



The triangle between the anterior and posterior cruciate ligaments: an arthroscopic anatomy study

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Objective: The goal of anterior cruciate ligament (ACL) reconstruction is to place the graft in closest proximity to the native ACL anatomy. This study aims to examine the angular relation between intact anterior and posterior cruciate ligaments (PCL) from an arthroscopic perspective.

Methods: Forty patients (20 male, 20 female) with a mean age of 35.12 (range: 18–40) years that underwent knee arthroscopy for reasons other than ACL rupture were included in the study. Following diagnostic examination and repair of the primary pathology, the triangle between ACL and PCL was seen at different flexion degrees of the knee joint (120, 90, 60, and 30°) through standard anterolateral (AL) and anteromedial (AM) portals. The narrow top angle of the triangle between the long intersecting axes of ACL and PCL was measured using recorded images by 3 blind observers.

Results: The average ACL-PCL angle was 61°, (standard deviation \pm 2°) at 90° of knee flexion. The angles were narrower when viewed through the AM portal. The degree of the angles was not affected by age, sex, body mass index (BMI), or the side (right or left) on which the procedure was performed. There was good-to-excellent intra- and interobserver reliability.

Conclusion: The angular relation between intact ACL and PCL has the potential to provide a better view of the anatomy during arthroscopic ACL surgery. To perform better anatomic reconstructions, it is important to create a 60° angle between the ACL graft and PCL (as viewed through AL portal) at 90° of knee flexion.

Keywords: Anatomy; anterior cruciate ligament; arthroscopy; posterior cruciate ligament; reconstruction; triangle.

Level of Evidence: Level IV Therapeutic Study

Previous studies on anterior cruciate ligament (ACL) have mainly focused on its anatomy and function, in an attempt to develop better reconstruction techniques. The anatomy of the ACL has been detailed in cadaveric, biomechanical, and embryological studies,^[1–10] which have provided useful data for the identification of femoral and

tibial tunnel locations for anatomic ACL reconstruction.

Following arthroscopic ACL reconstruction, a triangular space should be visible at the apex of the notch with the knee in 90° of flexion.^[11] The borders of the triangle consist of the roof of the notch, the anteromedially directed fibers of the posterior cruciate ligament (PCL), and

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Submitted: November 10, 2014 **Accepted:** February 15, 2015

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Available online at
www.aott.org.tr
doi: 10.3944/AOTT.2015.14.0402
QR (Quick Response) Code



the posterolaterally directed fibers of the ACL graft.^[12]

The aim of this study was to demonstrate the angular relationship between ACL and PCL using arthroscopy. Since tunnels are established when the knee is in a flexed position during ACL reconstruction, the relationship between ACL and PCL at various flexion angles of the knee could provide helpful information about the reconstructed ligament's conformity to native ACL.

Patients and methods

Patients who were admitted to our hospital and underwent knee arthroscopy for conditions other than ACL rupture were included in this observational study. Patients <18 or >40 years and patients with a history of ACL injury, osteoarthritis, or findings of instability on physical examination were excluded. Twenty male and 20 female patients were studied, with 10 left and 10 right knees in each gender group. Demographical data including age, sex, site of involvement, height, and body mass index (BMI) were recorded. Mean age and BMI of patients were 35.12 (range: 18–40) years and 26.70 (range: 20–32) kg/m², respectively. The study protocol was approved by the ethics committee of university (approval number: 8088), and informed consent was obtained from all patients prior to study entry. The study was conducted according to the principles of the Declaration of Helsinki.

Two surgeons performed the arthroscopic operations in the study. Diagnostic knee arthroscopy using standard anterolateral (AL) and anteromedial (AM) portals was performed under spinal anesthesia with 4 mm, 30° arthroscope. The AL portal is located at the center of the soft spot area between the lateral border of patellar tendon, lateral femoral condyle, and the proximal tibia. For optimal insertion point, the AM portal was found with the help of a spinal needle, located just proximal to the meniscal rim, 1 cm distal and medial to the inferior pole of patella and halfway between the patellar tendon and anterior fibers of the medial collateral ligament. Attention was paid to determinate the portal locations relative to each other as much as possible with a standardized method as described above by marking these anatomical landmarks in every patient. Patients who were morbidly obese or in whom these landmarks were not clearly visible were excluded from the study. After diagnostic arthroscopy was performed, the following primary pathologies were treated: medial meniscus tears (n=14), lateral meniscus tears (n=7), medial patellar plicae (n=5), loose body (n=4), chondral lesions (n=6; 5 on medial and 1 on lateral femoral condyle), and patellofemoral problems (n=1). The ACL was exam-

