

Morphometric Measurements of Posterior Cruciate Ligament and its Clinical Implications: A Cadaveric Cross-sectional Study

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ABSTRACT

Introduction: Posterior Cruciate Ligament (PCL) is a band like structure which tightly adheres to femur and tibia with collagen fibres. It is considered as an active and primary stabiliser of the knee joint and it acts as the principal restraint against posterior tibial translation. Its anatomical knowledge is necessary for practicing surgeons.

Aim: To study the morphometric parameters of total length and width of Posterior Cruciate Ligaments (PCL) at three points (proximal, central and distal) on both knee joints and their clinical correlation.

Materials and Methods: The cross-sectional study was conducted at Smt. Bikhiben Kinjal Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India, from August 2021 to May 2022. This cadaveric study was conducted over 40 knee joints of 20 formalin-fixed cadavers of unknown sex and measured the length and width of PCL with the help of digital caliper. Total length and width (proximal, central and distal) of PCL were measured and Mean±Standard Deviation (Mean±SD) were recorded. Independent t-test and Karl Pearson's correlation coefficient were used to find out any possible association and

correlation for various morphometric measures of right and left knee at 5% and 1% level of significance, respectively. Statistical analysis was done by the trial version of Statistical Package for Social Sciences (SPSS) version 21.0.

Results: Total length of PCL of right and left knee was 33.19±3.09 mm and 33.12±3.40 mm, and range between 23.4-37.9 mm and 23.8-38.0 mm, respectively. The measurements of the width of PCL at different levels (proximal, central and distal) of right knee were 9.07±1.24 mm, 10.44±1.75 mm and 9.10±1.46 mm respectively, while in left knee they were 9.33±1.67 mm, 10.32±1.99 mm and 9.29±1.70 mm, respectively. T-test showed that there was no association for considered morphometric measures between right and left knee at $\alpha=5\%$. The correlation assessment showed strong positive correlations between left and right sides for both knees at different levels, which were significant p-value <0.001. However, no correlation was found between length and width (proximal, central and distal) for both knees.

Conclusion: This study gives the valuable result of parameters of length and width of PCL, which helps for orthopaedic surgeons in the surgery and grafting of ligament in the case of trauma.

Keywords: Allograft, Agenesis, Restoration, Restrain, Surgery

INTRODUCTION

Knee joint is one of the complex synovial joints in the body comprising of patello femoral joint and tibio femoral joint. The joint cavity is mainly formed by the tibia and femur, which are connected by four main ligaments: two collateral ligaments on the sides of the knee and two cruciate ligaments present inside the knee namely Anterior Cruciate Ligament (ACL) and Posterior Cruciate Ligament (PCL). The PCL originates from the posterior part of lateral surface of medial femoral condyle in inter-condylar notch runs distally, posteriorly and gets inserted to a depression posterior to the upper part of intra-articular surface of tibia [1-3]. It is considered as an extra capsular ligament because it is enclosed within its own synovial sheath [3,4] which is 32-38 mm long and 11 mm wide [2,5]. The PCL is easily recognisable before the development of the ACL [6,7]. PCL is made up of two bundles, Anterolateral (AL) bundle is larger, stiffer and tighter in flexion while another bundle is Posteromedial (PM) which is smaller, short and taut in extension [8]. Its thickness is double than ACL and it is innervated by tibial nerve and get nourishment from middle genicular artery [2]. PCL acts as active and primary stabiliser of the knee joint and it is also the principal restraint against posterior tibial translation [9]. In some of the cases, it was found that the agenesis of PCL over 0.017 per 1000 live births [10-12] which is associated with type-1 A fibular hemimelia [13]. During

the surgical repair of cruciate ligaments, the orthopaedic surgeon should have detailed knowledge about the different parameters of cruciate ligaments, which will guide them in appropriate size of the allografting procedure in surgical reconstruction [10]. Various previous studies [14-20] evaluating the measurements of PCL and focus on its length and width only after separation from its femoral and tibial attachment areas. To knowledge of the present authors, there is no any specific anatomical study that evaluates the correlation between the length of PCL along its width (proximal, central and distal). Therefore, the present study was designed to consider all the morphometric measures of both the knee joints.

MATERIALS AND METHODS

The study was a cross-sectional type which was carried out on 40 knee joints of 20 formalin-fixed cadavers obtained from the Department of Anatomy, Smt. Bikhiben Kinjal Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth Deemed to be University, Vadodara, Gujarat, India from August 2021 to May 2022 after prior Institutional Ethics Committee (SVIEC) approval (vide letter no. SVIEC/ON/MEDICAL/PhD/20016).

Normal knee joints were included in the present study however operative, traumatic and osteoporotic cases were excluded from the study. All the measurements of PCL were taken by a Digital caliper

(Oleander OL 68595, Caliper Plastic, India). The length of the PCL was measured by the point mark between lateral border of the medial femoral condyle and the posterior aspects of the medial and lateral tibial plateau. Its width measured by their femoral (proximal), middle portion (central) and Tibial (distal) attachments [Table/Fig-1,2].

STATISTICAL ANALYSIS

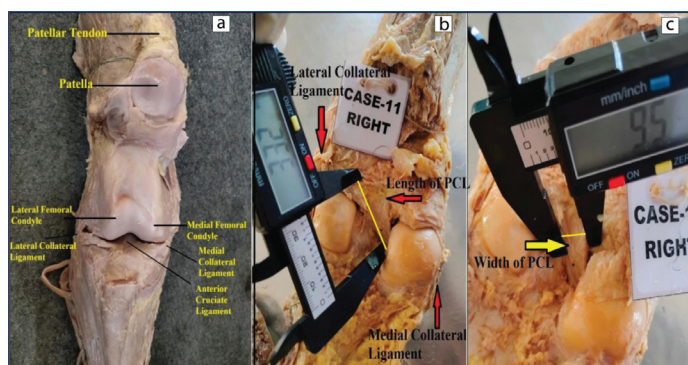
Data has been entered in Microsoft Excel 2010. Statistical analysis done by the trial version of SPSS version 21.0. The data was checked for normality using Shapiro-Wilk test at 5% level of significance. Mean along with standard deviation has been produced for various morphometric measures of Right and Left knee. Further Independent t-test and Karl Pearson's correlation coefficient was used to look for any possible association and correlation for various morphometric measures of right and left knee at 5% and 1% level of significance, respectively.

RESULTS

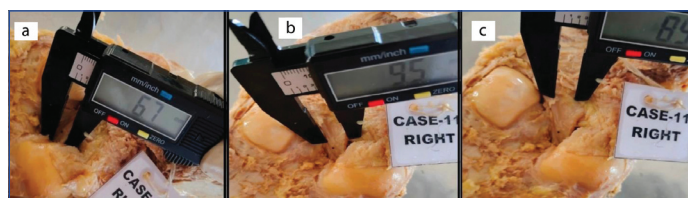
Total length of PCL of right and left knee were 33.19±3.09 mm and 33.12±3.40 mm respectively, the range between min-max were 23.4-37.9 mm and 23.8-38.0 mm, respectively. The width of PCL from proximal, central and distal level of right knee were 9.07±1.24 mm, 9.33±1.67 mm and 10.44±1.75 mm, respectively while 10.32±1.99 mm, 9.10±1.46 mm and 9.29±1.70 mm were the measurements for left knee respectively and the range was 6.6-11.7 mm, 6.4-13.0 mm and 8.1-13.9 mm for right knee whereas 6.0-13.0 mm, 6.7-12.6 mm and 6.9-13.6 mm for left knee respectively.

Independent t-test showed right and left knee were similar for considered morphometric measures with no statistically significant difference. p-value for total length PCL right vs left knees was 0.47 and proximal width of both knees were 0.28 which were not significant, p-value showing proximal width right and left knee (p-value=0.28), central width right and left knee (p-value=0.41) and distal width of both the knees (p-value=0.34) were also not significant at α=5% [Table/Fig-3].

Karl Pearson's correlation coefficient between PCL total length right and left knees were 0.753 (p-value=0.001), between right knee central width and right knee proximal width were 0.757 (p-value=0.001), between left knee central width and left knee proximal width were 0.706 (p-value=0.001), between right knee distal width and right knee proximal width were 0.758 (p-value=0.001), between right knee distal width and right knee central width were 0.631 (p-value=0.004), between left knee distal width and left knee proximal width were 0.873 (p-value=0.001) and between left knee distal width and left knee central width were 0.585 (p-value=0.007) showing significant positive correlation. While correlation between right knee proximal width and PCL total length of right knee (p=0.163; p-value=0.491), proximal width left knee and PCL total length of left knee (p=0.111; p-value=0.643), central width right knee and PCL total length of right knee (p=0.



[Table/Fig-1]: a) Dissected limb showing the ligaments of knee joints; b) Showing the measurements of length of Posterior Cruciate Ligament (PCL); c) Showing the measurements of width of PCL.



[Table/Fig-2]: a) Showing the Proximal width of PCL on femoral part; b) Showing the central width of PCL between femoral and tibial part; c) Showing the distal width of PCL on tibial part.

Parameters	Min-Max (mm)	Mean±SD	p-value
Total length PCL			
Right knee	23.4-37.9	33.19±3.09	0.4711
Left knee	23.8-38.0	33.12±3.40	
Proximal width			
Right knee	6.6-11.7	9.07±1.24	0.2899
Left knee	6.4-13.0	9.33±1.67	
Central width			
Right knee	8.1-13.9	10.44±1.75	0.4173
Left knee	6.0-13.0	10.32±1.99	
Distal width			
Right knee	6.7-12.6	9.10±1.46	0.3497
Left knee	6.9-13.6	9.29±1.70	

[Table/Fig-3]: Table showing the parameters of total length and width of PCL of both the knee.

*Independent t-test (p<0.05); Total number of cadavers (n)=20

363; p-value=0.116), central width left knee and PCL total length of left knee (p=0.441; p-value=0.052), distal width right knee and PCL total length of right knee (p=0.291; p-value=0.213), distal width left knee and PCL total length of left knee (p=0.077; p-value=0.747) were not significant [Table/Fig-4].

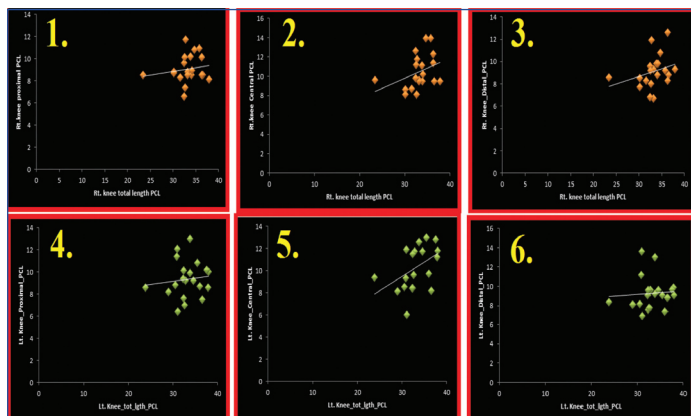
[Table/Fig-5] shows scatter plot graph showing the correlation between total length PCL and width at three points of PCL for both the knee joints.

Variables		PCL total length Rt. knee	PCL total length Lt. knee	Rt. knee proximal width	Lt. knee proximal width	Rt. knee central width	Lt. knee central width	Rt. knee distal width	Lt. knee distal width
PCL total length Rt. knee	Pearson's correlation coefficient	1							
	Sign (2-tailed)	-							
PCL total length Lt. knee	Pearson's correlation coefficient	0.753**	1						
	Sign (2-tailed)	<0.001	-						
Rt. knee proximal width	Pearson's correlation coefficient	0.163	-	1					
	Sign (2-tailed)	0.491	-	-					
Lt. knee proximal width	Pearson's correlation coefficient	-	0.111	-	1				
	Sign (2-tailed)	-	0.643	-	-				
Rt. knee central width	Pearson's correlation coefficient	0.363	-	0.757**	-	1			
	Sign (2-tailed)	0.116	-	<0.001	-	-			

Lt. knee central width	Pearson's correlation coefficient	-	0.441	-	0.706**	-	1	
	Sign (2-tailed)	-	0.052	-	0.001	-	-	
Rt. knee distal width	Pearson's correlation coefficient	0.291	-	0.758**	-	0.631**	-	1
	Sign (2-tailed)	0.213	-	<0.001	-	0.004	-	-
Lt. knee distal width	Pearson's correlation coefficient	-	0.077	-	0.873**	-	0.585**	-
	Sign (2-tailed)	-	0.747	-	<0.001	-	0.007	-

[Table/Fig-4]: Correlation matrix table for length and width of PCL of both sides of knee joints.

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed); Rt: Right; Lt: Left



[Table/Fig-5]: Scatter plot graph showing the correlation between total length and width at three points of PCL of both the knee joints.

1. Correlation between total length of PCL-Rt. knee vs Proximal width of Rt. knee
2. Correlation between total length of PCL-Rt. knee vs Central width of Rt. knee
3. Correlation between total length of PCL-Rt. knee vs Distal width of Rt. knee
4. Correlation between total length of PCL-Lt. knee vs Proximal width of Lt. knee
5. Correlation between total length of PCL-Lt. knee vs Central width of Lt. knee
6. Correlation between total length of PCL-Lt. knee vs Distal width of Lt. knee

DISCUSSION

The strongest ligament of the knee joints which are also very important clinically are cruciate ligaments which are two in number; one lies anteriorly and the other one in posteriorly [1]. Morphometric analysis of PCL has great value during surgical treatment of injured PCL, in fact, it is observed that graft stretching or shortening with flexion when the tunnels are misplaced while reconstructing the PCL [21]. Better conservative, surgical, and rehabilitative therapy options have been made possible by advances in our knowledge of PCL anatomy and biomechanics in recent years [22-27]. The present study results were in parallel with the findings of studies conducted by Minh DV et al., (2019) and Geetha Rani BG et al., (2019) [16,17]. The present study gives a valuable data which represent the correlation between the length and width of the ligament for finding out the interrelationship between their different widths. Pope T et al., reported that the length of PCL was 22 mm while Iyaji Pi and Soames Rw observed both the length and width of the AL and PM bundles at tibial insertion were 8.7 mm and 10.9 mm and 7.3 mm and 10.4 mm respectively [18,19]. The mean lengths and widths of PCL at femoral attachments were 9.4 mm and 12.8 mm for both AL and PL bundles were 7.5 mm and 11.4 mm on both the knee joints. Yelicharla AK et al., conducted their study in Maharashtra region and reported the mean length of PCL in males were 36.9±3.9 mm and in females 36.9±3.4 mm respectively [14]. They also reported the mean width of PCL were 9.2±2.3 mm, 9.1±2.2 mm in males and females respectively which is higher in range than the present study and also found that the gender difference in morphometric parameters of cruciate ligament while executing the surgical repair whereas the study was conducted by Mishra S et al., reported that the mean length and width of Rt. knee were 20.08±1.130 mm and 6.22±0.851 mm, while on Lt. knee it was 20.10±1.129 mm and 5.90±0.777 mm, respectively which is lower to the present study and concluded that the study is helpful to know the exact size in grafting [15]. The study conducted by Goyal T et al., reported that the mean area of femoral insertion were 17.4±14.3 mm² and 98.1±7.4 mm² found in tibial insertion, respectively [20]. The study

done by DV Minh et al., was 35.57±2.78 mm, reported that the length of PCL and Geetha Rani BG et al., reported that the length of PCL was 35.39±3.73 mm and the width was 5.93±0.778 mm, respectively which was similar to the present study, also compared between the length and width of PCL and concluded that, the clinical implications has been made for its knowledge is helpful in selection of quality and quantity while grafting [16,17]. Comparison of parameters of total length and width of PCL with previous studies can be seen in [Table/Fig-6] [14-20].

Authors (years)	Parameters	
	Total length PCL (Mean±SD) in mm	Total width PCL (Mean±SD) in mm
Yelicherla AK et al., [14] (2014)	36.90±3.90	Males=8.2±2.0 Females=9.1±2.2
Pope T et. al., [18] (2014)	22	-
Iyaji Pi and Soames Rw et al., [19] (2016)	Length and width of AL Bundle=8.7 and 10.9 Length and width of PM Bundle=7.3 and 10.4	-
Mishra S et al., [15] (2021)	Rt. knee=20.08±1.130 Lt. knee=20.10±1.129	Rt. knee=6.22±0.851 Lt. knee=5.90±0.777
Tarun Goyal et al., [20] (2018)	Femoral Insertion=17.4±14.3 Tibial Insertion=98.1±7.4	-
Minh DV et al., [16] (2019)	35.57±2.78	-
Geetha Rani BG et al., [17] (2019)	35.39±3.73	5.93±0.778
Present study	Rt. knee=33.19±3.09 Lt. knee=33.12±3.40	Rt knee (Proximal width) 9.07±1.24 Rt knee (Central width) 10.44±1.75 Rt knee (Distal width) 9.10±1.46 Lt knee (Proximal width) 9.33±1.67 Lt knee (Central width) 10.32±1.99 Lt knee (Distal width) 9.20±1.70

[Table/Fig-6]: Comparison of parameters of total length and width of PCL with previous studies [14-20].

In the present study, we have included both the knee joints along with their length and width also in which the length of Rt. knee and Lt. knee were 33.19±3.09 mm and 33.12±3.40 mm, respectively. Also reported the width at three point in which the proximal, central and distal width of Rt. knee were 9.07±1.24 mm, 10.44±1.75 mm and 9.10±1.46 mm, respectively whereas on Lt. knee were 9.33±1.67 mm, 10.32±1.99 mm and 9.2±1.70 mm, respectively. Also, tried to measure the exact area of attachments from where the ligament arises. In the present study, the have shown the width at the three points, which is better representation for the width of entire PCL.

Limitation(s)

Limitations included scarcity of cadavers and tissue degeneration. So, the findings may be more accurate upon the availability.

CONCLUSION(S)

There was no significant difference for considered morphometric measures of PCL between right and left knees. Various morphometric

measurements of both knees were also showed strong positive correlations. In the event of any type of avulsion, accurate understanding is necessary for the grafting and restoration of the PCL, which will better direct the orthopaedic surgeons for the proper repair of the ligament.

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