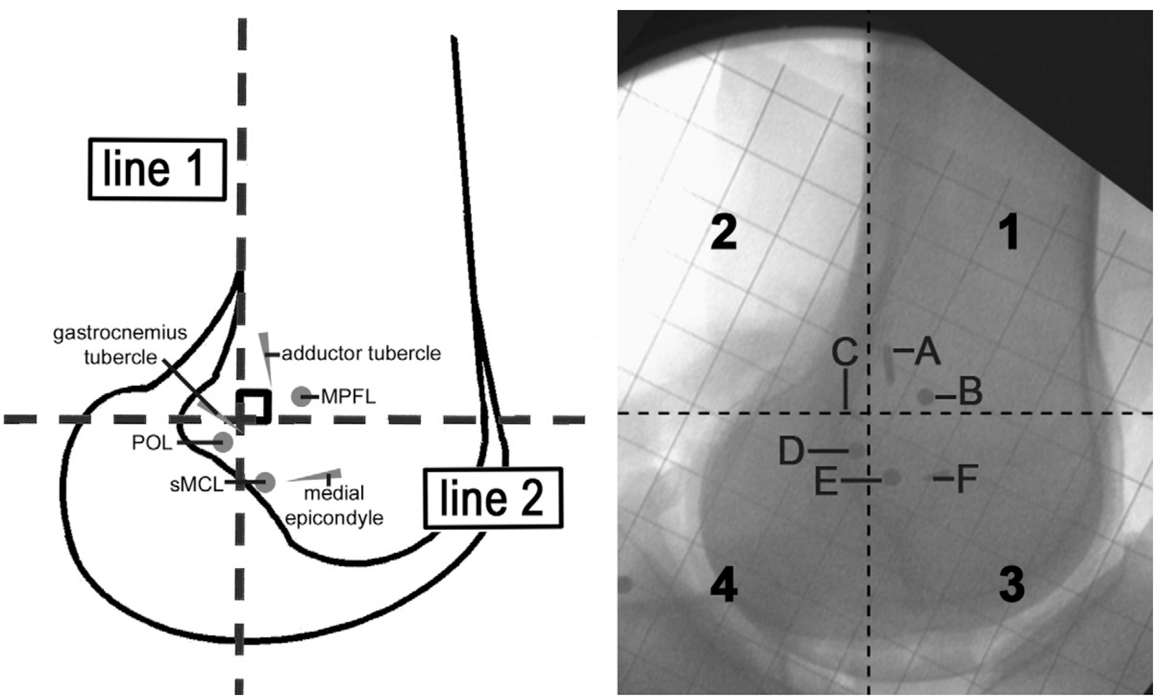

Fig. 4

Illustration (left) and lateral knee radiograph (right) demonstrating the placement of the femoral reference lines. Line 1 was drawn as an extension of the posterior femoral cortex, and line 2 was drawn perpendicular to line 1 and passed through the posterior portion of the Blumensaat line. The numbers 1 through 4 in the radiograph indicate quadrants of the lateral aspect of the distal part of the femur. A = adductor tubercle, B = medial patellofemoral ligament (MPFL) attachment, C = gastrocnemius tubercle, D = posterior oblique ligament (POL) attachment, E = superficial medial collateral ligament (sMCL) attachment, F = medial epicondyle, quadrant 1 = anteroproximal, quadrant 2 = posteroproximal, quadrant 3 = anterodistal, and quadrant 4 = posterodistal.

