Anatomy of the Cruciate Ligaments of the Knee Joint in a Thai Population

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Purpose: *To study the anatomy of the anterior cruciate and posterior cruciate ligaments.*
Methods: *Twenty-two Thai cadaveric knees without previous surgery were used for anatomical study of the ACL and the PCL for size and location.*
Results: *The anterior cruciate ligament had an average length of 33.1 millimeters, and an average width of 10.0 millimeters. The posterior cruciate ligament had an average length of 33.0 millimeters, and an average width of 11.0 millimeters. By using the Wilcoxon rank sum and sign rank tests, no difference was found between gender, sides, and length (P>0.05). We did find that the middle portion of the posterior cruciate ligament was statistically wider than that of the anterior cruciate ligament (P<0.05). The axis of the femoral attachment of the anterior cruciate ligament tilted forward to the vertical axis an average of 26.3 degrees. The average width of the attachment to the femur and the tibia was 16.3 millimeters and 20.0 millimeters, respectively. The attachment of ACL at femur is more posterior and at tibia is more anterior in Thai population. The posterior cruciate ligament was attached to the anterior part of the lateral surface of the medial femoral condyle. The axis of the attachment aligned with the horizontal. The average widths of the femoral and tibial attachment were 19.7 millimeters and 13.9 millimeters, respectively.*
Conclusion: *Clinical application of these findings to aid in the location of the attachment site of a tendon graft in the surgical treatment of chronic knee instability will benefit Thai patients.*

Keywords: *Anatomy, cruciate, ligament, knee, Thai*

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Introduction

Cruciate ligaments of the knee create most of the problems of chronic knee instability in all age groups. Major causes of injury are sports and traffic accidents. Anterior cruciate ligament(ACL) and posterior cruciate ligament(PCL) were the most common ligament injury in the knee joint[(1)], and an operation is acceptable for a patient who suffers from knee instability. One preferable operation nowadays is intraarticular reconstruction using bone-patella tendon-bone[(2-7)], or a tendon from the medial hamstring[(8-11)] which has equal or greater strength and does not compress the nearby structures: posterior cruciate ligament and intercondylar notch. The most critical factors in obtaining a successful operation is proper graft placement[(12-14)], so size and attachment location of the ACL and the PCL should be basic knowledge for bone surgeons.

The anatomy of the ACL and the PCL in a Thai population has not as yet been reported, hence our interest in this study for the following purposes:

1. anatomical study of the ACL and the PCL for size and location on the femur and the tibia;
2. comparison with previous studies in non-Thai populations;
3. clinical applications in ligament reconstruction; and
4. preparation for a further study to guide the size of a tendon graft in knee ligament reconstruction in a Thai population

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Materials and Methods

We studied the anatomy of 22 cadaveric knees provided by the Department of Anatomy, Faculty of Medicine, Chiang Mai University. Six male (12 knees) and 5 female cadavers (10 knees), with an age range from 25 to 82 years (average 56.5 years) were included. None had a history of knee trauma or knee surgery. The anatomy of the ACL and the PCL was studied as follows:

1. the tibia was cut 15 centimeters below the knee, and the femur 15 centimeters above;
2. the skin, muscle, vessels and synovial tissue was then dissected from the knee joint;
3. an oscillating saw was used to divide the femoral bone in the sagittal plane to view the origins of the ACL and the PCL;
4. the length and width of each ACL and PCL was measured; and
5. all ACL and PCL were cut at the bony attachment to measure the relationship between the

attachment site and bony structure (see figures 1 and 2).

A vernier caliper was used for length measurement and a goniometer for angle measurement. Each measurement was repeated three times and the mean calculated.

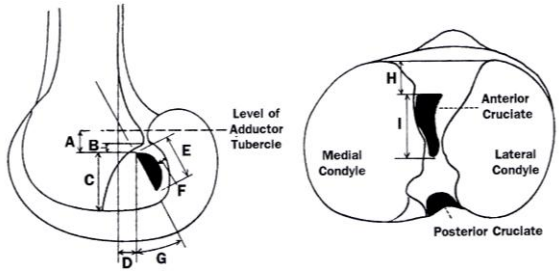

Fig. 1 Attachment site of anterior cruciate ligament and bony landmarks
A: distance between the most superior femoral attachment and the level of the adductor tubercle
B: distance between the most superior femoral attachment and the roof of posterior intercondylar notch
C: distance between the most superior femoral attachment and the border of the distal articular cartilage
D: distance between the most anterior femoral attachment and the axis of posterior femoral cortex
E: Length of the femoral attachment site
F: distance between the posterior femoral attachment and the border of the posterior articular cartilage
G: Angle between the axis of the attachment and the vertical axis
H: distance between the anterior edge of tibia articular surface and the most anterior tibial attachment
I: Length of the tibial attachment site

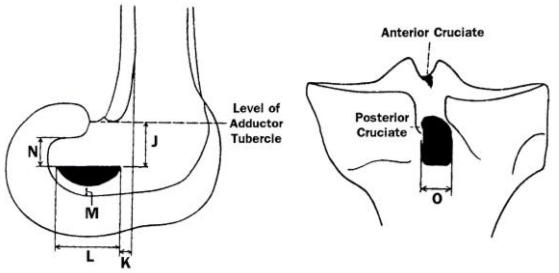

Fig. 2 Attachment sites of posterior cruciate ligament and bony landmarks
J: distance between the most superior attachment and a level of adductor tubercle
K: distance between the most anterior femoral attachment and the axis of posterior femoral cortex
L: Length of the femoral attachment site
M: distance between the most distal femoral attachment and the border of the distal articular cartilage
N: distance between the most superior femoral attachment and the roof of posterior intercondylar notch
O: Width of the tibial attachment site

Statistical analysis

1. Data was calculated for a mean and a standard deviation for a size and a distance between the bony structures, and separated for right and left knee and for male and female.

2. Wilcoxon rank sum test (Mann Whitney U test) was used for comparison between right and left knees and between males and females.

3. Wilcoxon sign rank test was used for comparison between ACL and PCL in the same knee.

Results

Anterior Cruciate Ligament

1. Dimensions

ACL: length from 30.5 to 38.7 millimeters (average 33.1 millimeters). There was a standard deviation of 1.8 millimeters and Mean ± SD 31.3-34.9 millimeters (table 1).

ACL: width from 8.1-12.1 millimeters (average 10.0 millimeters). There was a standard deviation 1.1 millimeters and Mean ± SD 8.9-11.1 millimeters (table 1).

There was no statistical significance between male and female, or between right and left knees in length and width of ACL ($p>0.05$) (table 1).

Table 1 Average length and width at mid portion of ACL in Thai population

Sample	Length (millimeter)			Width at mid portion (millimeter)		
	Range	Mean	SD	Range	Mean	SD
All samples (n=22)	30.5-38.7	33.1	1.8	8.1-12.1	10.0	1.1
By side						
Right knee (n=11)	31.2-35.8	33.0	1.4	8.1-12.1	10.0	1.2
Left knee (n=11)	30.5-38.7	33.2	2.2	8.4-12.0	10.0	1.0
By gender						
Right knee (n=12)	30.5-38.7	33.2	2.3	8.1-12.1	9.9	1.3
Left knee (n=10)	31.7-34.1	32.9	0.8	9.1-11.3	10.1	0.7

2. Femoral attachment

ACL was attached to the posterior aspect of the medial surface of the lateral femoral condyle and the attachment site was semicircular. The axis of the femoral attachment tilted forward to the vertical axis and the relationship with the bony structure is shown in table 2.

3. Tibial attachment

ACL was attached laterally to the anterior tibial spine. A distance from the anterior edge of tibial articular surface to the most anterior tibial attachment (H) ranged from 10.2-14.4 millimeters (average 12.7 millimeters). The length of the ACL tibial attachment (I) ranged from 15.0-22.8 millimeters (average 20.0 millimeters), (table 2).