ined by arthroscopy probe, and patients were excluded from the study if ACL was elongated or if there was any doubt regarding the function of the ACL. Debridement, including excision of ligamentum mucosum and limited excision of synovial tissue between ACL and PCL, was performed in patients in whom the intercondylar notch was not clearly visible. The triangle between ACL and PCL was visualized at different flexion degrees of the knee joint (120, 90, 60, and 30° of flexion angle was determined with a sterile goniometer) through AL and then AM portals, respectively. The scope position was standardized as much as possible; the camera was held vertical to the floor and the light source was located inferomedially and directed to the intercondylar femoral notch while viewed from the medial portal, located inferolaterally and directed to the intercondylar notch while viewed from the lateral portal. Prior to recording the images, the surgeon confirmed that 1/3 of the lateral femoral condyle, cartilage border of the medial femoral condyle, PCL, and ACL were included in the image. The scope was held posterior to the intermeniscal ligament while recording the images. From the 2 portals and at the 4 different knee flexion degrees, a total of 8 photographs were obtained for each patient.

Triangles formed between ACL and PCL at each flexion degrees and as viewed through AL or AM portals were examined using the recorded images. This is a 3-dimensional angle, but it can be measured 2-dimensionally. The narrow angle of the triangle between the long intersecting axes of the medial border of the AM bundle of ACL and lateral border of PCL was measured (Figure 1a). In some cases, the direction of ACL was not straight (curved over PCL); thus, points were marked on the medial border of the ACL at the intersection area with PCL and connected to form a line. Samples of the measurements in a left knee at 90, 60, and 30° of knee flexion are shown in Figures 1b–d. Measurements were performed using image processing software (Adobe Photoshop CS5, San Jose, CA, USA) and numerical values were recorded. Three independent observers measured and recorded the narrow angle of the triangles twice at different times (Figure 2).

Descriptive statistics including frequencies, mean, range, and standard deviation were recorded from all different measured variables. The mean measurement of all 3 observers was used for further statistical analysis. Independent t-test was used to determine if there was a difference in ACL-PCL angle between male and female subjects. The alpha level for statistical significance was set at 0.05. Intra- and interobserver reliability was calculated using the intraclass correlation coefficient (ICC).

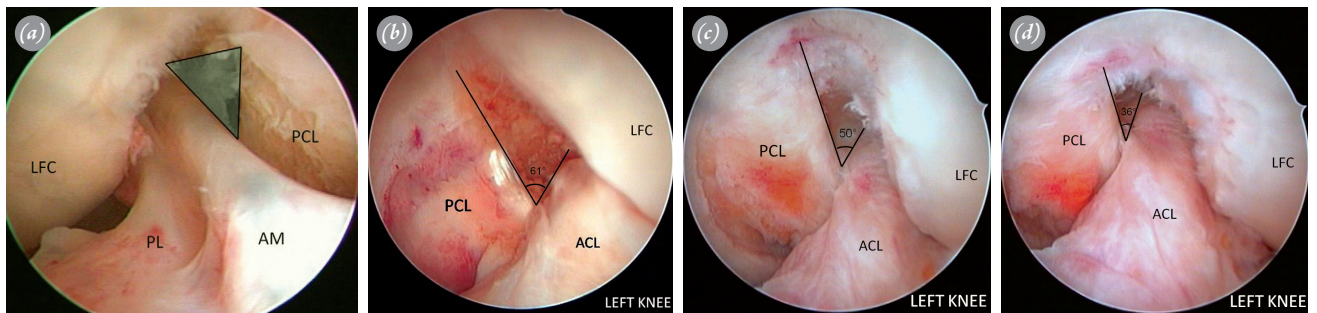


Fig. 1. (a) The triangle formed between ACL and PCL. (b) A 61° angle between ACL and PCL, as viewed through the AL portal when the left knee joint is at 90° flexion. (c) A 50° angle between ACL and PCL as viewed through the AL portal when the left knee joint is at 60° flexion. (d) A 36° angle between ACL and PCL as viewed through the AL portal when the left knee joint is at 30° flexion. (ACL: Anterior cruciate ligament; PCL: Posterior cruciate ligament; LFC: Lateral femoral condyle; AM: Anteromedial bundle of ACL; PL: Posterolateral bundle of ACL.) [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

