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Original Research Article

THE MORPHOMETRIC STUDY OF ANTERIOR CRUCIATE LIGAMENT: A CADAVERIC STUDY

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ABSTRACT

Introduction: The anterior cruciate ligament is frequently injured ligament of the knee. It divides into anteromedial and posterolateral budles attached into tibia and femur. This study aimed to measure the length and width of two bundles of ACL separately to observe the morphormetrical difference. Since single or double bundle ACL reconstructive surgical procedure are commonly used by orthopaedic surgeon, our study may help them in hamstring or tendon graft procedures.

Material and Methods: The Cadaveric study was conducted in the department of Anatomy at Pondicherry institute of Medical sciences, Pondicherry from December 2015 – May 2016. Randomly selected thirty cadaveric was included for the study and knees with ACL tear; macroscopic degenerative changes or any evidence of trauma was excluded from the study. The data was presented as frequencies and proportions, mean and standard deviations. Statistical significance (p value) was considered at 0.05 levels.

Results: There was a statistically significant increase in transverse diameter. We observed P value of transverse diameter of anteromedial bundle at tibial attchment (0.01) and (0.05) in anteroposterior diameter of posterolateral at tibial and in middle (0.04) showed a statistically significant increase in transverse diameter.

Conclusion: ACL tears are managed surgically by a double bundle or single bundle ACL reconstruction technique. Recently, the anatomic double bundle ACL reconstruction has been found to be better in restoring the intact knee function compared to the conventional single bundle surgery when done perfectly. So our study of morphometric measurements of ACL can help the surgeons during accurate tendon graft procedure of anterior cruciate ligament reconstructive surgeries.

KEY WORDS: Reconstruction, anteromedial bundle, posterolateral bundle, Double-bundle, ACL.

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INTRODUCTION

The knee joint has two strong intra-capsular ligaments namely, anterior and posterior cruciate ligaments. The anterior cruciate ligament is attached to the anterior inter-condylar area of the tibia, just anterior and slightly lateral to the medial tibial eminence, partly blending with the anterior horn of the lateral meniscus. It ascends posterolaterally twisting on it and fanning out to attach high on the posteromedial aspect of the lateral femoral condyle. The average length and width of an adult anterior cruciate ligament are 38mm and 11mm respectively [1].

The anterior cruciate ligament consider as very important for function of knee joint and get injured commonly than other ligaments of knee. The ACL tears are managed surgically by a double bundle or single bundle ACL reconstruction technique. In recent times, the anatomic double bundle ACL reconstruction is found to be better in restoring the intact knee kinetics compared to the traditional single bundle surgery when done accurately [2-4].

The study done by Saxena et al. stated that the width of tibial end of ACL is greater in Indian population compared to the west [5]. Arthroscopic ACL reconstruction using bone-patellar tendon-bone autograft and hamstring grafts is necessary for a severe tear of the ACL ligament [6]. However, detailed studies on morphology and morphormetry of knee joint among the Indian population are very few in number.

AIM: To study the morphology and morphormetry of anterior cruciate ligament in cadavers.

Objectives: To measure the length and thickness of anterior cruciate ligament (ACL) in thirty cadaveric knee.

MATERIALS AND METHODS

Thirty cadaveric knees were selected randomly from the department of Anatomy at Pondicherry institute of medical sciences, Pondicherry in the duration of December 2015- May 2016. In the cadaver, an "I" shaped incision was made, following which, the skin, patellar ligament and the capsule of knee joint was reflected to visualize and study the morphology of ACL (Fig.1). Knees with ACL tear; macroscopic degenerative changes or any evidence of trauma was excluded. The Knees were kept in the angle of 30^0 60^0, 90^0 flexion position with the help of goniometer (Fig.3) and the ACL was bluntly separated into two bundles (Fig.2). The length of Anteromedial and posterolateral bundles of ACL was measured from femoral to tibial attachments (Fig.5, 6). The width of ACL in tibial, femoral attachments as well as the middle portion (Fig.7) of anteromedial and posterolateral bands separately was measured using Digital vernier caliper in millimeter (Fig.4).

