Quantitative Insertion Morphology of the Posterior Meniscal Root in Relation to the Posterior Cruciate Ligament

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Introduction:
Injuries to the posterior cruciate ligament (PCL) account for approximately 3% to 38% of all knee injuries [1,2]. Many studies have advocated the use of an anatomical approach to performing PCL reconstruction. However, reconstructing the PCL with respect to its native footprint has been a challenge. Several approaches to PCL reconstruction with respect to certain landmarks have been proposed [3], while the relationship of the postero-medial and postero-lateral meniscal roots (PMMR and PLMR) and the PCL are usually not taken into consideration when determining tunnel placement. This has important implications for accurate placement for better tunnel position and also avoiding iatrogenic injury to the meniscal roots. The purpose of this study was to establish the relationship of the posterior meniscal root to the native insertion site of the PCL.

Material and Methods:
Seventeen cadaveric knees were used in this study (mean ± SD age: 61.8 ± 4.5 years). After high-resolution CT scan and careful dissection, three spherical fiducial markers were placed on the proximal tibia and affixed with plastic screws. These markers (10 mm in diameter) were placed in non-collinear positions in order to establish a reference plane and were also used as size references in analysis.

The peripheries of the PCL insertion site and the posterior meniscal roots, and the surfaces of fiducial markers were digitized using a surgical navigation system. The digitized insertion sites were then mapped on the CT-based 3D bone models coordinates via a co-registration procedure [4], which required determination of the centroid of each spherical fiducial marker by a least-square fitting algorithm. The centroids of three markers allowed establishment of a 3D coordinate system for quantitative description of the insertion site morphology. In the current study, the centers of the digitized insertion sites were used to calculate the areas of the native PCL footprint and the posterior meniscal root as well as the distances from the PCL insertion to the PMMR (a) and PLMR (b) insertions.

Results:
Table 1 presents the area of the PCL footprint and the posterior meniscal root. In addition the ratio of the PCL to the PM and PL, respectively, was calculated. Table 2 presents the distances measured from the PMMR (a) and PLMR (b) to the center of the PCL footprint and the ratio of a/b. We found that the PMMR is closer to the PCL insertion site when compared to the PLMR.

Table 1: Area measurements of the PCL and the posterior meniscal root

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<th>Mean</th>
<th>SD</th>
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<tbody>
<tr>
<td>PCL insertion</td>
<td>84.9 mm²</td>
<td>23 mm²</td>
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<tr>
<td>PMMR insertion</td>
<td>47.1 mm²</td>
<td>13.3 mm²</td>
</tr>
<tr>
<td>PLMR insertion</td>
<td>45.1 mm²</td>
<td>19.5 mm²</td>
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Table 2: Distance measured from center of meniscal root to center of the PCL

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<th>Mean</th>
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<tr>
<td>PMMR to PCL (a)</td>
<td>9.81 mm</td>
<td>1.35 mm</td>
</tr>
<tr>
<td>PLMR to PCL (b)</td>
<td>14.73 mm</td>
<td>1.94 mm</td>
</tr>
<tr>
<td>Ratio (a/b)</td>
<td>0.66</td>
<td>0.085</td>
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Discussion:
Anatomic reconstruction of cruciate ligaments has been found to lead to better outcome; however defining the accurate positions for tunnel placement has been a challenge, particularly intra-operatively. While many studies have examined the relationship of the ACL native insertion sites and anatomic landmarks, very few studies have looked into the PCL [3,5]. Kantaras and Johnson [6] described the meniscal root as landmark for PCL reconstruction in 2002 and demonstrated that the posterior root of the meniscus is an easily identifiable landmark for aiding in PCL tunnel placement. Our study provided quantitative data to facilitate the implementation of a clinical tool. The triangle formed by the centers of PCL, PM and PL meniscal root insertions appear to have a highly constant shape as suggested by the small variability in the distance ratio value. The ability to combine the insertion site morphology data with a 3D CT bone model via co-registration would also facilitate presentations of the information in a clinician-friendly form (e.g., digitally simulated plane X-ray can be generated). Understanding this relationship is also critical for the surgeon when drilling the tibial tunnel to avoid damage to the meniscal root, especially medial.

Significance:
Intra-operative determination of the relationship between meniscal root insertion to the PCL insertion can aid in accurate tunnel placement for anatomic reconstruction and can also decrease the risk of iatrogenic injury to the meniscal roots.

References: