The Anatomic Characteristics of the Tibial Insertion of the Posterior Cruciate Ligament

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**Purpose:** The purpose of the study was to better define the tibial insertion of the posterior cruciate ligament (PCL) and to identify landmarks that could be used to aid in placement of independent tibial tunnels for a 2-bundle PCL reconstruction. **Type of Study:** Descriptive anatomic study. **Methods:** Ten knees from 8 cadavers were dissected and the PCL was identified. The ligament was peeled away from its insertion and the sides of the insertion site were measured and recorded. The 4 corners of the insertion site were identified and marked. Observations were made of the morphology of the insertion site and the presence of any reproducible anatomic landmarks. A note was made of landmarks that could be easily identified on all of the specimens by direct vision and by palpation with a probe. **Results:** The ligament consisted of 2 regions, 1 anterolateral, and 1 posteromedial, with a gradual change in the laxity of the ligament as the knee was passed through flexion and extension. The insertion site was situated in a depression between the plateaus of the tibia and extended below the articular surface. The average length ± standard deviation of the 4 sides was 128 ± 21.2 mm (medial side), 107 ± 26.5 mm (superior side), 160 ± 30.0 mm (lateral side), and 169 ± 34.5 mm (inferior side). The shape and sides of the insertion site were visually similar among the 10 specimens. The superolateral and superomedial corners were both represented by depressions and a reproducible ridge represented the inferior border. These structures could be visualized as well as palpated on all specimens. **Conclusions:** Based on the findings of this study, we describe the anatomic characteristics of the tibial footprint of the PCL. Anatomic reference points that represent the corners of the tibial insertion of the PCL were identified by direct vision or palpation consistently on all specimens included in the study. These reference points could potentially aid in the placement of an anterolateral and posteromedial tibial tunnel for a 2-tunnel PCL reconstruction. **Clinical Relevance:** Reproducible anatomic reference points exist at the tibial insertion of the PCL that can be identified by direct vision and palpation. These reference points may potentially aid in the placement of separate tibial tunnels for a 2-bundle PCL reconstruction. **Key Words:** Knee—Posterior cruciate ligament—Anatomy—Reconstruction.

Injuries of the posterior cruciate ligament (PCL) and the options for treating such injuries have received increasing attention in the orthopaedic literature. Whether these injuries require surgical treatment remains controversial. Some studies have suggested that patients with PCL deficiency treated nonoperatively may have symptomatic instability and pain, and may develop arthritic changes over time. Options for reconstruction of the ligament also remain controversial, and include both single- and 2-bundle reconstructions of the ligament.

The anatomy and biomechanics of the PCL have been described in the literature by numerous authors. The ligament lies within a synovial sheath reflected from the posterior capsule, but remains extra-articular. The synovium covers the PCL on the medial, lateral, and anterior aspects. The ligament runs from the medial wall of the femoral notch to the posterior aspect of the tibia, inserting in a fossa between the medial and lateral plateaus, be-
low the articular surface. The PCL has previously been shown to have an average length of 38 mm and an average width of 13 mm.\(^9,10\) The ligament is narrowest in its middle portion and becomes gradually wider as it approaches its insertions on the femur and tibia.\(^9,10\)

The PCL is located near the longitudinal axis of rotation. The ligament is directed vertically in the frontal plane and angles forward 30° to 45° in the sagittal plane, depending on the knee flexion angle. The ligament functions as the primary restraint to posterior displacement of the tibia, and as a secondary restraint to varus and valgus forces applied to the knee and external rotation of the tibia.\(^9,10\)

In 1975, Girgis et al.\(^9\) described 2 components of the PCL, although they stated that they were inseparable. This has become known as the 2-bundle concept of the PCL, which divides the ligament into anterolateral and posteromedial portions. The anterolateral bundle, which comprises approximately two thirds of the ligament, becomes taut in midrange knee flexion and resists posterior tibial translation from 40° to 120° of knee flexion.\(^9,11,12\) The posteromedial bundle, which becomes tight in extension and in hyperflexion, resists posterior tibial translation in extension and in knee flexion greater than 130°.\(^9,11,12\) The secondary stabilizers of the knee also provide a significant contribution to the total restraint to posterior tibial translation in full extension.\(^12\)