Statistical Analysis: The results were expressed as frequencies and proportions, mean and standard deviations. The comparison of morphometric dimensions of the right and left sides was performed using Student's t-test. P value less than 0.05 was considered to be statistically significant.

Fig. 1: Arrow shows the anterior cruciate ligament

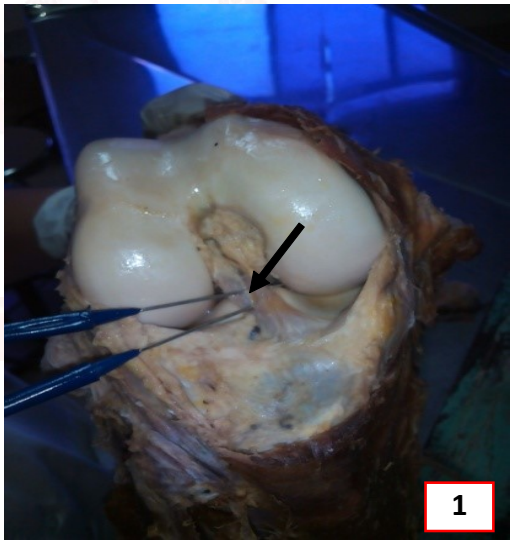
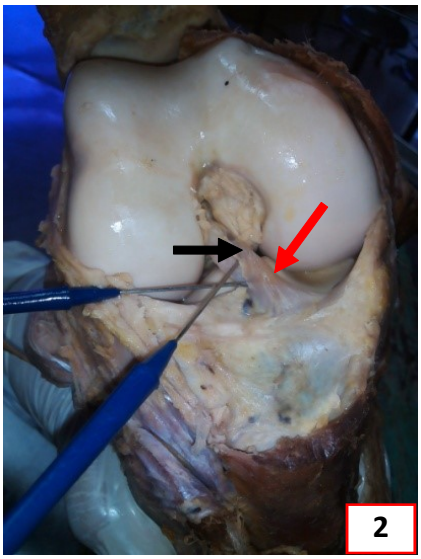


Fig. 2: Black arrow shows the



posterolateral bundle and the red arrow shows the anteromedial bundle

Fig. 3: shows the Digital vernier caliper

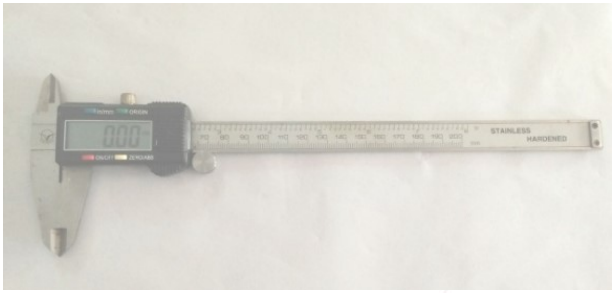


Fig. 4: shows the Goniometer

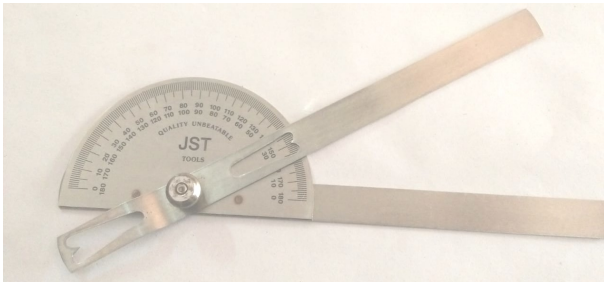
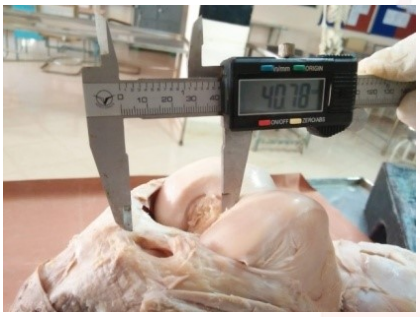


Fig. 5 and 6: shows the measurement of anteromedial and posterolateral bundles **Fig. 7:** shows the measurement of width in the middle of the ligament



RESULTS

Table 1: Length and width of anteromedial bundle of anterior cruciate ligament.