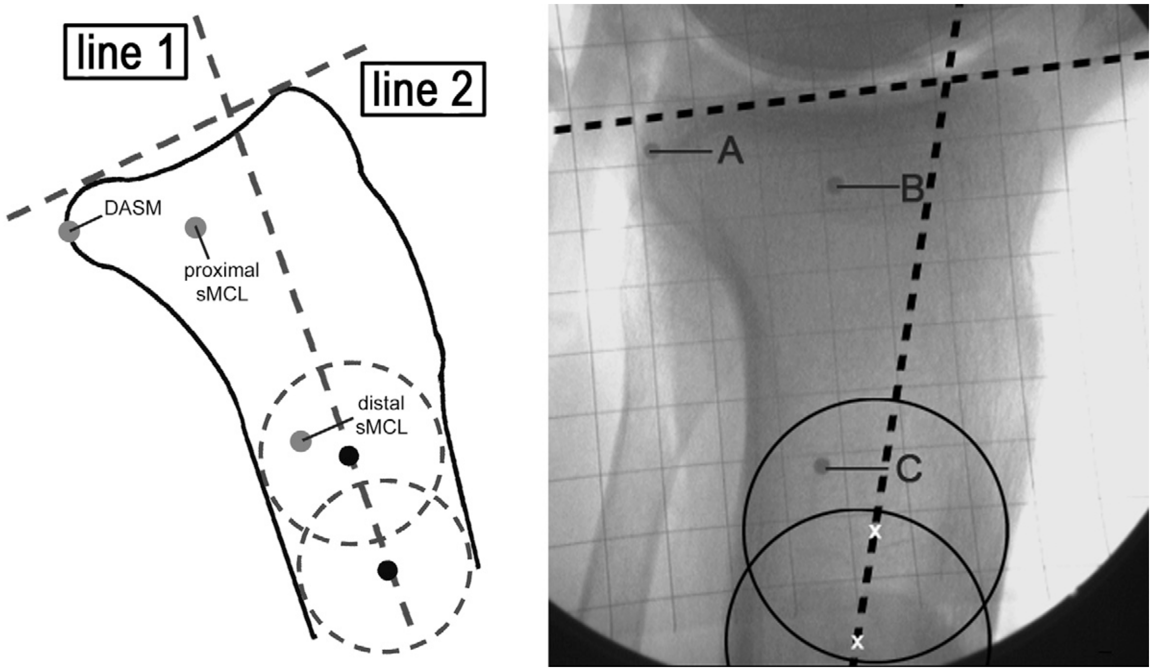

Fig. 5

Illustration (left) and lateral knee radiograph (right) demonstrating the technique used to identify the center of the tibial diaphyseal axis (line 1) and the line parallel to the medial tibial plateau (line 2). A = direct arm of semimembranosus muscle (DASM) attachment, B = proximal tibial superficial medial collateral ligament (sMCL) attachment, and C = distal tibial superficial medial collateral ligament attachment.

surement method would reproducibly describe the locations of these important medial knee attachment sites in reference to each other, to projected radiographic reference lines, and to other osseous and soft-tissue medial knee landmarks.

Materials and Methods

Specimen Preparation

Eleven fresh-frozen, nonpaired cadaveric knees from donors who had had a mean age of 72.2 years (range, forty-five to eighty-nine years) and no evidence of previous ligament injury, large osteophytes, or prior disease were utilized for the present study. The sartorius, gracilis, and semitendinosus muscles and tendons were isolated and detached from their tibial attachments. Deeper dissection isolated the direct arm of the semimembranosus, the medial epicondyle, the adductor tubercle, the gastrocnemius tubercle, and the osseous attachments of the superficial medial collateral ligament, posterior oblique ligament, and medial patellofemoral ligament. The soft tissues were then removed from six attachments: (1) the femoral attachment of the superficial medial collateral ligament, (2) the proximal tibial attachment of the superficial medial collateral ligament (described as the point where the anterior arm of the semimembranosus crosses deep to the superficial medial collateral ligament)[15], (3) the distal tibial attachment of the superficial medial collateral ligament, (4) the femoral attachment of the posterior oblique ligament, (5) the femoral attachment of the medial patellofemoral ligament, and (6) the tibial attachment of the direct arm of the semimembranosus. A 2-mm stainless steel sphere (Small Parts, Miami Lakes, Florida) was embedded into the center of each attachment site by placing the sphere within the center of an osteochondral transfer device (OATS system; Arthrex, Naples, Florida) that corresponded to the diameter of the attachment site of the respective structure and by using a small mallet to drive the sphere into the subchondral bone. The sharp ends of 1-mm-diameter T-pins (Advantus, Jacksonville, Florida), cut to approximately 5 mm in length, were embedded flush with the cortical bone surface at the centers of the medial epicondyle, the adductor tubercle, and the gastrocnemius tubercle (Fig. 1).