Table 2 Distance between the attachment site of ACL (n=22) and the bony landmark in Thai population

Parameters	Range	Mean	SD	Mean ± SD
A	4.2-9.0	6.0	1.6	4.4-7.6
B	0.9-8.3	3.7	2.3	1.4-6.0
C	14.1-18.9	15.8	1.4	14.4-17.2
D	13.3-20.8	16.8	2.6	14.2-19.4
E	12.1-18.5	16.3	1.6	14.7-17.9
F	0.0-4.1	1.4	1.4	0.0-2.8
G	19-38	26.3	6.2	20.1-32.5
H	10.2-14.4	12.7	1.2	11.5-13.9
I	15.0-22.8	20.0	2.1	17.9-22.1

Table 3 Average length and width at mid portion of PCL in Thai population

Sample	Length (millimeter)			Width at mid portion (millimeter)		
	Range	Mean	SD	Range	Mean	SD
All samples (n=22)	29.4-38.1	33.0	2.5	9.8-13.0	11.0	0.8
By side						
Right knee (n=11)	29.4-38.1	32.9	2.7	10.0	13.0	1.1
Left knee (n=11)	29.7-36.5	33.0	2.3	9.8-12.1	10.9	0.8
By gender						
Right knee (n=12)	29.4-38.1	32.7	3.2	10.2-13.0	11.4	0.8
Left knee (n=10)	32.0-35.0	33.3	1.1	9.8-11.7	10.5	0.6

Posterior Cruciate Ligament

1. Dimensions

PCL: length from 29.4 to 38.1 millimeters (average 33.0 millimeters). There was a standard deviation of 2.5 millimeters and Mean ± SD 30.5-35.5 millimeters (table 3).

PCL: width from 9.8-13.0 millimeters (average 11.0 millimeters). There was a standard deviation 0.8 millimeter and Mean ± SD 10.2-11.8 millimeters (table 3).

There was no statistical significance comparing between male and female, or between right and left knee in length and width of PCL ($p>0.05$) (table 3).

2. Femoral attachment

The PCL was attached on the anterior of lateral surface of medial femoral condyle and the attachment site was semicircular shape similar to the ACL. The axis of the femoral attachment paralleled to the horizontal axis and the relationship with the bony structure was shown in table 4.

3. Tibial attachment

The PCL was attached at the posterior edge of tibia and the width (O) was ranged from 11.1 to 18.7 millimeters (average 13.9 millimeters). There was a standard deviation 2.1 millimeters and Mean ± SD 11.8-16.0 millimeters (table 4).

Table 4 Average distance between the attachment site of PCL (n=22) and the bony landmark in Thai population

Parameters	Range	Mean	SD	Mean ± SD
J	7.5-21.8	15.6	4.1	11.5-19.7
K	0.0-11.2	6.5	3.6	2.9-10.1
L	16.0-27.4	19.7	3.6	16.1-23.3
M	0.0-5.2	1.0	1.6	(-0.6)-2.6
N	7.2-17.9	12.9	2.8	10.1-15.7
O	11.1-18.7	13.9	2.1	11.8-16.0

The relationship between ACL and PCL

In the same knee, there was no statistical significance in comparison of the length of the ACL and the PCL ($P>0.05$), but at the mid portion of the tendons, the width of the PCL was larger than the ACL (statistically significant, $P<0.05$).

Discussion

The operative treatment in the patient with knee instability from anterior cruciate ligament injury has been reported by many authors[2-11]. The most popular procedure is an intraarticular procedure which provides similar biomechanics to the natural ACL, more so than provided by extraarticular procedures[14]. A bone-patella tendon-bone graft (BPTB) is one of the most popular tissues for a ligament reconstruction because it provides good strength compared to other grafts[15]. However, good treatment results depend on many factors such as graft fixation, graft tension, and notchplasty but the most important factor is the anatomical location of the graft[12-14], especially the femoral attachment site of the reconstructed tendon. If the graft is placed more anteriorly, it is too tight in flexion and too loose in extension. Conversely, a graft placed more posteriorly would produce looseness in flexion and tightness in extension. Thus the patient cannot perform full knee extension, lacks stability, and may suffer from many complications.

Reconstruction procedures require knowledge of the basic anatomy of the ACL and the PCL. No previous study has been reported yet in Thailand. Previous data from international journals may not apply clinically in a Thai population. Hence the authors decided to undertake the present research to establish Thai reference data for these two ligaments.