Position of Knee	Length of AMB Mean±SD	TD of AMB middle Mean±SD	TD of AMB tibial Mean±SD	TD of AMB femoral Mean±SD	AP AMB middle Mean±SD	AMB AP tibial Mean±SD	AMB AP femoral Mean±SD
30°	40.3 ±1.61	5.06±1.02	5.76±1.29	4.99±1.36	2.7±0.934	2.12±0.734	1.52±0.381
60°	35.94±2.37	-	-	-	-	-	-
90°	32.27 ±2.33	-	-	-	-	-	-

AMB – anteromedial bundle TD-transverse diameter AP-antreoposterior

Table 2: Right and left side of anteromedial bundle of anterior cruciate ligament.

Position of knee	length of RT AMB Mean±SD n=13 (right)	length of LT AMB Mean±SD n=17 (left)
30°	40.87±1.77	39.86±1.38
60°	36.09±2.61	35.82±2.24
90°	32.25±2.25	32.28±2.45

RT-right AMB-anteromedial bundle LT-left

Table 4: Mean ± standard deviation Right and left side of posterolateral bundle of anterior cruciate ligament.

Position of knee	length of RT PLB Mean±SD n=13(right)	length of LT PLB Mean±SD n=17(left)
30°	32.33±3.43	31.86±2.74
60°	29.23±2.77	28.18±2.76
90°	26.56±2.03	25.69±2.86

Table 3: The mean ± standard deviation of length and width of posterolateral bundle of anterior cruciate ligament.

Position of knee	length of PLB Mean±SD	TD of PLB middle Mean±SD	TD of PLB tibial Mean±SD	TD of PLB femoral Mean±SD	AP of PLB middle Mean±SD	AP of PLB tibial Mean±SD	AP of PLB femoral Mean±SD
30°	32.07±3.01	4.29±1.02	4.01±0.71	3.52±1.19	1.95±0.572	1.51±0.503	1.27±0.36
60°	28.63 ± 2.77	-	-	'-	-	-	-
90°	26.07±2.53	-	-	-	-	-	-

PLB-posterolateral bundle TD-transverse diameter AP-anteroposterior

The results of anteromedial bundle of ACL in different angle position shown in (Tab. 1). The right and left sides of anteromedial bundle is shown in (Tab. 2) and the posterolateral bundle were measured like AMB and shown in (Tab. 3 &4). There was a statistically significant increase in transverse diameter. We observed P value of transverse diameter of anteromedial bundle at tibial attchment (0.01) and (0.05) in anteroposterior diameter of posterolateral at tibial and in middle (0.04) showed a statistically significant increase in transverse diameter.

Table 6: Mean ± standard deviation Right and left side of posterolateral bundle of anterior cruciate ligament.

Position of knee	length of RT PLB Mean±SD n=13(right)	length of LT PLB Mean±SD n=17(left)
30°	32.33±3.43	31.86±2.74
60°	29.23±2.77	28.18±2.76
90°	26.56±2.03	25.69±2.86

Table 5: The mean ± standard deviation of length and width of posterolateral bundle of anterior cruciate ligament

Position of knee	length of PLB Mean±SD	TD of PLB middle Mean±SD	TD of PLB tibial Mean±SD	TD of PLB femoral Mean±SD	AP of PLB middle Mean±SD	AP of PLB tibial Mean±SD	AP of PLB femoral Mean±SD
30°	32.07 ±3.01	4.29±1.02	4.01±0.71	3.52±1.19	1.95±0.572	1.51±0.503	1.27±0.36
60°	28.63± 2.77	-	-	-	-	-	-
90°	26.07±2.53	-	-	-	-	-	-

PLB-posterolateral bundle TD-transverse diameter AP-anteroposterior

DISCUSSION

The anterior cruciate ligament has anteromedial and posterolateral bundles. These two bundles create distinct anatomical foot-prints in response to traction forces which help them to identify easily during arthroscopic ACL surgeries [7]. In the present study we observed the bundles of ACL while reflecting the ligamentum patellae at knee in 90^0 positions (Fig.1).