Image Collection and Measurements

With use of a fluoroscopy C-arm (OEC Miniview 6800 Mobile Imaging System; GE OEC Medical Systems, Salt Lake City, Utah), the locations of the previously identified landmarks were captured on true anteroposterior and lateral radiographs. The knees were positioned at 30° of flexion for lateral images and in full extension for anteroposterior images. True anteroposterior radiographs were made by superimposing the anterior and posterior margins of the tibial plateaus on each other and positioning the tibial eminences in the center of the femoral condyles[23]. True lateral radiographs were made by superimposing the posterior aspects of the medial and lateral femoral condyles on each other. A 1 × 1-cm radiopaque grid was included on all radiographs to correct for any magnification disparity between specimens.

Measurements were collected with use of a picture archiving and communication system (PACS) program (Imagecast; IDX

TABLE I Quantitative Relationships of Medial Knee Structures to Landmarks and Reference Lines on Femoral Anteroposterior Radiograph

Relationship	Distance* *(mm)*
Distance from femoral attachment of superficial medial collateral ligament to:	
Femoral condylar line	30.5 ± 2.4
Medial epicondyle	2.8 ± 1.1
Adductor tubercle	17.9 ± 0.4
Gastrocnemius tubercle	11.0 ± 2.5
Posterior oblique ligament	5.9 ± 2.1
Medial patellofemoral ligament	12.2 ± 2.4
Distance from femoral attachment of posterior oblique ligament to:	
Femoral condylar line	34.8 ± 2.7
Medial epicondyle	7.0 ± 2.0
Adductor tubercle	13.3 ± 1.1
Gastrocnemius tubercle	6.6 ± 1.6
Medial patellofemoral ligament	7.7 ± 1.3
Distance from femoral attachment of medial patellofemoral ligament to:	
Femoral condylar line	42.3 ± 2.1
Medial epicondyle	13.3 ± 2.4
Adductor tubercle	6.2 ± 1.5
Gastrocnemius tubercle	3.1 ± 1.0

*The values are given as the mean and the standard deviation.

Systems [division of GE Healthcare], Burlington, Vermont). Distances between structure attachments were measured to the center of the radiopaque markers, while measurements to the medial epicondyle, gastrocnemius tubercle[15], and adductor tubercle were made to the blunt ends of the T-pins, which were, as previously stated, flush with the edge of the osseous cortex.

Interstructure distances as well as perpendicular distances between structures and reference lines were measured by three independent examiners with differing experience levels, including a research fellow (Examiner 1 [C.A.W.]), a fourth-year medical student (Examiner 2 [C.J.G.]), and a board-certified orthopaedic surgeon (Examiner 3 [R.F.L.]). All measurements were repeated after an interval of at least two weeks in order to limit any recall bias. Each observer was blinded to the others' readings.

On the anteroposterior radiographs, the positions of femoral landmarks were measured perpendicular to a reference line drawn tangential to the most distal aspect of the femoral condyles (Fig. 2). Similarly, tibial landmarks were measured perpendicular to a reference line intersecting the most proximal aspects of the medial and lateral tibial plateaus (Fig. 3). On the lateral radiographs, femoral structures were measured both in relation to a reference line projected distally along the posterior femoral cortex and also in relation to a reference line that intersected the posterior aspect of the Blumensaat line and was perpendicular to the posterior femoral cortex extension line (Fig. 4)[24]. The locations of the tibial attachments on the lateral radiographs were determined by measuring the distances between the structures and a reference line defining the diaphyseal axis of the tibia[25]. Two circles (one proximal circle, which was immediately distal to the tibial tubercle, and one distal circle, which was approximately 3 cm distal to the first circle) were digitally created in the PACS program such that the anterior and posterior tibial diaphyseal cortices were tangential to the circumferences of the circles. A line drawn intersecting the centers of both circles represented the diaphyseal axis. Finally, a line that represented the tibial slope was drawn parallel to the anterior and posterior edges of the medial tibial plateau on the lateral radiographs (Fig. 5).

Statistical Analysis

Statistical analysis was performed to examine intraobserver reproducibility and interobserver reliability. Single-measure intraclass correlation coefficients were calculated to determine variability within and among observers for measurement groups[26]. Intraclass correlation coefficients of >0.75 were considered excellent[27].

