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Original Research Article

MORPHOMETRIC ANALYSIS OF CRUCIATE LIGAMENTS

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ABSTRACT

Introduction: Anterior cruciate ligaments (ACL) and posterior cruciate ligaments (PCL) are tough band of fibrous structures extending between tibia and femur. Cruciate ligaments are at risk of injury in sports personnel. Injured ligaments are treated by reconstruction surgeries which require the morphometric understanding. Therefore, this study intended to find the length and width of ACL and PCL in cadavers and by MRI in healthy individuals.

Material and methods: Thirty embalmed cadaver knees were dissected to expose the ligaments. Length and width of the ligaments was measured by the Vernier's calipers. Thirty MRIs of knee joint with no previous detected knee pathology were obtained and reviewed. The data was tabulated for statistical analysis. Student't' test was used for comparison. P value <0.05 was considered as statistically significant.

Results: In the cadavers, ACL was significantly longer than PCL in length (p <0.014). PCL width was larger than ACL width (p <0.001).

Conclusion: The present study contributes to the relative morphometric data on ACL and PCL and stresses that PCL is shorter and wider than ACL making it a more stable structure.

KEY WORDS: Morphometry, Anterior Cruciate Ligaments, Posterior Cruciate Ligament.

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INTRODUCTION

Knee joint is a complex synovial joint and the problems related to it are complex due to its associated ligamentous injuries. In 1892, Bugnion enchantingly compares the knee and femoral condyles to a chariot with tilted wheels stabilized by internal oblique guides, the cruciate ligament [1]. Cruciate ligaments are tough band of fibrous structures in the knee joint extending between Tibia and Femur as they twist around each other in a longitudinal axis during attachment to the opposing surfaces of same bones i.e Femur & Tibia. They are further named as anterior and posterior based on their attachments on tibia. Anterior Cruciate ligament (ACL) and Posterior cruciate ligament (PCL) play important role in providing stability to the knee joint [2]. Anterior cruciate ligament (ACL)

extends proximally from medial surface of lateral femoral condyle & the intercondylar notch of femur running anteriorly, distally and medially to get attached to a wide depressed area anterior and lateral to the medial tibial tubercle in the intercondylar fossa of Tibia [3]. On magnetic resonance imaging (MRI), ACL is best visualized on sagittal images because of oblique course. It appears with low signal intensity. Any discontinuity in its fibers results in edema and hemorrhage indicating a tear [4]. Further studies on ACL is said to consist of two distinct bundles, the antero medial bundle which becomes taut at 90æ% of flexion. The postero-lateral bundle becomes taut at full extension. ACL primarily provides approximately 85% of the resistance to anterior tibial translation. Secondary functions include restraint to varus/valgus forces and also it provides rotational stability through the posterolateral bundle [4].

Posterior cruciate ligament (PCL) originates from the posterior part of lateral surface of medial femoral condyle in intercondylar notch runs distally, posteriorly and gets inserted to a depression posterior to the intra articular upper surface of Tibia. It also sends a slip to blend with the posterior horn of lateral meniscus. The PCL is split into two functional bundles; the anterolateral bundle (ALB) and the posteromedial bundle (PMB). The ALB is tight at flexion, while the PMB is tight at extension [5]. On MRI, PCL is well visualized in both sagittal and coronal plane. PCL appears with low signal intensity along with a hockey stick shape and more uniform than ACL owing to the presence of a tighter and stronger investing sheath [6]. In addition, the PCL is the primary stabilizer of the knees because it provides the central rotational axis and responds to 95% of the posterior displacement of the tibia over the femur. It also limits the varus and valgus as well as the external rotation of this joint [5].

The Cruciate ligaments often get injured in people who play sports like soccer, football, tennis, basketball, volleyball, or gymnastics. ACL injuries are due to non contact injuries that happen when the athletes stop and quickly change directions while they're running [7]. PCL injuries are contact injuries often due to a blow/ falling on the knee while it's bent (dash board injury) [8]. It is estimated that ACL and PCL injuries account for about 60% and 3% of the total knee injuries respectively. It may be due to the fact that PCL is almost twice as strong as ACL. It takes considerable force to rupture the PCL than it does the ACL as the PCL has more abundant blood supply than ACL. Cruciate ligament injuries are treated by reconstruction surgeries. The systematic morphometric values of theses ligaments strongly influence the cruciate ligament reconstruction. Therefore, this study intended to study the length and width of ACL and PCL. This study was also interested in correlating the anatomical findings with MRI conclusions.

