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The Anatomical Numerical Measurement of Posterior Cruciate Ligament: A Vietnamese Cadaveric Study

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Abstract

BACKGROUND: The posterior cruciate ligament (PCL) is crucial to restrain the posterior translation of the tibia. Its anatomical structure is complex. A proper understanding of PCL anatomy may assist surgeon in reconstructing anatomically native PCL.

AIM: To describe the anatomical numerical measurement of the PCL in Vietnamese adults.

METHODS: Twenty-one fresh cadaveric knees were examined. The macroscopic details of the intra-articular PCL, the attachment of the anterolateral bundle (ALB), posteromedial bundles (PMB) to the femur and tibia were analysed. We used a digital camera to photograph the cadaveric specimens and used the ImageJ software to analyse the collected images.

RESULTS: The ALB and PMB length were 35.5 ± 2.78 and 32.6 ± 2.28 mm, respectively. The smallest and the biggest diameter of middle third of the PCL were 5.9 ± 0.71 and 10.0 ± 1.39 mm, respectively. The area of cross section of middle third of the PCL was 53.6 ± 12.37 mm^2. The femoral insertion area of ALB and PMB were 88.4 ± 16.89 and 43.5 ± 8.83 mm^2, respectively. The distance from the central point of femoral ALB, PMB, and total PCL insertion to the Blumensaat line were 5.5 ± 0.91, 11.5 ± 1.98, and 7.6 ± 1.42 mm, respectively. The shortest distance from medial femoral cartilage rim to the central point of femoral ALB, PMB, and total PCL insertion were 7.0 ± 0.79, 7.3 ± 0.95, and 7.8 ± 1.73 mm, respectively. The tibial insertion area of ALB and PMB were 84.5 ± 12.52 and 47.8 ± 6.20 mm^2 respectively. The shortest distance from the posterior cartilage corner of the medial tibial plateau to the central point of ALB, PMB, and total PCL insertion to tibia were 8.5 ± 1.02, 9.4 ± 1.11, and 8.3 ± 1.1 mm, respectively. The central point of tibial PCL insertion was 9.7±1.08 mm below cartilage plane of the medial tibial plateau.

CONCLUSION: This study describes the detailed anatomical measurement of the PCL and its bundles in adults.

Introduction

The posterior cruciate ligament (PCL) is crucial to restrain the posterior translation of tibia. Shelbourne et al., found that 1%-44% of all acute injuries of the knee are PCL injuries [1]. Although non-operative and operative management have been described, the optimal management strategy remains to be determined. In general, non-operative management has been advocated for patient with isolated grade 1 or 2 PCL injuries or for those with grade 3 injuries with non-serious symptoms or low activity requirement. PCL reconstruction is typically indicated for patients with acute or chronic symptomatic grade 3 PCL injuries in whom non-operative management was unsuccessful. Bedi et al., reviewed the literature and reported that PCL reconstruction generally have worse post-operative clinical outcomes than ACL reconstruction [2]. Excellent post-operative clinical outcome of PCL reconstructions depends on appropriate reproduction of the PCL anatomy [2], [3], [4]. Therefore, orthopaedic surgeons pay great attention to the comprehension of anatomical PCL structure. Up to now, there have been little research on numerical anatomical measurement of PCL. The study objective is to measure anatomical sizes of intra-articular PCL and attachment footprints of the

PCL bundles in Vietnamese adults in order to help surgeons to understand the principles of anatomical reconstruction of PCL.

Materials and Method

The study was designed to be a descriptive anatomical study. We studied twenty-one articulated knees. Eight cadaveric knees from 4 donors were dissected in the Anatomy Department of University of Medicine and Pharmacy in Ho Chi Minh city. Thirteen knees from above knee amputation specimens were dissected in Anatomic Pathology, Cytological Pathology and Forensic Medicine Department in Viet Duc University Hospital. We excluded all cadavers with a history of knee surgery or trauma. We exposed 21 articulated knees and confirmed that all of them had intact anterior cruciate ligament (ACL) and PCL without any signs of osteoarthritis. The mean age of the specimens were 44 ± 13.3 years (24-59 years). 21 studied knees, which are composed of 8 right knees and 13 left knees, were from 15 males and 2 females.