Single-bundle reconstructions of the PCL have focused on recreating the larger anterolateral bundle. The majority of these reconstructions also attempt to recreate the origin and insertion of the anterolateral bundle, and are generally tensioned with the knee in flexion.\(^7\) Follow-up studies of patients undergoing single-bundle reconstructions of the PCL have had variable results. Johnson et al.\(^6\) reported good results with this technique in 41 patients evaluated 2 to 10 years after PCL reconstruction. Of the patients evaluated postoperatively, 97% had a normal or grade 1 posterior drawer test, and there was a statistically significant improvement in postoperative Tegner, Lysholm, and Hospital for Special Surgery knee scores.\(^6\) Lipscomb et al.\(^13\) had inconsistent results in 25 patients evaluated at an average of 7 years after reconstruction. They found no change in the preoperative and postoperative posterior drawer examination in 52% of patients, and medial and patellofemoral compartment arthrosis in 60% of knee radiographs.\(^13\)

Cadaveric biomechanical studies of an intact PCL, as well as cadaveric studies of single-bundle PCL reconstructions, have shown that both bundles play an important role in resisting posterior tibial translation. As with the clinical studies, the cadaveric studies suggest that a single-bundle reconstruction corrects knee kinematics at high flexion angles, but results in residual laxity nearer to extension.\(^14-16\) These studies have gone further in defining the composition of the PCL, suggesting that the 2-bundle concept oversimplifies the anatomic structure of the ligament. The authors of these studies suggest that the ligament is better thought of as a continuum of fibers that tighten and loosen in a sequential fashion as the knee moves through a range of motion. This provides a restraint to posterior translation of the tibia at all angles as different fibers become tight at varying knee positions.\(^17\)

Although the structural complexity of the PCL presently precludes true anatomic reconstruction, the 2-bundle concept has been applied to reconstruction of a torn PCL in an attempt to decrease tibial translation in both flexion and extension. Numerous authors have described a 2-bundle reconstruction of the PCL, with 1 of the bundles tensioned in flexion and the other bundle tensioned in extension. These reconstructions have focused on separate femoral tunnels combined with either a single tibial tunnel, or with the use of the tibial inlay technique. The inlay technique makes use of a bone block inserted into the fossa of the PCL at the posterior aspect of the proximal tibia and a split graft that is brought through separate femoral tunnels.\(^4,5,8\)

The placement of the femoral tunnel has been of much greater focus in the literature than the placement of the tibial tunnel. Single-bundle reconstructions have focused on recreating the anterolateral bundle, thereby placing the tibial tunnel lateral in the tibial footprint of the PCL. Two-bundle reconstructions, using either the tibial inlay technique or a single tibial tunnel, tend to center the graft within the PCL stump, as the graft is generally Y-shaped with the single limb on the tibial side.\(^5,8\)

To completely separate the bundles in a reconstruction of the PCL, 2 separate tibial tunnels would have to be created to allow the grafts to be kept independent. This may allow a more accurate reconstruction of both bundles. Although the grafts may be tensioned separately in 1 tunnel, the use of 2 tibial tunnels would allow for independent interference-fit fixation of the separate grafts. In a review of the literature, a study by Racanelli and Drez\(^18\) was found that describes the tibial attachment anatomy and radiographic landmarks for tibial tunnel placement. However, this study did not provide measurements of the tibial footprint of the PCL and only described the location for a single tibial
tunnel. The purpose of the study was to better define the borders of the tibial insertion of the PCL and to identify landmarks that could be used surgically, both by vision and by feel, to aid in placement of independent tibial tunnels for a 2-bundle PCL reconstruction.

**METHODS**

**Specimen Preparation**

The study was designed to be a descriptive anatomic study. Ten knees from 8 cadavers were dissected in the Anatomy Department of the University of Alberta, in Edmonton. The average age of the specimens was 75 years. Four of the specimens were male and 4 were female, with both of the paired knees coming from a male specimen. Each of the specimens was inspected during the course of the dissection for any sign of previous surgery, ligament damage, osteophytes in the femoral notch, or joint contracture. Any of these findings would have excluded the specimen from inclusion in the study.

All of the knees had been previously embalmed and were taken from specimens used for educational purposes. The knees were used only for the purposes of this study and had not previously been used in the educational setting. The limb was removed from the cadaver after both it and the cadaver had been marked appropriately so as not to confuse the specimens. The specimens were cut at mid-femur and mid-tibia, and then placed into a vice to aid in the dissection.

