Radiographic Landmarks for Tunnel Positioning in PCL Reconstructions

Introduction: Recent reports have highlighted precise qualitative and quantitative measurements of the attachment centers of the anterolateral bundle (ALB) and posteromedial bundle (PMB) of the posterior cruciate ligament (PCL) to the femur and tibia [1,2,3]. Despite these data, there remains a lack of information relating recent advances in knowledge of PCL anatomy to surgical methods for anatomical tunnel placement. Radiography is a standard method of assessing tunnel placement during reconstruction surgeries. This study aimed to establish quantitative and qualitative radiographic guidelines for identifying the femoral and tibial attachment sites of the ALB and PMB of the native PCL.

Materials and Methods: Twenty non-paired specimens were dissected and their PCL bundles separated, excised from the bone, and attachment centers labeled using 2-mm metal spheres. The medial intercondylar ridge (MIR) was labeled on the femur and the bundle ridge (BR) on the tibia using soldering wire. The posterior root attachments of the menisci and inferolateral corner of the shiny white fibers (SWF) of the posterior horn of the medial meniscus were labeled using 1-mm diameter t-pins of varying length.

Radiographs of the femur and tibia were obtained from the anteroposterior (AP) view at full-extension and the lateral view. To assess bundle attachment margins, the bundle attachment area was labeled using a radio-opaque barium sulfate (BaSO4) emulsion. Lateral femur, AP tibia (not reported), and lateral tibia (not reported) views were repeated after the addition of BaSO4.

Measurements were conducted using a picture archiving and communication system (PACS). Femoral measurements included bundle attachment centers and margins to reference lines either parallel or perpendicular to the long axis of the bone and intersecting the distal joint lines, MIR, medial epicondyle, apex of the intercondylar notch, and Blumensaat’s line. Similar measurements were taken on the tibia of distances to a line along the center of the long axis of the tibia, a horizontal line intersecting the champagne-glass drop-off (CGD), the tibial eminences, the posterior root attachments, the bundle ridge, and the perpendicular distance of a line mimicking a guide wire running at a 45° angle from the bundle ridge to a parallel line intersecting the nearest margin of the posterior tibia.

Results: On the AP femur view (Fig. 1A), the ALB and PMB centers were located 14.1 and 15.7 mm superior to the distal joint line, respectively (+/- 1.2 and 2.0). The ALB center was located 33.9 mm lateral to the medial epicondyle line (+/- 3.0), and the PMB center was located 29.1 mm lateral to this line (+/- 3.0).

Measurements on the lateral femur images (not shown) revealed that the ALB center was located 4.8 mm posteroinferior and perpendicular to Blumensaat’s line (+/- 1.3). The PMB center was located 10.6 mm posteroinferior and perpendicular to Blumensaat’s line (+/- 1.4). The ALB center was located 13.7 mm superior to the distal condyle line (+/- 1.4), while the PMB center was located 15.0 mm superior to this line (+/- 2.0).

On the lateral femur view with BaSO4 (Fig. 1B), the near and far margins of the ALB were 1.9 and 9.9 mm posteroinferior and perpendicular to Blumensaat’s line (+/- 0.9 and 1.7), while the near and far margins of the PMB were located 15.3 and 8.1 mm from Blumensaat’s line with the same orientation (+/- 1.6 and 1.5). The superior and inferior margins of the ALB were 18.8 and 7.6 mm superior to the distal condyle line (+/- 1.9 and 3.8), while the superior and inferior margins of the PMB were located 20.3 and 9.2 mm superior to the distal condyle line (+/- 2.5 and 1.8). The geometric center point of the femoral PCL attachment was located 8.1 mm posteroinferior and perpendicular to Blumensaat’s line (+/- 1.4), and 14.1 mm superior from the distal condyle line (+/- 1.7).

Analysis of the AP tibia images (not shown) revealed that the ALB and PMB centers were located 0.1 mm proximal and 5.1 mm distal to the proximal joint line, respectively (+/- 2.2 and 3.0). In reference to the lateral tibial eminence, the ALB and PMB were located 5.1 and 4.0 mm medial, respectively (+/- 2.0 and 1.7).

On the lateral tibia view (Fig. 1C), the ALB and PMB centers were located 9.2 and 3.4 mm superior to the CGD, respectively (+/- 2.1 and 2.1), while the BR was 6.5 mm superior to the CGD (+/- 2.0). The ALB was located 3.7 mm anterosuperior and perpendicular to the bundle ridge (+/- 1.1), while the PMB was located 3.7 mm posteroinferior and perpendicular to the bundle ridge (+/- 0.9). Lastly, the guide wire line was located 7.2 mm anterosuperior from the nearest concave edge of the posterior tibia.

Discussion: This study comprehensively identified radiographic guidelines of the native anatomy of the femoral and tibial bundle attachments of both the ALB and PMB of the PCL using clinically relevant radiographic landmarks. A limitation of the study is that the femoral PCL attachment center was superimposed rather than directly labeled with the individual bundles. This limits the study’s applicability in single-bundle reconstructions.

Significance: These findings can be directly applied to proper tunnel positioning intraoperatively during PCL reconstruction, and also to assess proper tunnel placement post-operatively.

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