Source of Funding

In support of the present study, grants from the Research Council of Norway (grant #175047/D15) and Health East Norway (grant #10703604) were used to pay for the salaries of laboratory personnel, University of Minnesota overhead expenses, supplies, illustrations, cadaveric knees, travel costs for the Norwegian authors, and other such expenses related to the study.

Results

All measurements were made in reference to the centers of the structures' attachment sites and are reported as the average and the standard deviation. For the purposes of the present study, we defined positions anterior or proximal to the

TABLE II Quantitative Relationships of Medial Knee Structures to Landmarks and Reference Lines on Tibial Anteroposterior Radiograph

Relationship	Distance* *(mm)*
Distance from proximal tibial attachment of superficial medial collateral ligament to:	
Tibial plateau line	−11.2 ± 3.5
Distal attachment of superficial medial collateral ligament	50.4 ± 5.0
Distance from distal tibial attachment of superficial medial collateral ligament to:	
Tibial plateau line	−60.1 ± 5.5
Distance from direct arm of semimembranosus muscle to:	
Tibial plateau line	−10.9 ± 3.7

*The values are given as the mean and the standard deviation. Negative values indicate a position posterior or distal in relation to the reference line.

TABLE III Quantitative Relationships of Medial Knee Structures to Landmarks and Reference Lines on Femoral Lateral Radiograph

Relationship	Distance* *(mm)*
Distance from femoral attachment of superficial medial collateral ligament to:	
Posterior femoral cortex extension line	8.6 ± 3.6
Perpendicular line to Blumensaat line†	−11.0 ± 2.3
Medial epicondyle	6.0 ± 0.8
Adductor tubercle	20.7 ± 2.9
Gastrocnemius tubercle	17.5 ± 2.7
Posterior oblique ligament	12.9 ± 3.0
Medial patellofemoral ligament	14.2 ± 2.6
Distance from femoral attachment of posterior oblique ligament to:	
Posterior femoral cortex extension line	−2.4 ± 4.4
Perpendicular line to Blumensaat line†	−5.6 ± 2.8
Medial epicondyle	18.1 ± 2.8
Adductor tubercle	16.4 ± 1.3
Gastrocnemius tubercle	7.7 ± 1.9
Medial patellofemoral ligament	14.2 ± 1.9
Distance from femoral attachment of medial patellofemoral ligament to:	
Posterior femoral cortex extension line	8.8 ± 5.3
Perpendicular line to Blumensaat line†	2.6 ± 2.1
Medial epicondyle	15.9 ± 3.2
Adductor tubercle	8.9 ± 2.0
Gastrocnemius tubercle	12.5 ± 3.0

*The values are given as the mean and the standard deviation. Negative values indicate a position posterior or distal in relation to the reference line. †Reference line perpendicular to the posterior femoral cortex extension reference line intersecting the posterior aspect of the Blumensaat line.

reference lines as having positive values and positions posterior or distal to the reference lines as having negative values. With regard to the anteroposterior radiographs, the line drawn parallel to the distal aspect of the femoral condyles was referred to as the femoral condylar line and the line that crossed the proximal aspect of the tibial plateaus was referred to as the tibial plateau line.

Results on the lateral femoral radiographs were qualitatively described according to their location with a quadrant[25]. The quadrants were created by two intersecting lines, one along the posterior femoral cortex and one perpendicular to the posterior femoral cortex extension reference line and passing through the posterior aspect of the Blumensaat line. The four quadrants created were the (1) anteroproximal, (2) posteroproximal, (3) anterodistal, and (4) posterodistal quadrants (Fig. 4).

Superficial Medial Collateral Ligament

Anteroposterior Radiographs

The femoral attachment of the superficial medial collateral ligament was 2.8 ± 1.1 mm proximal to the medial epicondyle, 17.9 ± 0.4 mm distal to the adductor tubercle, and 11.0 ± 2.5 mm distal to the gastrocnemius tubercle (Table I). The femoral attachment of the superficial medial collateral ligament was 5.9 ± 2.1 mm distal to the femoral posterior oblique ligament attachment point and 12.2 ± 2.4 mm distal to the femoral medial patellofemoral ligament attachment point. In addition, the femoral attachment of the superficial medial collateral ligament was 30.5 ± 2.4 mm proximal to the femoral joint line (Table I).