MATERIALS AND METHODS

The study was conducted in the Department of Anatomy and Department of Radiology, Vydehi Institute of Medical Sciences& Research Centre, Bangalore. Thirty two embalmed cadaver knees were obtained whose average age was 50 years without any gender differentiation. Exclusion criteria included any sign of previous surgery, ligament damage, cartilage deterioration, or joint contracture. Knees were stored at 20°C and thawed at room temperature overnight.

Dissection methodology: The knee was dissected according to Cunningham's manual of Anatomy. Initially skin, muscles, patellar and articular capsules were removed. Later, all soft tissues were removed from the specimens except the ligaments and the menisci. The synovial sheath covering the cruciate ligaments was carefully removed to preserve the menisco femoral ligaments. After exposure of the ligaments, each ligament was measured from proximal to distal attachment by the Vernier's calipers with knee in extended position. Their mid width circumference, the cross-sectional area at their site of attachment were measured. The ACL and PCL were transected at their tibial attachments and the tibia was disarticulated. The anterior and posterior meniscofemoral ligaments were meticulously dissected along their course adjacent to the PCL fibers.

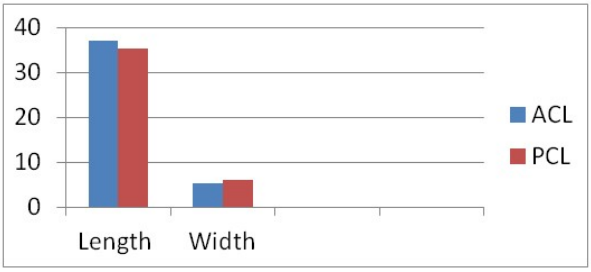
Thirty MRIs of knee joint with no previous detected knee pathology were collected from Department of radiology, Vydehi Institute of Medical Sciences & Research Centre. Sagittal

planes (t2 weighted image) of knee MRI images were reviewed and their Femoral and Tibia measurements & width was measured at mid portion. The data was tabulated for statistical analysis.

Statistical analysis: Mean and standard deviation for cadaveric findings and MRI findings were obtained for both the ligaments. Comparisons were made between ACL and PCL. Student't' test and Mann Whitney U test was used for comparison.

RESULTS

Fig. 1: Comparison of the length and width of the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL).



- Mean length of ACL 37.14mm and width is 5.2mm
- Mean length of PCL 35.39mm and width is 5.93mm
- Length – Independent Sample Test gives P value <0.14
- Width – Mann Whitney Test gives P value <.0001

Fig. 2: Photograph showing the anterior cruciate ligament and posterior cruciate ligament.

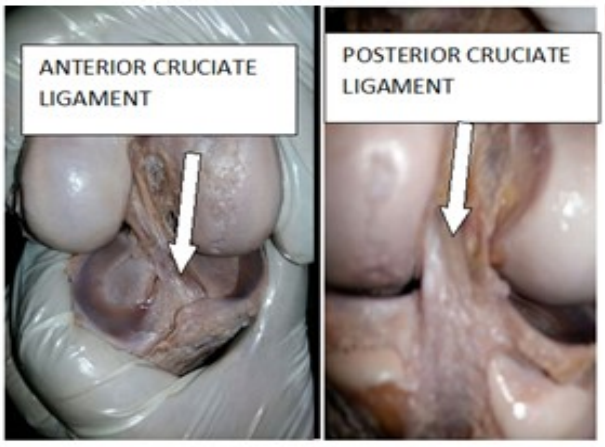
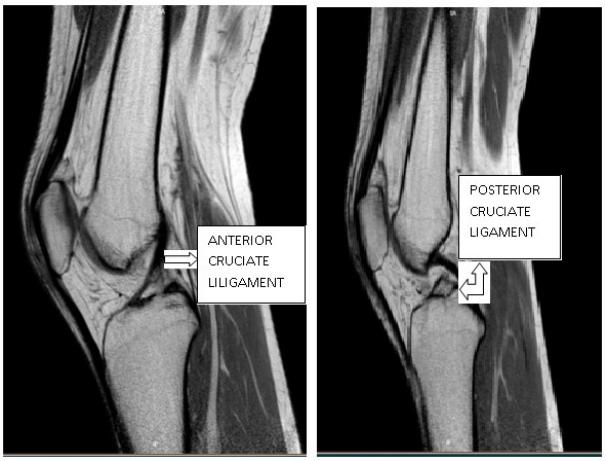


Fig. 3: MRI of anterior cruciate ligament and posterior cruciate ligament.



