Morphology of the Insertions of the Superficial Medial Collateral Ligament and Posterior Oblique Ligament Using 3-Dimensional Computed Tomography: A Cadaveric Study

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Purpose: To describe the insertions of the superficial medial collateral ligament (sMCL) and posterior oblique ligament (POL) and their related osseous landmarks. **Methods:** Insertions of the sMCL and POL were identified and marked in 22 unpaired human cadaveric knees. The surface area, location, positional relations, and morphology of the sMCL and POL insertions and related osseous structures were analyzed on 3-dimensional images. **Results:** The femoral insertion of the POL was located 18.3 mm distal to the apex of the adductor tubercle (AT). The femoral insertion of the sMCL was located 21.1 mm distal to the AT and 9.2 mm anterior to the POL. The angle between the femoral axis and femoral insertion of the sMCL was 18.6°, and that between the femoral axis and the POL insertion was 5.1°. The anterior portions of the distal fibers of the POL were attached to the fascia cruris and semimembranosus tendon, whereas the posterior fibers were attached to the posteromedial side of the tibia directly. The tibial insertion of the POL was located just proximal and medial to the superior edge of the semimembranosus groove. The tibial insertion of the sMCL was attached firmly and widely to the tibial crest. The mean linear distances between the tibial insertion of the POL or sMCL and joint line were 5.8 and 49.6 mm, respectively. **Conclusions:** This study used 3-dimensional images to assess the insertions of the sMCL and POL and their related osseous landmarks. The AT was identified clearly as an osseous landmark of the femoral insertions of the sMCL and POL. The tibial crest and semimembranosus groove served as osseous landmarks of the tibial insertions of the sMCL and POL. **Clinical Relevance:** By showing further details of the anatomy of the knee, the described findings can assist surgeons in anatomic reconstruction of the sMCL and POL.

The superficial medial collateral ligament (sMCL) and posterior oblique ligament (POL) are the 2 main static stabilizers of the medial side of the knee.[1,2] They act as primary restraints to valgus stress and internal rotation, respectively.[3,4] Together, they are also secondary restraints to valgus, rotatory, anterior, and posterior stresses[5-8] and have a complementary relation to achieve posteromedial stability.[4,5,9-11] Thus, injuries to the sMCL and POL can result in clinically significant valgus or rotational instability.[3,12] Furthermore, dysfunction of the sMCL and POL can increase the risk of damaging associated ligamentous structures, such as native and reconstructed anterior cruciate ligaments.[8,12,13] The medial collateral ligament (MCL) is the ligamentous structure of the knee that is injured most frequently. Most MCL injuries are isolated and can be treated nonsurgically with excellent results. However, combined sMCL and POL injuries can lead to chronic instability, which causes functional limitations and osteoarthritis.[14]

Treatment of sMCL and POL injuries of the knee remains controversial. Numerous surgical methods for the repair or reconstruction of these ligaments have been reported, with recent studies showing better clinical

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results with reconstruction than with repair.[15-17] An anatomic method for reconstruction of the medial knee has been shown to achieve near-normal stability.[18,19] However, a recent systematic review showed that most medial reconstruction methods are nonanatomic: On the basis of a review of 4,600 references, only 2 methods were classified as "anatomic reconstructions."[20]

Insertions of the sMCL and POL have been described in several anatomic studies, but only a few have focused on the positional relation between them and the related osseous landmarks (especially with regard to the tibial insertion of the POL).[3,19,21,22] A prerequisite for the precise repair or anatomic reconstruction of the sMCL and POL is definition of the optimal positions of those insertions and assessment of their related osseous landmarks. The aim of this study was to describe the insertions of the sMCL and POL and their related osseous landmarks. We hypothesized that these insertions and their related osseous landmarks would be consistent among individuals.