Saxena et.al studied the morphormetry of anterior cruciate ligament in fourteen right and twelve left knees from 21 male and 5 female adult cadavers using digital caliper. The anterior cruciate ligament was measured as whole bundle without separating as anteromedial and posterolateral the result of the study showed the length and width of ACL were 32.5 ± 4.33 mm and 9.38 ± 1.58 mm (amb+plb)[5].

In the present study we measured the length of anterior cruciate ligament, mean and standard deviation was 32.2±2.43 and width was 9.38±1.02. So the result of our study is similar to the results of Saxena et.al. (Table 1).

Hanno Steckel et.al in 2010 studied the femoral insertions of anteromedial and posterolateral bundles. They chosen four fresh-frozen cadaver knees (two left and two right knees) and measured the femoral insertion of each bundle on the lateral roentgenogram. Each bundles were assessed at 0^0, 30^0 60^0 and 90^0 position of knee flexion. The clinical relevance of this study states that the centers of the AM and PL bundle become horizontally aligned when the knee is flexed beyond 90^0. They suggested the degree of knee flexion should be taken into account for femoral tunnel placement and for describing tunnel positioning [8].

The present study measured the length and width of ACL by digital vernier caliper in different angle position in 30^0, 60^0, and 90^0 using goniometer. We also observed the anteromedial and posterolateral bunles were horizontally arranged in 90^0 flexion of knee. (Fig.1)

Odenston et.al in 1985 studied the Functional anatomy of anterior cruciate ligament and its basis for reconstruction in thirty-three adult normal cadaveric knees. The average length of ACL in mead and standard deviation 31 ± 3 millimeters and the angle between the ligament and the long axis of the femur was 28 ± 4 degrees at knee was in 90^0 flexion [9].

In this study we measured the length of ACL in 30 randomly selected cadaveric knees at 90^0 angle flexion position. The average length was 32.2±2.43 (amb + plb) mean and standard deviation. So the results of our study of the length was little greater than Odenston et.al.

Table 7: Comparison of P value between anteromedial and posterterolateral bundle.

Position of knee	Length of AMB of ACL	Length of PLB ACL	AMB TD M	PL TD M	AMB TD T	PLB TD T	AMBTD F	PLB TD F	AMB AP M	PLBAP M	AMB AP T	PLB AP T	AMB AP F	PLBAP F
30°	0.09	0.7	0.5	0.6	0.01	0.8	0.5	0.3	0.3	0.04	0.8	0.05	0.6	0.2
60°	0.8	0.3	-	-	-	-	-	-	-	-	-	-	-	-
90°	0.9	0.4	-	-	-	-	-	-	-	-	-	-	-	-

ACL - anterior cruciate ligament AMB - anteromedial bundle TD – transverse diameter M-middle T-tibial F-femoral PLB – posterolateral bundle AP - anteroposterior

Kulkamthom. N et.al in 2012 studied the anterior cruciate ligament footprint in cadaveric Thai pulation. Among 77 knees from 39 cadavers were dissected to identify bony landmarks of ACL at both tibia and femoral attachment. The footprint on tibia and femur were measured in length and width at 0, 30, 60, 90, 120, and 180° degrees of knee flexion. The length and width of ACL was measured in distance between the anterior and the posterior edge of the tibial insertion and the width was measured at its widest part between tibial condyle. The length of the femoral insertion was measured from the most proximal to the most distal point of ACL insertion in the direction of posterior femoral cortex. The width was measured as the greatest perpendicular distance between the line of femoral insertion length and the beginning of the joint surface at the point of outer femoral condyle's greatest convexity (Table 7) [10].

Table 8: The foot prints of ACL length and width of femoral and tibial attachment of ACL.