This study was done on 32 cadaveric knee joints and 30 MRIs of apparently healthy knee joints. After their dissection to expose the anterior and posterior cruciate ligaments, measurements taken and statistical analysis was performed.

The findings are shown in figure 1, 2 & 3. Figure 1 shows the comparison of length and width between ACL and PCL in cadavers and MRI studies.

In the cadavers & MRI measurements, it was observed that ACL was significantly (p value - 0.014) longer than PCL in length. PCL width was larger than ACL width and the difference was statistically highly significant (<0.001).

DISCUSSION

First known description of cruciate ligament is approximately 5000 years old. The anatomy of knee was mentioned in an Egypt papyrus scroll (3000BC) [9]. Hippocrates (460-377 BC) described subluxation of knee and correlated this to ligament injury. In 2nd century Galen of Pergamum gave first description of anatomy and function of the ACL. Next 1600 years, there was barely sufficient work on cruciate ligaments. Earlier, it was thought that cruciate ligaments were a part of nervous system and had contractile properties.

During last ten days of embryological period, the knee joint and its associated structures develop in an orderly process from the blastemal inter zone with no evidence of migration and it is essentially adult in orientation requiring only growth during the fetal development. At horizon 45 days of chronological age, 25-27 days of crown rump length there is appearance of

cruciate ligaments along with chondrification of patella and appearance of menisci.

ACL injuries are due to noncontact injuries that happen when the athletes stop and quickly change directions while they're running. PCL injuries are contact injuries often due to a blow to the knee while it's bent like falling on the knee while it's bent. Cruciate ligament injuries are treated by reconstruction surgeries. These injuries result in joint effusion, altered movement, muscle weakness, reduced functional performance and long term clinical sequelae that include meniscal tears, chondral lesions and an increased risk of early onset post traumatic osteoarthritis within past two decades [10]. ACL injury frequently affects young, active individuals and females are at reported 2 to 10 fold greater risk than males playing the same sport. usually an allo or auto graft tendon taken either from the medial hamstrings or the middle 1⁄3 of the patellar tendon but the reconstruction fails to restore normal joint kinematics and kinetics –mainly due to non-anatomic ligamentous insertion. Over last decade substantial effort has been made to make the surgical reconstruction more anatomical by altering tunnel position and introducing the concept of a double bundle reconstruction. Zantop et al concluded that if the graft was too long the tibial plug would protrude from the tunnel and if the graft was too short the graft would be buried and hence fixation with screw would not be possible. Therefore the length and thickness of the ligaments is important for choosing the graft [11].

Cruciate ligament tears are reconstructed by surgeries where the morphometric studies come in handy. Therefore, this study measured the length and width of ACL and PCL in cadavers and MRI. This study was also interested in correlating the anatomical findings with MRI conclusions.

It was seen in this study that each of the specimen follow a pattern on length and width of the cruciate ligaments both in cadavers and MRI studies. ACL was longer than PCL and PCL was wider than ACL. The mean values also reflected the same. Statistical analysis showed that mean ACL length is significantly longer than PCL in cadaver specimens and on MRI studies. On the contrary PCL width is significantly larger than ACL in both cadaveric and MRI studies. Thus the short stout PCL with a larger area of attachment could explain it being less prone for injury than with the ACL.

This study also compared the results with that of the literature as shown in table 1 & 2. Girgis said that ACL is attached to the posterior part of the medial surface of the lateral femoral condyle and to a wide depressed area in front and lateral to anterior tibial spine (medial intercondylar tubercle) with some fibres extending to the base [2]. Zantop described ACL to originate at the lateral femoral condyle and getting inserted at the medial and lateral tibial spine and to the area in between the spines [12]. However, another study mentioned that ACL is attached to middle of intercondylar area and ACL pass beneath transverse meniscal ligament. Thus the descriptions about the proximal attachment were described to be similar but its distal attachment description varied around the eminences. Our study showed ACL to be attached on medial wall of lateral femoral condyle and getting attached to the intercondylar area behind the anterior horn of medial meniscus and in front of the eminences. Grays commented that bundles of ACL are not visible to the naked eye but can be demonstrated by micro dissection techniques and named them as anteromedial, intermediate and Posterolateral [13]. Kweon accepted that ACL consisted of two discrete bundles [14]. Arnoczky, Petersen SP suggested that ACL has multiple collagen bundles that give rise to multiple fascicular natures. Our study however showed ACL to be consisting of two distinct bundle, (anteromedial bundle & posterolateral bundle) on gross examination which became more evident on movement of knee joint. Amis AA et al said that PCL has an extensive origin on the roof and medial wall of intercondylar notch and a compact tibial insertion on superior surface of posterior tibial shelf. It was also described PCL as attached between posterior horns of the two menisci [15].

Our studies showed PCL to be attached to the lateral surface of the medial femoral condyle running downwards to attach behind the posterior horn of lateral menisci even extending beyond the posterior shelf of tibia, unlike amis findings we didn't find tibial attachments

of PCL between the two horns of menisci.

Table 1: Length &Width of anterior cruciate ligament.

Author	Length (mm)	Width (mm)
Grays [13]	38	11
Girgis FG et al [2]	31-38	10-Dec
Odenstein et al [23]	32 ± 3	
Yelicharla AK et al [21]	Males: 43.5 Females:41.9	Males: 12.1 Females:11
Awadelsied MH [22]	37	5
Iriuchishima T et al [24]	32.28	3
This study	37.14 ± 3.916	5.2 ± 1.094

Table 2: Length & width of posterior cruciate ligament.

Author	Length (mm)	Width (mm)
Grays [13]	38	13
Girgis FG et al [2]	38	13
Covey DC [19]	38	13
Pope T et al [25]	22-38	31
Yelicharla AK et alb[21]	Males: 35.9 Females:37.1	Males: 8.2 Females:9.1
This study	35.39 ± 3.738	5.93 ± 0.778

PCL is supported by two lesser ligaments, namely anterior menisco-femoral and posterior menisco-femoral ligaments. Both the ligaments are seen rarely together, but at least one of them is present in 93% of knees. Menisco-femoral ligaments act as a splint for the injured PCL to heal after its surgical reconstruction we also noted the presence of meniscofemoral ligament around the PCL (37%, PMFL>AMFL). Grays said that PCL is thicker and stronger than ACL and with regard to bundles said that the anterolateral and posteromedial bundles are named (against convention) according to their femoral attachments [13]. Kennedy JC et al showed it to be twice as strong as the ACL or the tibial collaterals [16]. Houghston JC et al have stressed that it is the fundamental stabilizer of the knee, as it is being at the axis of flexion – extension and rotation [17]. In 1836, Weber brothers were the first to describe that there were two bundles in cruciate ligaments [1]. Amis AA et al described PCL as having antero-lateral and postero-medial functional bundles related to femoral attachment [15]. Saddler SC et al, in their study described three bundle in PCL namely, antero-lateral, postero-medial and an oblique reinforcing fibres, while Covey DC et al mentioned that PCL had four geographical fibers [18,19]. Tria AJ also mentions that PCL is more of a compact fiber bundle [20]. Present study also saw two discrete bundles in PCL namely an anterolateral & a posteromedial bundle.

Grays didn't study the difference in length of the ACL and PCL but described PCL broader than ACL. Yelicharla AK et al studied the gender difference in ACL and PCL ligaments. He found that males had significantly longer ACL length. He found no statistical difference in PCL length between males and females [21]. He also found ACL width was larger in males that were statistically significant. Yelicharla AK et al didn't compare the ACL and PCL statistically but it can be seen that mean ACL is longer but narrower than mean PCL values in both males and females. Awadelsied MH found mean radiological length of ACL as 37 mm and mean ACL width as 8mm, which are similar to the findings of this study [22]. Future studies with huge sample size with good randomized method should be done to evaluate the anthropometric measurements.

CONCLUSION

As these ligaments are so much prone for injury and debility, their morphometrics is necessary for proper reconstruction and management preventing unnecessary iatrogenic injury. Future prospective studies with huge sample size with good randomized method should be done to evaluate the anthropometric measurements. The present study contributes to the relative morphometric data on ACL and PCL and stresses that PCL is shorter and wider than ACL making it a more stable structure. This study would be helpful in selecting the quantity and quality of graft for surgical reconstruction of cruciate ligaments.

Conflicts of Interests: **None**

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