All specimens had been only used to study the anatomy of PCL. We removed all adjacent soft tissue and surrounding structures, and isolated the knee by cutting the femur and tibia. The proximal tibia was cut at 2 cm below the anterior tubercle. We cut the distal femur above the intercondylar notch.

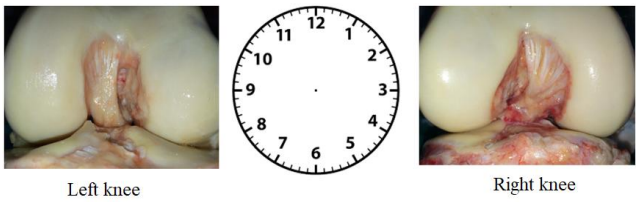

Figure 1: The femoral attachment of PCL when we viewed the knee from the anterior aspect

We removed all tissues except PCL (Figure 1) then cut the femoral intercondyle between the insertion of ACL and PCL to the femur. Next step, we separated 2 bundles of the PCL based on the level of tension and fibre orientations at different position when the knee is flexed. The PCL was marked to divide into an ALB and PMB with a small soft wire (Figure 2). We measured the length of the intra-articular part of ALB when the knee is flexed 90 degrees and the length of the intra-articular part of PMB in extended knee. We measured both the smallest and biggest diameter of the middle PCL.

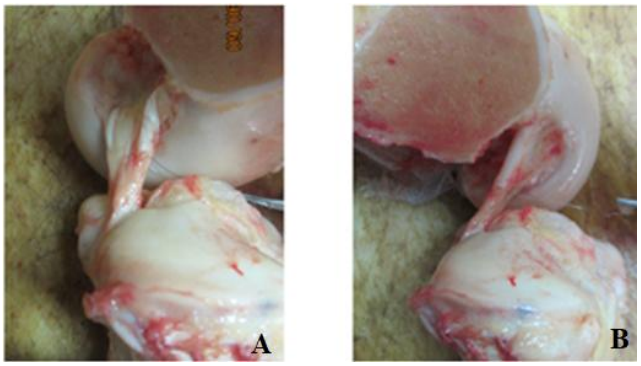

Figure 2: PCL imaging when the knee was full extended (A) and when the knee was flexed at 90 degrees (B)

We separated the body of the PCL into ALB and PMB from the middle part of the ligaments to the femoral and tibial attachment footprints. Two bundles of PCL were removed from the bone and the attachment footprint was marked with ink pen (Figure 3). We photographed the femoral and tibial specimens with a measurement scale using a Canon EOS 70D with macro lens. All the images were perpendicular to the PCL attachment footprint area. The images were transfered into a computer. We performed all measurement and analysis by the use of the ImageJ software (https://imagej.nih.gov/ij/index.html).

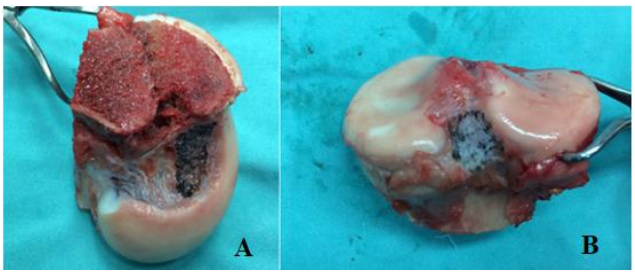

Figure 3: Femoral and tibial footprint of PCL

To define the central point of the native ALB, PMB and total PCL insertion footprint on the femur and tibia, the entire morphed ALB, PMB and total PCL footprint were analysed and best-fit ellipses applied using the ImageJ software. The center of these ellipses were defined as the central point of ALB, PLB and total PCL insertion footprint.