No of cases	Length of footprint of ACL Femoral attachment Mean±SD	width of ACL Femoral attachment Mean±SD	length of ACL tibial attachment Mean±SD	width of ACL tibial attachment Mean±SD
77	12.01 +/- 1.66	9.52 +/- 1.37	15.36 +/- 2.33	11.03 +/- 1.77
Male	12.68 +/- 1.48	9.99 +/- 1.38	16.84 +/- 1.07	11.32 +/- 1.43
Female	10.68 +/- 1.1	8.64 +/- 0.79	12.48 +/- 1.08	10.1 +/- 0.96

The average size of ACL tibial footprint in Thai female were smaller than 14 mm and the average size of ACL femoral footprint in Thai male is greater than 14 mm. So they suggested their findings can be alert the surgeon that double bundle technique could be performed in Thai male patients.

In the present study we measured the foot print of ACL as anteroposterior(AP) and transverse diameter(TD) at tibial and femoral attachment of anterior cruciate ligament. The AP measurement was done by the jaws of digital vernier caliper. The one end of caliper jaw kept at proximal insertion of ACL of tibia and the other end of the jaw was on to the distal attachment area on tibia. The transverse diameter of ACL measured the in horizontal position of jaw of caliper at lateral and medial ends of ligament on tibia. The femoral attachment was measured like tibial measurement. The results of the measurement were (amb+plb) together of bundles of ACL showed in (Table 8).

Table 9: Mean ± standard deviation of anteroposterior and transverse diameter of anterior cruciate ligament.

No of cases	Mean ± standard deviation anteroposterior diameter ACL in Femoral attachment	Mean ± standard deviation tranverse diameter (width) of ACL Femoral attachment	Mean ± standard deviation length of tibial attchment	Mean ± standard deviation width of ACL tibial attachment
30	2.79±0.74	8.51±2.55	3.63±1.24	9.77±2.0

Ahmed Bheheri et.al studied the structure and position of anterior cruciate ligament in twelve cadaveric knees. The two bundles were identified as distinct anteromedial bundle attached in the location of anterior region as semi-lunar and in one case the attachment was round in nature. The two bundles were parallel in full extension of knee and the fibers of AMB were anterior to the posterolateral bundle. Also they observed that the fiber of femoral attachment of AMB was directed backwards but the PLB were directed forwards. At 90^0 flexed position of knee the two bundles were in cross. They concluded that the anteromedial bundle were firm in 90° and less stiffness in full extension of knee. The posterior cruciate ligament was excised and to expose the femoral attachment of the ACL the medial femoral condyle was removed with a spots Tension pattern and anatomical position change of each bundle were evaluated at 0, 30, 60, 90, 120, and 180° of knee flexion [11].

We also observed the ACL bundles in 30 randomly selected cadaveric knees kept in 30^0,60^0, 90^0 flexed position of knee like ahmed Bheheri et.al and measured the length and width

of the anteromedial and posterolateral bundles of ACL and observed the length and width was not same and the AMB was taut than PLB in 90^0 position of knee (Table1-6).

Lazar Stijak et.al in 2009 conducted a study in 50 cadavers with intact anterior cruciate ligament. They measured the length of anteromedial and posterolateral bundle and the mean length and the width of the ligament, the length and width of tibial insertion, the length and width of femoral insertion. Accordingly, with greater width of intercondylar notch, men have wider ACL than women. ACL width is in positive correlation with the male intercondylar notch width but it is not in correlation with the female intercondylar notch width. The width of male intercondylar notch correlates with the length and width of ACL femoral insertion. Taking into account the length and width of femoral insertion in examined cadaver knees, double bundle reconstruction would theoretically be possible in 76% of cases [12].

We observed the morphormetry of ACL in measuring the length and width of anteromedial and posterolateral bundle by digital vernier caliper and we observed two areas showed statistically significant P value in transverse diameter of anteromedial bundle at tibial attchment (*p 0*.01) and (*p 0*.05) in anteroposterior diameter of posterolateral bundle in middle part (*p 0*.04) and in tibial attachment showed statistically significant result. (Table.6)

CONCLUSION

Anterior cruciate ligament injuries become the common injury of knee in all age groups and in any gender and it will affect the normal function of gait. This cadaveric morphormetric study of ACL can help for tunnel placement and tendon graft surgical procedures.

ABBREVATIONS

AMB – Anteromedial Bundle
PLB – Posterolateral Bundle
ACL – Anterior Cruciate Ligament

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Conflicts of Interests: None

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