Methods

Specimen Preparation

The 22 unpaired human cadaveric knees (18 male and 4 female specimens; age range, 61-92 years; mean age, 78 years) used in this study had no severe macroscopic degenerative or traumatic changes. All cadavers had been fixed in 10% formalin and preserved in 50% alcohol for 6 months. This cadaveric study was approved by our institutional review board (H27-99). Preparation began by removing the skin and soft subcutaneous tissue on the medial side of the knee, followed by removal of the sartorius, gracilis, and semitendinosus muscles. Then, the medial retinaculum and medial patellofemoral ligament were peeled away from the sMCL and POL, which allowed the latter 2 ligaments to be identified and observed grossly. The sMCL was dissected from the tibial side. Tibial insertions of the sMCL had 2 distinct attachments located at the proximal and distal portions of the bone. However, because the proximal tibial insertion of the sMCL was merged with the deep MCL, the outline of the insertion could not be defined. The distal tibial insertion of the sMCL was broad based and attached strongly and directly to the bone. We then cut the sMCL between the proximal and distal tibial insertions and lifted it off, leaving the underlying deep MCL intact. The sMCL was attached loosely to the anterior portion of the POL and thus separated readily. Dissection of the POL from the femoral side showed that it was located superficial to the medial joint capsule in an extra-articular layer. This position allowed its release from the articular capsule. The POL was cut at its midsubstance and dissected, but the underlying capsule was left intact. The anterior portion of the POL was also dissected from the semimembranosus tendon (SM) and fascia cruris. Turning over the dissected SM revealed the tibial insertion of the POL. Insertions of the sMCL and POL were defined as the areas of the ligament fiber arising from the femur and tibia, respectively. Native insertions of both ligaments were outlined using a drill (diameter, 1.2 mm), with care taken to avoid destruction of the bone and surrounding structures.

Three-Dimensional Measurements and Visualization

Knees were imaged using a 16-row multislice computed tomography (CT) scanner (ECLOS; Hitachi Medical, Tokyo, Japan). Axial-plane images with 0.5-mm slices were obtained and saved as Digital Imaging and Communications in Medicine (DICOM) data. All digital imaging data were uploaded to dedicated software (Mimics, version 15.0, and MedCAD module; Materialise, Leuven, Belgium), and 3-dimensional (3D) images of the knee were created and referenced off the bone automatically. Then, images were used to analyze the insertion sites of the sMCL and POL as well as the related osseous structures. Insertion sites were marked and colored automatically using dedicated software. They were referenced off the bone, which was outlined by a drill during dissection. The surface area of the insertions was calculated from the 3D images using the aforementioned software, which automatically defines the center of the insertion site as the centroid of the area. Apices of the related osseous structures were determined as the furthest-protruding points, based on coronal CT images of the femur and tibia. Linear distances and angles between the center of the insertions of the sMCL and POL and the apex of the related osseous landmarks were measured on the 3D images. The accuracy of the length and area measurements was less than 0.1 mm and less than 0.1 mm^2, respectively. Comparison of the accuracy of the 3D models generated from the CT data with the optical scan showed that the mean error was 0.2 ± 0.31 mm, or approximately one-third of the pixel size.[23] The tolerance and margin of error of the CT measurements (according to the manufacturer) were ± 0.39 mm. The distribution of each variable was checked for normality using the Kolmogorov-Smirnov test. Statistical data were calculated using SPSS software (version 20.0; IBM, Armonk, NY).

We used a coordinate plane to standardize and ensure the reproducibility of the size variation of each cadaver, which had a normal distribution. A true lateral view of the femur and tibia was created based on the methods of Fujino et al.[24] and Tajima et al.[25] With the dedicated software in transparent mode ("toggle transparency"), the 3D images of the femur were set so that the posterior portions of the medial and lateral femur condyle overlapped. The 3D images of the tibia were set so that the medial and lateral aspects of the tibial plateau overlapped, after which the images were adjusted to the medial and lateral posterior tibial condyle. These images were projected onto a 2-dimensional view, and