A posterior approach to the knee was made down to the posterior capsule. All of the soft tissues outside of the capsule were removed to provide adequate visualization of the capsular insertions and allow for its careful removal. The capsule was opened and carefully removed to expose the posterior intra-articular structures of the knee. The synovial sheath surrounding the cruciate ligaments was also carefully removed to protect the ligaments as well as the meniscofemoral ligaments. The PCL was identified along with the anterior cruciate ligament and the posterior meniscofemoral ligament of Wrisberg.

The regions of the PCL were then identified by flexion and extension of the cadaveric knees. In all specimens, 2 independent bundles could not be identified. However, with flexion and extension it was possible to visualize the tightening of the different fiber regions. These regions were felt to represent the 2 bundles of the PCL. These bundles were then followed to their individual insertion sites.

Once the tibial insertion site and the 2 bundles of the PCL were clearly identified, the PCL was carefully peeled away from its insertion on the tibia. This was performed on all of the specimens. This allowed for a clear visualization of the borders of the insertion site because the underlying bone was of a different color and texture. The difference in the underlying bone permitted a clear demarcation of the borders of the tibial PCL insertion.

**Measurements and Anatomic Observations**

After careful removal of the PCL from the tibial insertion site, the insertion site of each specimen was marked and measured. Four points were identified and labeled SM, SL, IL, and IM, representing the superomedial, superolateral, inferolateral, and inferomedial corners of the PCL insertion, respectively. The distance between these points was labeled M, S, L, and I, representing the medial, superior, lateral, and inferior sides, respectively (Fig 1). These sides were measured and their lengths were recorded.

After taking the measurements, observations were made regarding the morphology of the insertion site...
and the presence of any reproducible anatomic landmarks. A note was made of landmarks that could be easily identified on all of the specimens by direct vision and by palpation with a probe.

**RESULTS**

**Insertion-Site Measurements**

The measurements obtained for each specimen are shown in Table 1. The average length ± standard deviation of the medial side (M) was 128 ± 21.2 mm. The superior side (S) averaged 107 ± 26.5 mm and the lateral side (L) measured 160 ± 30.0 mm. Finally, the inferior side (I) measured 169 ± 34.5 mm.

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**Anatomic Observations**

The ligament appeared as 2 regions located anterolaterally and posteromedially. These 2 regions were identifiable with flexion and extension of the knee. During flexion, the anterolateral band became taut and the posterior medial band was lax. During extension, the reverse occurred, with the anterolateral band becoming lax and the posteromedial band becoming taut. These 2 regions were not discreet but rather there was gradual change in the laxity of the ligament as the knee was moved through a full range of motion.

The bands could be traced along their length to their insertion sites in the tibia. The anterolateral band inserted at the superior and lateral aspect of the fossa while the posteromedial band inserted at the inferior and medial aspect of the fossa.

The posterior meniscofemoral ligament of Wrisberg was a discreet structure in the specimens in which it was present. It inserted into the posterior horn of the lateral meniscus and became taut with the knee in extension. The ligament was identified in 6 of the 10 specimens. The anterior meniscofemoral ligament of Humphrey was not seen in any specimen because the dissection techniques did not allow accurate identification of this structure.

The insertion site was situated in a depression or fossa between the plateaus of the tibia and extended below the articular surface. The shape of the insertion site was trapezoidal in appearance, with the medial and lateral sides relatively vertical, the inferior side horizontal, and the superior border diagonal sloping in an inferior direction from lateral to medial.

With the aid of a probe, the insertion fossa was readily identifiable as a discreet structure. The medial and lateral sides of the fossa could be followed with a probe as the walls were approximately 5 mm deep. The inferior extent of the fossa was also identifiable as a palpable ridge that ran across from medial to lateral.

The previously identified corners of the fossa, marked SM, SL, IL, and IM, were correlated with anatomic landmarks at the tibial fossa. A depression between the posterior insertions of the medial and lateral menisci could be visualized and easily palpated using a probe. This point, also palpable from the anterior aspect of the knee using a probe passed over the lateral tibial spine, represented point SL, the superolateral corner of the fossa.

The superomedial corner of the fossa, point SM, was represented by a depression located distal and medial to the depression representing point SL. As the probe was taken medially and slightly distal from the point SL, it fell into a second depression representing point SM. This is the point where the insertion fibers of the posterior horn of the medial meniscus could be seen to cross the articular cartilage tidemark. Point SM could also be located as the most posterior fibers of the medial meniscus were traced laterally to their insertion, where the probe fell off into a depression.