The proximal tibial attachment of the superficial medial collateral ligament was 11.2 ± 3.5 mm distal to the tibial joint line. The distal tibial attachment of the superficial medial collateral ligament was 60.1 ± 5.5 mm distal to the tibial joint line and 50.4 ± 5.0 mm distal to the proximal tibial attachment (Table II).

Lateral Radiographs

Qualitatively, the femoral attachment of the superficial medial collateral ligament was located in the anterodistal quadrant (Fig. 4). Quantitatively, it was 6.0 ± 0.8 mm from the medial epicondyle, 20.7 ± 2.9 mm from the adductor tubercle, and 17.5 ± 2.7 mm from the gastrocnemius tubercle (Table III). The femoral attachment of the superficial medial collateral ligament was 12.9 ± 3.0 mm from the femoral attachment of the posterior oblique ligament and 14.2 ± 2.6 mm from the femoral attachment of the medial patellofemoral ligament. With regard to the osseous reference lines, it was 8.6 ± 3.6 mm anterior to the posterior femoral cortex extension line and 11.0 ± 2.3 mm distal to the reference line perpendicular to the posterior femoral cortex and intersecting the posterior aspect of the Blumensaat line.

TABLE IV Quantitative Relationships of Medial Knee Structures to Landmarks and Reference Lines on Tibial Lateral Radiograph

Relationship	Distance* *(mm)*
Distance from proximal tibial attachment of superficial medial collateral ligament to:	
Diaphyseal axis of tibia	−26.5 ± 5.8
Tibial slope line	−15.9 ± 5.2
Distal attachment of superficial medial collateral ligament	51.7 ± 4.6
Direct arm of semimembranosus muscle	15.9 ± 3.0
Distance from distal tibial attachment of superficial medial collateral ligament to:	
Diaphyseal axis of tibia	−11.8 ± 3.2
Tibial slope line	−66.1 ± 3.6
Distance from direct arm of semimembranosus muscle to:	
Diaphyseal axis of tibia	43.0 ± 2.5
Tibial slope line	13.9 ± 3.5

*The values are given as the mean and the standard deviation. Negative values indicate a position posterior or distal in relation to the reference line.

TABLE V Quantitative Radiographic Measurement Comparison of Medial Knee Structures to Previously Defined Gross Anatomy Measurements

Relationship	Distance* *(mm)* Current Study†	Distance* *(mm)* LaPrade et al.[15]‡
Lateral radiograph		
Distance from femoral attachment of superficial medial collateral ligament to:		
Medial epicondyle	6.0 ± 0.8	6.4 (3.9 to 9.6)
Posterior oblique ligament	12.9 ± 3.0	11.1 (5.7 to 14.9)
Distance from femoral attachment of posterior oblique ligament to:		
Medial epicondyle	18.1 ± 2.8	16.5 (11.2 to 19.0)
Distance from attachment of medial patellofemoral ligament to:		
Medial epicondyle	15.9 ± 3.2	14.2 (6.9 to 18.8)
Anteroposterior radiograph		
Distance from femoral attachment of superficial medial collateral ligament to:		
Femoral condylar line	30.5 ± 2.4	26.8 (13.1 to 32.2)
Distance from proximal tibial attachment of superficial medial collateral ligament to:		
Tibial plateau line	−11.2 ± 3.5	−12.2 (−8.8 to −15.3)
Distance from distal tibial attachment of superficial medial collateral ligament to:		
Tibial plateau line	−60.1 ± 5.5	−61.2 (−52.4 to −70.5)
Proximal tibial attachment of superficial medial collateral ligament	51.7 ± 4.6	49.2 (41.7 to 55.9)
Distance from direct arm of semimembranosus to:		
Tibial plateau line	−10.9 ± 3.7	−12.1 (−9.2 to −14.9)

*Negative values indicate a position posterior or distal in relation to the reference line. †The values are given as the mean and the standard deviation. ‡The values are given as the mean, with the range in parentheses.

The proximal tibial attachment of the superficial medial collateral ligament was located 51.7 ± 4.6 mm from the distal tibial attachment of the superficial medial collateral ligament and 15.9 ± 3.0 mm from the attachment of the direct arm of the semimembranosus muscle (Table IV). Overall, it was 26.5 ± 5.8 mm posterior to the tibial diaphyseal axis and 15.9 ± 5.2 mm distal to the tibial slope line. The distal tibial attachment of the superficial medial collateral ligament was 11.8 ± 3.2 mm posterior to the tibial diaphyseal axis line and 66.1 ± 3.6 mm distal to the tibial slope line.