We performed anatomical measurements on the tibial and femoral attachment footprint of ALB, PMB and total PCL. At the femoral site, we measured the distance from the central point of ALB, PMB, and total PCL footprint to the Blumensaat line and the articular cartilage rim of medial femoral condyle. The measure from central point of the ALB, PMB and PCL were perpendicular to the Blumensaat line and articular cartilage rim. We calculated the area of every footprint of attachment to the femur (Figure 4).

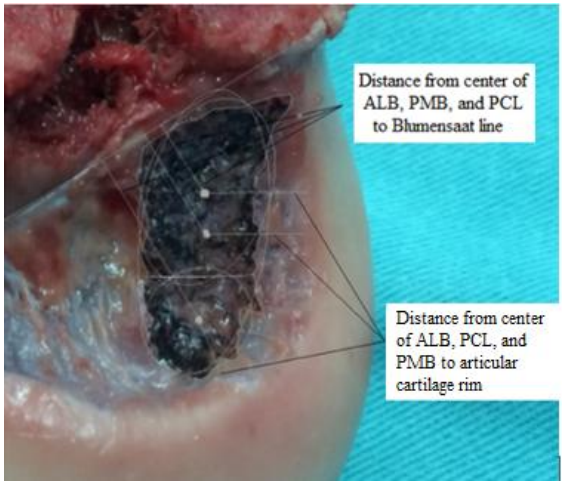

Figure 4: Femoral PCL attachment footprint analysis

At the tibial site, we measured the attachments of ALB, PMB, and PCL on the posterior tibial plan. The area of each tibial attachment footprint was determined. The shortest distance from the central point of tibial ALB, PMB and total PCL footprint to posterior cartilage corner of the medial tibial plateau to were measured (Figure 5). The distance from the articular plane of the medial tibial plateau to the central point of total PCL attachment footprint and to the inferior margin of total PCL attachment footprint were measured.

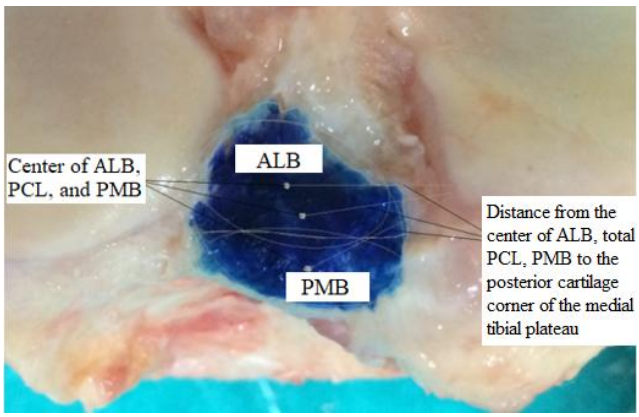

Figure 5: Tibial PCL attachment footprint analysis

Results

The anatomical features of intra-articular PCL

The numerical measurement of intra-articular PCL including the length of the ALB and PMB, the smallest and the biggest diameter of the middle third of the PCL, and the area of cross section of middle third of the PCL were shown in Table 1.

Table 1: Anatomical features of intra- articular PCL

Anatomical index	Mean ± SD	Min- Max
ALB length at 90 degree of knee flexion (mm)	35.5 ± 2.78	31.2-38.8
PMB length at full knee extension (mm)	32.6 ± 2.28	30.1-36.9
Smallest diameter of middle third (mm)	5.9 ± 0.71	5.0-7.6
Biggest diameter of middle third (mm)	10.0 ± 1.39	7.7-12.3
Cross- sectional area of middle third (mm^2)	53.6 ± 12.37	30.7-75.2

The anatomical femoral attachment of PCL

The femoral insertion of PCL presented as an oval shape. The femoral insertion area of PCL and its bundles and the distance from the central point of the femoral ALB, PMB and total PCL footprint to the Blumensaat line and the articular cartilage rim were shown in Table 2.

Table 2: Quantitative measurements on femoral insertion of PCL

Anatomical index	Mean ± SD	Min-Max
ALB footprint (mm^2)	88.4 ± 16.89	60.7-128.3
PMB footprint (mm^2)	43.5 ± 8.83	31.8-61.4
Total PCL footprint (mm^2)	131.9 ± 23.94	95.3-182.0
Distance from the rim of cartilage to the central point of		
ALB (mm)	7.0 ± 0.79	5.1-8.2
PMB (mm)	7.3 ± 0.95	5.9-9.3
Total PCL (mm)	7.8 ± 1.73	5.5-11.1
Distance from Blumenssat line to the central point of		
ALB (mm)	5.5 ± 0.91	4.2-7.4
PMB (mm)	11.5 ± 1.98	7.8-16.2
Total PCL (mm)	7.6 ± 1.42	5.3-11.0

The anatomical tibial attachment of PCL

The attachment of PCL to the tibia is trapezoidal in shape. The tibial PMB footprint is placed distally and medially to the ALB footprint.

The tibial attachment area of PCL and its bundles, the shortest distance from the central point of tibial ALB, PMB and total PCL footprint to posterior cartilage corner of the medial tibial plateau along with the distance from the articular plane of the medial tibial plateau to the central point of total PCL attachment footprint and to the inferior margin of total PCL attachment were shown in Table 3.

Table 3: Quantitative measurements on tibial insertion of PCL

Anatomical index	Mean ± SD	Min-Max
ALB footprint (mm^2)	84.5 ± 12.52	68.8-110.2
PMB footprint (mm^2)	47.8 ± 6.20	37.0-57.3
Total PCL footprint (mm^2)	132.3 ± 16.64	105.8-164.8
Shortest distance from the posterior cartilage corner of the medial tibial plateau to the central point of		
ALB (mm)	8.5 ± 1.02	6.5-10.8
PMB (mm)	9.4 ± 1.11	7.4-11.5
PCL (mm)	8.3 ± 1.1	6.5-10.5
Distance from articular plane of the medial tibial plateau to the central point of PCL attachment footprint (mm)	9.7 ± 1.08	8.1-12.2
Distance from articular plane of the medial tibial plateau to the inferior margin of PCL attachment footprint (mm)	13.6 ± 0.96	11.6-15.5

Discussion

Our study focused on describing the numerical anatomical data of PCL. So far, there is a limited number of reports on the numerical anatomical data of the PCL. As reported by Girgis et al., the

length and width of PCL are about 32-38 mm and 11-13 mm respectively [5]. It is reported by Makris et al., that the PCL length is 38 ± 2 mm when the knee is flexed at 90 degrees, and the middle third anteroposterior diameter and mediolateral diameter of PCL ligament were approximately 5 ± 0.5 mm and 14 ± 0.8 mm respectively [6]. In our evaluation, we noted a shorter intra-articular length of the ALB and PMB, and a smaller diameter of the middle third of the PCL, as compared to other author's findings. Knowledge of the intra-articular length and diameter of PCL is critical for the selection of an appropriate graft size in PCL reconstruction.

According to Amis et al., the footprint of femoral attachment of the PCL to the femur makes a "haft- moon" shape [7]. In our study, all described femoral attachments of the PCL were oval shaped.

Regarding the areas of the PCL attachment to femur, a study by Takahashi et al., on 32 femurs revealed that the mean area of attachment of the ALB and PMB to femur were 58.0 ± 25.4 mm^2 and 64.6 ± 24.7 mm^2, respectively [8]. In this study, measurements were obtained by evaluating photographs integrated with a measure scale, and computer analyses were performed using a MacSCOPE software. By the help of a specific software, Lopes et al., evaluated photos of 20 knees obtained from a specific digital camera equipped with three-dimensional laser. According to this study, the mean femoral attachment areas of ALB, PMB and the PCL were 118.0 ± 23.95 mm^2, 90.0 ± 16.13 mm^2, and 209.0 ± 33.82 mm^2 respectively [9]. Gali et al., photographed 24 knees using Canon EOS Rebel T1i camera with a measure scale, and performed subsequent computer analyses using ImageJ software. As reported by this study, the mean attachment area of the ALB, PMB, and the total femoral attachment area of PCL were 47.13 ± 19.14 mm^2, 40.67 ± 16.19 mm^2, and 87.80 ± 31.42 mm^2 respectively [10]. In our evaluation, the insertion area of ALB was greater than that of PMB. The results of this study were like that of Lopes et al., and Gali et al., but oppose to the findings of Takahashi et al.

There have been several reports about numerical measurements description of the central point of femoral PCL insertion [11]. According to Cosgarea and Jay, the central point of the attachment of the PCL to the femur is described 10 mm behind the cartilage rim of the medial condyle of femur [3]. However, Wind et al., found that this point is 10 mm proximal to this border [12]. According to the study conducted by Takahashi et al., the average measure from the central point of the attachments of ALB and PMB to the Blumensaat line were 4.8 mm and 11.4 mm, and to the anterior cartilage rim were 9.6 mm and 10.6 mm, respectively [8]. As reported by Gali et al., the shortest distance from the edge of the posterior cartilage corner of medial tibial plateau to the central point of ALB and PMB were 5.00 ± 2.06 mm and 5.58 ± 1.64 mm, respectively [10]. In our evaluation, we used two anatomical index that may be clearly view during knee arthroscopy to identify the center of femoral ALB, PMB and total PCL insertion to support surgeon in creating femoral tunel.

Regarding the anatomical tibial footprint of the PCL, it is reported by Harner et al., that the average area of ALB and PMB were 70 ± 26 mm^2 and 62 ± 17 mm^2, respectively [13]. According to the report by Tajima et al., the average areas of attachment of the ALB and PMB were 93.1 ± 16.6 mm^2 and 150.8 ± 31.0 mm^2, respectively [14]. In this study, three-dimensional laser photography was used to evaluate the tibial attachment area of 21 unpaired cadaveric knees, and collected data were analysed with a specific software. Takahashi et al., evaluated photographs integrated with measurement scales of 33 tibias and use MacSCOPE software to analyse collected data, which revealed that the mean area of attachment of the ALB and PMB were 46.7 ± 15.6 mm^2 and 115.8 ± 54.6 mm^2, respectively [8]. Gali et al., photographed 24 knees using Canon EOS Rebel T1i camera equipped with a measurement scale and subsequently analysed their photos using the ImageJ software. According to this study, the mean attachment area of the ALB and PMB were 46.79 ± 14.10 mm^2 and 41.54 ± 9.15 mm^2, respectively. The total area of insertion of PCL to tibia was 88.33 ± 21.66 mm^2 [15]. In our study, the attachment area of ALB was greater as compared to that of PMB.

Few reports on numerical anatomical description of the center of tibial PCL insertion have been done. This point is located 2 – 3 mm below the articular plane, according to the study by Girgis et al., [5]. According to Cosgarea and Jay, it is 10 – 15 mm below the articular plane [3]. According to report by Takahashi et al., the tibial ALB attachment is nearly on the articular plane (that means the tibial PMB attachment center is close to 0 mm), and the central point of the tibial PMB attachment is located 4.6 mm below the articular plane [8]. According to our evaluation, the central point of the tibial PCL footprint is 9.7 ± 1.08 mm below the articular plan. In this study, we described two anatomical index that can clearly view during knee arthroscopy to identify the center of tibial PCL insertion to support surgeon in creating tibial tunnel.

Our study has some limitations. We had a relatively small sample size. Additionally, a three-dimensional view of PCL ligament attachment areas was not possible with the use of photographs taken with a digital camera.

In conclusion, our study described the detail numerical measurements of the intra- articular PCL and attachment footprint of the ALB, PMB, and total PCL in adults. These findings can assist surgeons in performing graft preparation and anatomical tunnel placement in anatomical native PCL reconstruction.

Ethical approval

This study protocol was approved by Ethic Committee of Viet Duc University Hospital.

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