Morphometry of Posterior Cruciate Ligament in Knee joint - A Cadaveric Study

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Introduction

Posterior cruciate ligament (PCL) injuries involve 3–4% of cases of total knee injuries and 38–40% of acute traumatic knee hemarthroses based on different study settings and populations (1). An isolated PCL injury is a rare phenomenon. Operative and non-operative treatments have been described. Better outcome via non-surgical treatment was observed in isolated PCL injury, while multi-ligament injured knees have better results with invasive procedures (2,3). Therefore, orthopaedic surgeons should have accurate anatomical information about different morphometric data of cruciate ligaments, which will guide them in the surgical repair of cruciate ligaments and help to determine the appropriate dimension of the allograft to be applied during reconstruction.

Materials and methods

From November 2019 to May 2021, 50 knees from 25 cadavers were dissected in the Department of Anatomy at AIIMS Jodhpur after taking ethical permission from the Institute Ethics committee. Any cadaver with a history of chronic knee condition, like knee degeneration (damage of cartilage), knee bone fracture, and damage to relevant ligaments like ACL and PCL, were excluded from the study.

Each cadaver was laid in the supine position, and reflecting the skin on overlying tissue. Then all adjacent soft tissue and structures were removed, and uncover the cruciate ligaments. In the next step, two bundles of the PCL were separated based on the level of tension and fiber orientations at the different positions when the knee was flexed (Fig. 1). Then the measurement of the intra-articular part of ALB during 90-degree knee flexion and the intra-articular part of PMB in the extended knee was taken.

Both bundles of PCL were removed from both bones (femur and tibia), and the attachment footprint was marked with an ink pen and photographed by Nikon D7200 with the macro lens. The pictures were moved into a computer and calculated the area by the ImageJ software (https://imagej.nih.gov/ij/index.html).

Key words: posterior cruciate ligament, anterior-medial bundle (AMB), posterolateral bundle (PLB), reconstruction

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At the femoral site, the distance between the central point of ALB, PMB, and total PCL footprint to the articular cartilage rim of the medial femoral condyle was measured. While at the tibial site, the area of ALB, PMB, and total PCL footprint and distance between the central point of tibial ALB, PMB, and total PCL footprint to the posterior cartilage edge of the medial tibial plateau was measured.

**Statistical analysis**

The data obtained were expressed in mean ± SD, and its normality was analyzed by Kolmogorov-Smirnov test. To identify any correlation between anthropometric measurements (like stature/height, age, and sex of individual) and PCL length, Pearson correlations were calculated among the variables by SPSS software (IBM, Version 20.0). Means were compared between males and female using the independent sample t-test and between the left and right sides of the same individual using paired t-test. The level of significance was established at p<0.05.

**Result**

Fifty knees from 25 cadavers with an average age of 47.4 years (25 - 65 years) were dissected. The male (fifteen) outnumbered the female (ten). The mean height was 166.25 cm for male while 152.17 cm for female.

**Bilateral Asymmetry**

The mean differences between the left and right sides were less than 1mm in all cadavers. The difference was insignificant when analyzed by paired t-test. Therefore, the average was taken for the final measurement.

The anatomical features of intra-articular PCL

The measurement of the patellar tendon, and intra-articular PCL, which include the length of the ALB and PMB, were shown in Table 1.

**Table 1. Anatomical measurements of ligaments**

<table>
<thead>
<tr>
<th>Anatomical features</th>
<th>Mean ± SD (Male)</th>
<th>Mean ± SD (Female)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>49.3 ± 13.47</td>
<td>45.10 ± 10.90</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.25 ± 5.43</td>
<td>152.17 ± 3.13</td>
</tr>
<tr>
<td>AM bundle length (mm)</td>
<td>35.52 ± 0.66</td>
<td>35.37 ± 0.07</td>
</tr>
<tr>
<td>PL bundle length (mm)</td>
<td>32.76 ± 0.64</td>
<td>32.58 ± 0.61</td>
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</table>
The anatomical features of the femoral attachment of PCL

The insertion of PCL on the femoral site has an oval shape. The femoral footprint of PCL and its bundles and the distance from the central point of the femoral ALB, PMB, and total PCL footprint to the articular cartilage rim are shown in Table 2 and Fig. 2.