Posterior Oblique Ligament

Anteroposterior Radiographs

The femoral attachment of the posterior oblique ligament was 34.8 ± 2.7 mm proximal to the femoral joint line. It was 7.0 ± 2.0 mm proximal to the medial epicondyle, 13.3 ± 1.1 mm distal to the adductor tubercle, 6.6 ± 1.6 mm distal to the gastrocnemius tubercle, and 7.7 ± 1.3 mm distal to the medial patellofemoral ligament attachment point (Table I).

Lateral Radiographs

Qualitatively, the femoral attachment of the posterior oblique ligament was located in the posterodistal quadrant (Fig. 4). Quantitatively, the posterior oblique ligament attachment was 18.1 ± 2.8 mm from the medial epicondyle, 16.4 ± 1.3 mm from the adductor tubercle, 7.7 ± 1.9 mm from the gastrocnemius tubercle, and 14.2 ± 1.9 mm from the medial patellofemoral ligament attachment site. With regard to the reference lines, the posterior oblique ligament attachment was 2.4 ± 4.4 mm posterior to the posterior femoral cortex extension line and 5.6 ± 2.8 mm distal to the perpendicular line at the posterior aspect of the Blumensaat line (Table III).

Medial Patellofemoral Ligament

Anteroposterior Radiographs

The femoral attachment of the medial patellofemoral ligament was 42.3 ± 2.1 mm proximal to the femoral joint line. It was 13.3 ± 2.4 mm proximal to the medial epicondyle, 6.2 ± 1.5 mm distal to the adductor tubercle, and 3.1 ± 1.0 mm proximal to the gastrocnemius tubercle (Table I).

Lateral Radiographs

Qualitatively, the medial patellofemoral ligament femoral attachment was in the anteroproximal quadrant (Fig. 4). Quantitatively, the medial patellofemoral ligament was 15.9 ± 3.2 mm from the medial epicondyle, 8.9 ± 2.0 mm from the adductor tubercle, and 12.5 ± 3.0 mm from the gastrocnemius tubercle. With regard to the femoral reference lines, it was 8.8 ± 5.3 mm anterior to the posterior femoral cortex extension line and 2.6 ± 2.1 mm proximal to the perpendicular line at the posterior aspect of the Blumensaat line (Table III).

Data Analysis

Intraobserver intraclass correlation coefficients were 0.996, 0.995, and 0.997 for Examiners 1, 2, and 3, respectively. The overall combined intraobserver intraclass correlation coefficient was 0.996, which demonstrates a high likelihood that the examiners were able to consistently draw accurate reference lines and to obtain reproducible measurements between these medial knee structures. Interobserver reliability was assessed between each of the examiners in the first and second trials as well as for both trials combined. There was no significant difference between examiners for either trial state. The overall interobserver intraclass correlation coefficient for the combined trial was 0.994, which indicates that persons not involved with this study would have a high probability of measuring similar distances between these medial knee structures on the same radiographs.

Discussion

Reconstructions of chronic medial knee injuries have been associated with varying success rates, and one reason for this inconsistency might be imprecise reattachment of the repaired or reconstructed structures. We found that we were able to consistently assess, both qualitatively and quantitatively, the anatomic attachment sites of the superficial medial collateral ligament, the posterior oblique ligament, and the femoral insertion of the medial patellofemoral ligament on standard radiographs. These attachment sites were correlated with known radiographic locations on the distal part of the femur and proximal part of the tibia and with standard radiographic reference lines. All examiners were able to reproducibly and accurately measure the distances between attachment sites and the projected reference lines despite a variability in experience level, as evidenced by the high interobserver and intraobserver intraclass correlation coefficients. This observation is important because it demonstrates that these guidelines can be utilized by surgeons unfamiliar with the complex anatomy associated with chronic or revision medial knee injuries. The qualitative descriptions of the femoral attachment sites on the lateral radiographs are important because they allow these results to be applied to both large and small knees. Furthermore, the qualitative descriptions also can be an effective method for intraoperative verification of tunnel placement on fluoroscopy or plain radiographs, similar to the common intraoperative practice for radiographic confirmation of tibial tunnel location during posterior cruciate ligament reconstruction[28].