Anterior Cruciate Ligament

According to our study, the average width of the Thai ACL at the mid portion is 10.0 millimeters and average length 33.1 millimeters. This is less than found in the study by Girrgis FG[16], in which the ACL had an average width of 11.0 millimeters and an average length of 38.0 millimeters (table 5). A difference of a distance of the attached location on a bony structure was shown in table 6.

Data that must be known in order to perform an operation of anterior cruciate ligament reconstruction are:

1. the distance between the most superior femoral attachment and the roof of posterior intercondylar notch (B) in a Thai population is 3.7 millimeters;
2. the length of the femoral attachment site (E) in Thai population is 16.3 millimeters;
3. the distance between the posterior femoral attachment and the border of the posterior articular cartilage (F) in Thai population is 1.4 millimeters.

Posterior Cruciate Ligament

According to our study, PCL had the average width at the mid portion of 11.0 millimeters, and an average length of 33.0 millimeters which were less than the study from Girgis FG[16], where the PCL had the average width 13.0 millimeters and average length 38.0 millimeters (table 5). Difference in the distance of the attachment location on a bony structure are shown in table 7.

Data that must be known in order to perform an operation of posterior cruciate ligament reconstruction are

1. length of the femoral attachment site (L) in Thai population is 19.7 millimeters; and
2. distance between the most distal femoral attachment and the border of the distal articular cartilage (M) in Thai population is 1.0 millimeter

Table 5 Average dimensions of ACL and PCL as compared to another study

Study	Anterior Cruciate Ligament		Posterior Cruciate Ligament	
	Length	Width	Length	Width
Girgis FG[16]	38.0	11.0	38.0	13.0
Chiang Mai	33.1	10.0	33.0	11.0

Table 6 An average distance between the attachment site of ACL and the bony landmark

Study	Anterior Cruciate Ligament								
	A	B	C	D	E	F	G	H	I
Girgis FG[16]	12	4	12-20	8	23	4	25	15	30
Chiang Mai	6.0	3.7	15.8	16.8	16.3	1.4	26.3	12.7	20.0

Table 7 An average distance between the attachment site of PCL and the bony landmark

Study	Posterior Cruciate Ligament					
	J	K	L	M	N	O
Girgis FG[16]	23	5	32	3	15	13
Chiang Mai	15.6	6.5	19.7	1.0	12.9	13.9

Brantigan OC[17] and Palmer I[18] concluded that the PCL was shorter than the ACL, but our study has shown that the length of the two ligaments is similar in the same knee, with no statistical significance (P>0.05) for the two ligaments similarly to study of Girgis FG[16].

The limitation of this study is small sample size which perhaps does not reflect the whole Thai population. The data from our study have shown that the width and length of the Thai ACL and PCL are less than the measurements reported in many international reports. This may be caused by the smaller stature of Thai people when compared to Europeans. It is interesting to note that the proper width of a graft for ligament reconstruction in a Thai population should less than that which would be used in European people[2-7]. The lower width of the graft (10millimeters) could reduce the complication of graft compression between the intercondylar notch and the PCL. The smaller width may also reduce complications at the donor site. This requires further study to verify the the proper graft size for Thais requiring knee reconstruction.

Compared to the study of Girgis FG[16], the anatomy of ACL and PCL in a Thai population is shown in figure 3. For ACL reconstruction, the attachment at femur is more posterior and at tibia is more anterior in Thai population, so the reference attachment from the study of Girgis FG can cause too anterior at femur and too posterior at tibia for Thai population. For PCL reconstruction, the attachment at femur and tibia is similar from Thai population and from study of Girgis FG.

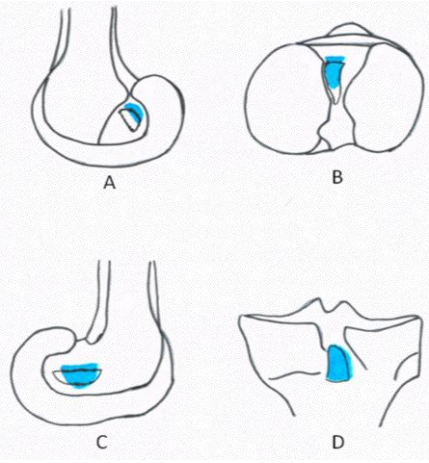

Fig. 3 The anatomy of ACL (A and B) and PCL (C and D) in Thai population (blue) compared to the study of Girgis FG[16] (black).