The anatomical features of the tibial attachment of PCL

The insertion of PCL on the tibial site as a trapezoid shape. The tibial ALB footprint is placed proximally and laterally to the PMB footprint. The tibial footprint area of PCL and its bundles, distance from the central point of tibial ALB, PMB, and total PCL footprint to the posterior cartilage corner of the medial tibial plateau are shown in Table 3 and Fig.3.

Table 2. The anatomical measurements of the femoral attachment site of the PCL

<table>
<thead>
<tr>
<th>Anatomical index</th>
<th>Mean ± SD (Male)</th>
<th>Mean ± SD (Female)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALB footprint (mm²)</td>
<td>89.08 ± 0.45</td>
<td>88.99 ± 0.53</td>
</tr>
<tr>
<td>PMB footprint (mm²)</td>
<td>44.02 ± 0.5</td>
<td>44.05 ± 0.33</td>
</tr>
<tr>
<td>Total PCL footprint (mm²)</td>
<td>133.10 ± 0.7</td>
<td>133.05 ± 0.7</td>
</tr>
<tr>
<td>Distance from the rim of cartilage to the central point of</td>
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<tr>
<td>ALB (mm)</td>
<td>7.13 ± 0.22</td>
<td>7.06 ± 0.19</td>
</tr>
<tr>
<td>PMB (mm)</td>
<td>7.53 ± 0.17</td>
<td>7.26 ± 0.16</td>
</tr>
<tr>
<td>Total PCL (mm)</td>
<td>7.84 ± 0.4</td>
<td>8.06 ± 0.13</td>
</tr>
</tbody>
</table>

Table 3. The anatomical measurements of the tibial attachment site of the PCL

<table>
<thead>
<tr>
<th>Anatomical index</th>
<th>Mean ± SD (Male)</th>
<th>Mean ± SD (Female)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALB footprint (mm²)</td>
<td>84.52 ± 0.68</td>
<td>84.42 ± 0.77</td>
</tr>
<tr>
<td>PMB footprint (mm²)</td>
<td>47.69 ± 0.63</td>
<td>48.01 ± 0.4</td>
</tr>
<tr>
<td>Total PCL footprint (mm²)</td>
<td>132.21 ± 1.02</td>
<td>132.42 ± 0.8</td>
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<tr>
<td>Distance from the posterior cartilage corner of the medial tibial plateau to the central point of</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALB (mm)</td>
<td>8.3 ± 0.09</td>
<td>8.29 ± 1.01</td>
</tr>
<tr>
<td>PMB (mm)</td>
<td>9.34 ± 1.1</td>
<td>9.32 ± 0.94</td>
</tr>
<tr>
<td>Total PCL (mm)</td>
<td>8.29 ± 1.2</td>
<td>8.27 ± 1</td>
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The mean length of ligaments was significantly higher in males than in females (p<0.001). The height of individuals correlates with the mean length of ligaments (Pearson’s correlation) (p<0.001). Nevertheless, no correlation between age and the mean length of ligaments was observed (p-value 0.42).

Discussion

The middle genicular artery passes from the PCL insertion; therefore, the PCL has some inherent healing capacity (8-10). Hence, the non-operative treatment option opted for Grades 1 and 2 isolated PCL injuries. However, some residual laxity was observed in those patients (8,11). Numerous techniques for PCL reconstruction have been defined in the literature, depending on tibial graft fixation, patellar tendon graft, single or double bundle, and the type of graft used (12-15). The outcome of the single bundle (SB) and double-bundle (DB) technique remains controversial. Literature suggests that the SB PCL technique reconstructs only the ALB, while the DB PCL technique reconstructs both ALB and PMB (4–6, 8, 13, 16-19). Therefore, for better surgical outcomes, the present study focused on numerical anatomical data of PCL.