Our results compare well with those of one previous study in which the investigators quantitatively determined the anatomic locations of these attachment sites and osseous landmarks[15]. For example, on anteroposterior radiographs, the distances from the femoral and tibial attachments of the superficial medial collateral ligament to the femoral and tibial joint lines, and the distance from the attachment of the direct arm of the semimembranosus tendon to the tibial joint line, are very close between the two studies (Table V). Furthermore, comparison of the results of the two studies with regard to the distances between the medial epicondyle and the superficial medial collateral ligament, the posterior oblique ligament, and the medial patellofemoral ligament on lateral radiographs yielded measurement differences of ≤1.8 mm. These slight differences in measurements may be due to the fact that the previous study utilized three-dimensional distances between structures, whereas radiographs only allow measurement of two-dimensional distances. Overall, we believe that the similar measurements between the two studies further validate the radiographic findings of the present study.

A qualitative review of the structure attachment sites reveals that, on the anteroposterior radiographs, the superficial medial collateral ligament had the most distal femoral attachment of the investigated structures, with the posterior oblique ligament attaching slightly proximal to it. The medial patellofemoral ligament was the most proximal soft-tissue attachment on the medial femoral condyle and was located approximately 1.5 times the distance from the femoral condylar line in comparison with the attachment of the superficial medial collateral ligament. On the lateral radiographs, evaluation of the femoral landmarks of the medial knee structures revealed that the posterior oblique ligament was located slightly posterior and was the closest structure to the posterior femoral cortex extension line whereas the superficial medial collateral ligament was located anterior to this reference line and nearly equidistant from this line as the medial patellofemoral ligament was. In addition, both the posterior oblique ligament and the superficial medial collateral ligament were located distal to the perpendicular line through the posterior aspect of the Blumensaat line.

We found similarities between our study and the study by Schottle et al.[24] in terms of the qualitative location of the femoral attachment of the medial patellofemoral ligament. In both studies, the femoral attachment of the medial patellofemoral ligament was found to be located anterior to the posterior femoral cortex extension line and proximal to the perpendicular line at the posterior aspect of the Blumensaat line. However, we did find quantitative differences between these studies. In the present study, we found that the medial patellofemoral ligament was located an average of 8.8 mm anterior to the posterior femoral cortex extension line and 2.6 mm proximal to the perpendicular line through the posterior aspect of the Blumensaat line, which correlates with the femoral location of the medial patellofemoral ligament in a previously published quantitative anatomic study[15]. In the study by Schottle et al., this attachment was reported to be located 1.3 mm anterior and 5.5 mm proximal, respectively, to these projected lines, which, on the basis of the previous quantitative anatomic study[15], is defined as the location of the adductor tubercle. However, Schottle et al. did not utilize a mechanism of specimen calibration (i.e., a 1 × 1-cm calibration grid), nor did they perform intraclass or interclass correlations between examiners to validate their readings.

One of the limitations of the present study was that it involved a small number of specimens (n = 11); however, the number of specimens was greater than the number of specimens (n = 8) in a study investigating the radiographic location of the femoral attachment of the medial patellofemoral ligament[24]. In addition, our specimens were from donors who had been older than the usual ages of patients who undergo medial knee surgery, but the soft-tissue attachment sites and osseous landmarks of interest do not vary with age and our specimens had no evidence of previous injury or large osteophyte formation. The age range in the present study also compares favorably with that in a study that defined the anatomy of the medial part of the knee[15]. After analysis of our data, we can conclude that our measurements were highly correlative. Furthermore, joint-space narrowing resulting from mild osteoarthritis, not observable on gross examination, did not affect the results as no measurements were made across the joint line.

In conclusion, we believe that the attachment locations of the main medial knee structures can be qualitatively and quantitatively correlated to osseous landmarks and projected radiographic lines, which will allow for more consistent radiographic assessments of anatomic repairs and reconstructions. Utilization of these radiographic guidelines will allow for improved identification of the medial knee structure attachment sites and for preoperative, intraoperative, and postoperative assessments of surgical repairs and reconstructions of the main medial knee structures. ■

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