Table 1. No significant difference was found in AC-PCL angle between men and women for any of the measured portal or knee flexion angles.

	Frequency	Mean	Range	SD
Sex	20:20			
Age		35.12	18–40	6.354
Height		167.85	151–196	8.279
Weight		75.20	49–98	10.737
Side	20:20			
BMI		26.70	20–32	3.360
AL 120°		69	68–72	1.00
AL 90°		62	59–63	1.00
AL 60°		52	50–55	1.90
AL 30°		40	36–45	1.70
AM 120°		62	59–65	1.75
AM 90°		53	50–56	2.00
AM 60°		42	40–45	2.10
AM 30°		31	30–35	1.80

SD: Standard deviation; AL: Anterolateral portal; AM: Anteromedial portal.

Results

Results of the demographics and measurements for each flexion angle are displayed in Table 1. Intra- and interobserver reliability is demonstrated in Table 2.

Discussion

This was an observational study on young patients with normal ACL and PCL, and results of the study showed that there is approximately 60° of angle between ACL and PCL at 90–120° flexion of the knee joint while looking from the AL portal with scope. To the best of our knowledge, no such study has been previously performed.

Successful ACL reconstruction depends on various factors, including graft fixation, graft tensioning, as well as femoral and tibial tunnel positioning.^[10,13,14] Detailed anatomy, including the tibial and femoral attachments

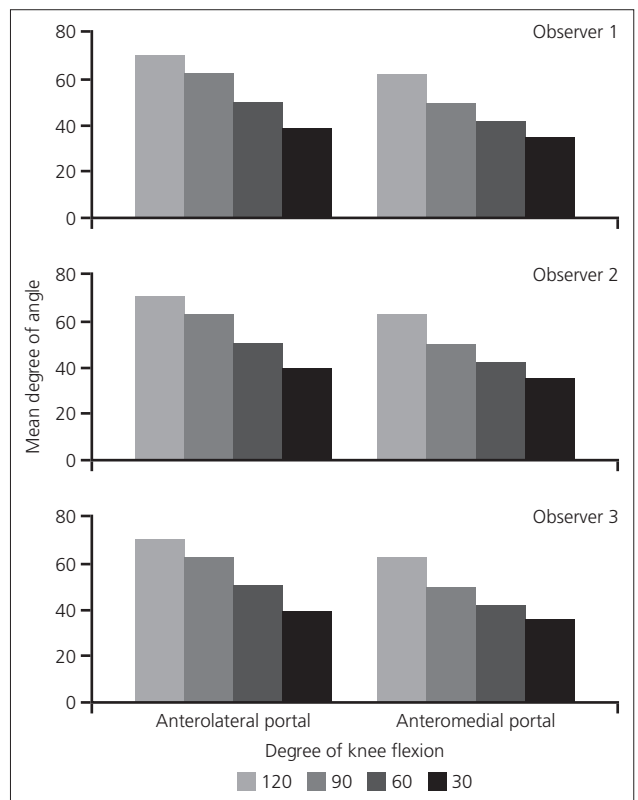


Fig. 2. Mean measurements of angles by 3 different observers.

of the human ACL, have been comprehensively described described in previous studies.^[1,2,4–8,10,13–15] Accurate measurements of the insertion points are critical when determining placement of bone tunnels during ACL reconstruction. More anatomic ACL reconstructions and improvement of knee mechanics were the aims of these studies. Patients in this study were in an age group in which ACL injuries are most frequent and most arthroscopic ACL reconstructions are performed, and the angular relation was documented from an ar-

Table 2. The reliability was good-to-excellent for all measured dimensions.