Conclusion

The results of this study have demonstrated the anatomy of the ACL and the PCL in Thais. This should be considered basic data for the Orthopedist when treating the patient with knee instability due to ligaments injury. Often we cannot clearly identify the attachment site of the ligaments, so we may use these data to point to the proper attachment of the tendon graft using bony structures as a reference. Finally, these data will help the investigator to study further how to select the best location for a tendon graft in knee ligament reconstruction.

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กายวิภาคของเอ็นไขว้ในข้อเข่าในคนไทย

ประสิทธิ์ วงศ์ตรีรัตนชัย, พบ, นพพร นิวัฒนนันท์, พบ, สัตยา โรจนเสถียร, พบ

วัตถุประสงค์*: เพื่อศึกษากายวิภาคของ Anterior cruciate ligament (ACL) และ Posterior cruciate ligament (PCL) ในแง่ของขนาดและตำแหน่งในคนไทย*

วัสดุและวิธีการ*: ข้อเข่าจากศพ จำนวน 22 เข่า ที่ไม่เคยได้รับการผ่าตัดเข่ามาก่อน*

ผลการศึกษา*: เอ็นไขว้หน้ามีความยาวเฉลี่ย 33.1 มิลลิเมตร (30.5-38.7 มิลลิเมตร) และมีความกว้างที่จุดกึ่งกลางเส้นเอ็นเฉลี่ย 11.0 มิลลิเมตร (29.4-38.1 มิลลิเมตร) และมีความกว้างที่จุดกึ่งกลางเส้นเอ็นเฉลี่ย 11.0 มิลลิเมตร (9.8-13.0 มิลลิเมตร) ไม่พบความแตกต่างระหว่าง เพศชายกับเพศหญิง (P>0.05) ไม่พบความแตกต่างระหว่างเข่าขวากับเข่าซ้ายในศพเดียวกัน (P>0.05) และไม่พบความแตกต่างเมื่อเปรียบเทียบความยาว ของเอ็นไขว้หน้ากับ เอ็นไขว้หลังในข้อเข่าข้างเดียวกัน (P>0.05) ที่ระดับความเชื่อมั่นร้อยละ 95 ความกว้างที่จุดกึ่งกลางเส้นเอ็นของเอ็นไขว้หลังมีค่ามากกว่าเอ็นไขว้หน้า อย่างมีนัยสำคัญทางสถิติ (P<0.05) เอ็นไขว้หน้ายึดเกาะอยู่บริเวณส่วนหลังของ Medial surface ของ Lateral femoral condyle โดยจุดยึดเกาะบนกระดูกมีรูปร่างเป็นส่วนของวงกลม แกนของจุดยึดเกาะเอียงไปข้างหน้าเล็กน้อย ทำมุมกับแกนตั้งเฉลี่ย 26.3 องศา ความกว้างของจุดยึดเกาะบนกระดูก Femur และ Tibia เฉลี่ยเป็น 16.3 มิลลิเมตร และ 20.0 มิลลิเมตร ตามลำดับ เอ็นไขว้หลังยึดเกาะอยู่บริเวณส่วนหน้าของ Lateral surface ของ Medial femoral condyle โดยจุดยึดเกาะบนกระดูกมีรูปร่างเป็นส่วนของวงกลมมีแกนอยู่ในระนาบพื้น ความกว้างของจุดยึดเกาะบนกระดูก Femur และ Tibia เฉลี่ยเป็น 19.7 มิลลิเมตร และ 13.9 มิลลิเมตร ตามลำดับ*

สรุป*: ผลการศึกษานี้สามารถนำไปประยุกต์ใช้ในการกำหนดจุดฝังเส้นเอ็นบนกระดูกในการผ่าตัดสร้างเส้นเอ็นสำหรับผู้ป่วยที่มีภาวะข้อเข่าหลวม*