Girgis et al., observed length of PCL is about 32-38 mm (20), while Makris et al. reported the PCL length is 38 ± 2 mm (21), and Mihn DV et al. showed ALB length at 90 degrees of knee flexion 35.5 ± 2.78mm and PMB length at full knee extension 32.6 ± 2.28 mm (22). The present study observed intra-articular length of the ALB and PMB, 35.52 ± 0.66 and 32.76 ± 0.64mm, respectively. An acquaintance of the intra-articular length of PCL is precarious for choosing the right graft size in PCL reconstruction.

Amis et al. observed that the footprint of the femoral attachment of the PCL to the femur was a “haft- moon” shape (23), while Mihn DV et al. reported it was an oval shape (22). A similar observation was found in the present study that it is oval, and the footprint of PCL on the tibial site is a trapezoid shape.

Takahashi et al. observed that the ALB and PMB footprint on the femur were 58.0 ± 25.4 mm² and 64.6 ± 24.7 mm² respectively (24). Lopes OV et al. found the mean femoral attachment areas of ALB, PMB and the PCL were 118.0 ± 23.95 mm², 90.0 ± 16.13 mm², and 209.0 ± 33.82 mm² respectively (25). Gali et al. showed this area for ALB, PMB, and the total femoral attachment area of PCL were 47.13 ± 19.14 mm², 40.67 ± 16.19 mm², and 87.80 ± 31.42 mm² respectively (26). Mihn DV et al. reported this area for ALB, PMB, and the total femoral attachment area of PCL were 88.4 ± 16.89 mm², 43.5 ± 8.83 mm² and 131.9 ± 23.94 mm² respectively (22). In the present study, the footprint area of ALB was greater than PLB, which is supported by the study of Lopes et al., Gali et al., and Mihn DV et al. but opposed the results of Takahashi et al.

Harner et al. observed that the tibial footprint of the PCL of ALB and PMB were 70 ± 26 mm² and 62 ± 17 mm², respectively (27). Tajima et al., observed this area of ALB and PMB were 93.1 ± 16.6 mm² and 150.8 ± 31.0 mm², respectively (28). Takahashi et al., revealed that the mean
area of attachment of the ALB and PMB were 46.7 ± 15.6 mm² and 115.8 ± 54.6 mm², respectively (24). Gali et al. showed this area of the ALB and PMB were 46.79 ± 14.10 mm² and 41.54 ± 9.15 mm², respectively. The total area of insertion of PCL to the tibia was 88.33 ± 21.66 mm² (26). Mihn DV et al. reported this area for ALB, PMB, and the total tibial attachment area of PCL was 84.5 ± 12.52 mm², 47.8 ± 6.20 mm² and 132.3 ± 16.64 mm² respectively (22). The present study results were comparable with the results mentioned earlier. In the current study, the tibial footprint of ALB was greater as compared to that of PMB.

In the present study, a three-dimensional view of PCL footprint areas was not possible due to the use of the digital camera for the photograph.

Conclusion

In the present study, the detailed numerical measurements of the intra-articular PCL and attachment of the ALB, PMB, and total PCL in adults were described, which help surgeons in graft preparation and anatomical tunnel placement during reconstruction surgeries. The PCL was composed of AM bundle and PL bundle, with an average length of 35.52 ± 0.66 mm and 32.76 ± 0.64 mm, respectively in male and 35.37 ± 0.07 & 32.58 ± 0.61 mm in female. The length of ligaments was higher in male than female. There was a strong correlation between height and length of ligaments but no correlation with age.

Conflict of interest: There is no conflict of interest in this article.

References

15. Panchal HB, Sekiya JK. Open tibial inlay versus arthroscopic transtibial posterior cruciate ligament reconstructions. Arthroscopy. 2011; 27(9):1289–95