	Intraobserver reliability	95% confidence interval	Interobserver reliability	95% confidence interval
AL 120°	0.834	0.708–0.909	0.943	0.905–0.967
AL 90°	0.698	0.429–0.840	0.996	0.993–0.998
AL 60°	0.977	0.957–0.988	0.989	0.981–0.994
AL 30°	0.978	0.960–0.989	0.985	0.975–0.992
AM 120°	0.984	0.970–0.991	1.000	–
AM 90°	0.983	0.968–0.991	0.990	0.984–0.995
AM 60°	0.987	0.976–0.993	0.964	0.940–0.979
AM 30°	0.989	0.980–0.994	1.000	–

AL: Anterolateral portal; AM: Anteromedial portal.

thoscopic point of view, the method routinely used for ACL repair.^[5,6]

This study showed the angles of a triangle between the longitudinal axes of the ACL and PCL and the roof of the notch. The angle between the longitudinal axis of ACL and PCL changes with knee motion. The measurements of the observers were consistent, suggesting that these angles can be used after the suture or graft passage during arthroscopic ACL reconstructions to provide additional guidance to the surgeon. Our results demonstrated that age, sex, height, and BMI do not have any significant relation with ACL-PCL intersection angle. The angles may change according to the portal locations and position of light source; however, in this study we aimed to observe the angular relation of ACL and PCL with standard AL and AM portals, viewed with the light source directed to the intercondylar notch. Accordingly, the values obtained from this study can better inform surgeons on the angular relation between ACL and PCL.

Selecting the localization of the femoral tunnel in particular presents a greater challenge than selecting that of the tibial tunnel. Due to the double-bundle morphology of the ACL, its femoral footprint is larger than the diameter of the ACL body. Femoral insertion site anatomy changes with varying degrees of knee flexion. The placement of traditional ACL grafts in a high and proximal position at the femoral attachment and PCL grafts at the tibial attachment results in vertical graft orientation.^[16,17] This graft placement results in a limited ability to provide rotational stability and is inferior when compared to an anatomic reconstruction. Traditional 2-dimensional evaluations such as the subjective clockwise method did not prove sufficient to adequately define the position of the femoral tunnel, as the knee is flexed to 90° and the horizontal plane cannot be well-matched with the clock face.^[10] In a cadaveric study, Mochizuki et al. showed that the center of the AM bundle

of ACL was at a clock position of 1:40 in the left knee.^[5] Siebold et al. showed that the ACL is aligned horizontally when the femoral shaft axis was lifted 12° from the horizontal plane,^[6] which can be obtained in a knee flexion angle of 102°. With this flexion angle, centers of the AM and PL bundles of the ACL align horizontally, allowing for use of the clock method. Other techniques such as the AM portal technique may be used in determining the insertion points of grafts.^[18] Our study supports the horizontal or low tunnel position to form a broad triangle. If the femoral tunnel is drilled via the transtibial portal, the surgeon may use these angles with the guide pin in order to determine the tunnel location. Transtibial drilling guides the wire to a more vertical direction, resulting in a highly-positioned femoral tunnel. This approach results in a narrow angle between ACL and PCL and may cause roof impingement. Studies show that horizontal graft placement provides better results.^[19,20] Zantop et al. showed that non-anatomical double-bundle reconstruction may fail to demonstrate any clinical superiority to single-bundle reconstruction.^[14] These results may indicate that the primary critical factor is the anatomic placement of the graft rather than the choice to use single- or double-bundle procedure.

This study provides additional information on the dynamic anatomy of ACL from an arthroscopic perspective. For more anatomic reconstructions, it is important to create a triangle of approximately 60° between ACL and PCL, as viewed through the AL portal at 90–120° degrees of knee flexion. The angle between ACL and PCL was not affected by sex in this study. In addition, age, sex, BMI, and side (right or left) on which the procedure was performed did not affect mean degree of the angle.

Acknowledgement

We greatly thank to Prof. Freddie H. Fu, M.D., and Dr. Carola F. Van Eck, M.D. for their kindly contribution and statistical help for our study.

Conflicts of Interest: No conflicts declared.

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