Points IL and IM, representing the inferolateral and inferomedial corners of the fossa, could be identified with a probe by passing it distally from points SL and SM, respectively, until the inferior ridge that defined the inferior border of the fossa was palpated. The 4 points, each palpable with a probe from both the anterior and posterior aspects of the knee, defined the corners of the tibial insertion of the PCL (Fig 2).
DISCUSSION

Insertion-Site Measurements and Anatomic Observations

Our review of the literature on the anatomy of the PCL did not provide us with a detailed description of the tibial insertion of the PCL. A study by Racanelli and Drez identified radiographic landmarks to aid in guidewire placement for a single tibial tunnel. This tunnel was to be used in single-bundle anterolateral PCL reconstruction. However, the authors did not attempt to measure the boundaries of the tibial insertion of the PCL, or identify a second tunnel location for a posteromedial bundle.

Based on the study findings, the tibial insertion can generally be described as trapezoidal in shape, with the superior border slanting inferiorly from lateral to medial. The insertion begins in a fossa located in between the posterior aspects of the medial and lateral plateau of the tibia and is level or just above the articular cartilage tidemark. The posterior horns of the medial and lateral menisci insert just above the superior border of the insertion. This fossa, demarcated by the articular cartilage tidemark medially and laterally, and the insertions of the menisci superiorly, defines the superior extent of the tibial insertion of the PCL.

The superolateral corner can be well visualized and is the easiest to define by palpation. A probe directed from the back of the knee or passed over the lateral tibial eminence will drop into the depression representing this corner. It is the most superior and lateral depression located in the tibial insertion site located just below the articular cartilage tidemark. The superomedial corner is also well visualized and relatively easy to define by palpation; a probe passed medially and slightly inferiorly will fall into a second depression that represents this corner. Both these landmarks could be visualized and palpated in all specimens and, although not all of the insertion sites were of the same size, these depressions were consistent in their location.

The inferior border of the tibial insertion of the PCL was also easily identifiable, both by vision and palpation, as a palpable ridge approximately 16 mm from the superolateral corner, point SL, and approximately 13 mm from the superomedial corner, point SM. As with the 2 previously described depressions, this ridge was consistently identifiable in all specimens and could be used to identify the 2 inferior corners of the tibial insertion. Racanelli and Drez also noted an inferior ridge that represented the inferior border of the tibial insertion of the PCL and was present in all of their specimens. They also commented that this ridge had not previously been described in the literature.

Tunnel Location

The anatomic landmarks corresponding to the corners of the PCL insertion were used to identify potential sites for independent tibial tunnel locations for a 2-bundle PCL reconstruction. In the case of the anterolateral tunnel, the superolateral depression, or point SL, was used as a reference point for this tunnel. Moving the probe approximately 3 mm medial and inferior placed the probe in a location that was felt to approximate the center of the anterolateral bundle. This point then became the center of the proposed anterolateral tunnel.

The posteromedial tunnel location was identified by first placing the probe in the superomedial depression, or point SM. The probe was then passed inferiorly to the ridge that represented the inferior border of the tibial insertion of the PCL. This point also represented the inferomedial corner, or point IM. Moving the probe approximately 3 mm laterally and superiorly placed the probe in a location that was felt to approximate the center of the posteromedial bundle. This point then became the center of the proposed posteromedial tunnel.

Taking into account the average length of the inferior side, I, and the lateral side, L, it was considered that the anatomic footprint of the tibial insertion of the PCL was sufficiently large to allow for placement of 2 independent tunnels. Depending on graft selection and the caliber of the grafts, the anterolateral tunnel and...
posteromedial tunnel could be placed entirely within the footprint of the PCL, or with a small portion slightly outside the boundaries of the footprint to ensure maintenance of a bridge of bone between the 2 tunnels.

CONCLUSIONS

Based on the findings of this study, we have described the anatomic characteristics of the tibial footprint of the PCL. Anatomic reference points that represent the corners of the tibial insertion of the PCL were identified by direct vision or palpation consistently on all specimens included in the study. These reference points could potentially aid in the placement of an anterolateral and posteromedial tibial tunnel for a 2 tibial tunnel PCL reconstruction. The reference points could be used with either an all-arthroscopic, arthroscopically assisted, or open technique, and be viewed and palpated from the back of the knee and palpated from the front of the knee through the notch of the femur.

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REFERENCES