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Graft Inclination Angle is Associated with the Outcome of the Anterior Cruciate Ligament Reconstruction

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Abstract

Background: Anterior cruciate ligament reconstruction (ACLR) surgery is frequently used to manage anterior cruciate ligament (ACL) tear. The non-anatomic positioning of the graft may cause graft failure. This study aimed at evaluating the association of the ACLR outcome with factors affecting the anatomic positioning of the graft, including the tibial tunnel, femoral tunnel, and graft inclination angles.
Methods: A total of 37 patients, who had undergone ACLR surgery, were included in this retrospective study. All surgeries were performed by the transportal arthroscopic reconstruction technique. The tibial and femoral tunnel angles were evaluated on both anteroposterior (AP) and lateral radiographs. Graft inclination angle was evaluated on AP radiograph. Outcome measures included: International Knee Documentation Committee (IKDC), the Lachman and the pivot shift test, and KT-1000 arthrometer score.
Results: The mean age of the patients was 30.1 ± 9.4 years. The ACLR surgery was successful in 36 (97.3%) patients and failed in one patient (2.7%). No significant association was found between the femoral/tibial tunnel angles and outcome measures on both AP and lateral view. A negative significant correlation was found between the IKDC score and the graft inclination angle ($P = 0.049$, $r = -0.326$), indicating that with graft angle between 20° and 36°, the more horizontal graft was associated with better IKDC score.
Conclusions: According to the results, graft inclination angle, yet not femoral/tibial tunnel angles, were associated with the outcome of the ACLR surgery However, further studies are required to address the inconsistent results of different investigations.

Keywords: Anterior Cruciate Ligament Reconstruction, Femoral Tunnel Angle, Tibial Tunnel Angle, Graft Inclination Angle

1. Background

The anterior cruciate ligament (ACL) tear is one of the most frequent injuries of the knee leading to knee instability (1). The treatment of ACL tear requires surgical intervention and ACL reconstruction (ACLR) is one of the most frequently performed orthopedic procedures. This procedure includes the accurate anatomic placement of the new ACL in the drilled tibial and femoral tunnels (2).

Despite several modifications of ACLR surgery, it is still associated with a variety of postoperative complications (3). Consequently, many studies have attempted to identify factors that affect the outcome of ACLR surgery. Accordingly, surgical factors, such as graft type and nonsurgical factors, such as activity level and body mass index, have been associated with the outcome of ACLR surgery (4, 5).

Recently, considerable interest has been devoted to anatomic ACLR surgery, as malpositioned or non-anatomic reconstruction may cause graft failure and subsequent failure in the restoration of the knee kinematics and persistent instability (3). Accurate positioning of graft tunnels, including the tibial and femoral tunnel is introduced as a key factor in the successful application of anatomic ACL reconstruction (6). In this respect, several techniques have been introduced for the accuracy of tunnel positioning (7-9). However, tunnel malposition still occurs frequently (10, 11), especially after the advent of arthroscopy, as in arthroscopy less attention is paid to the anatomy of the ACL, and more focus is placed on the efficiency of the surgery (12).

Postoperative radiographs provide a reliable and valid approach for the evaluation of anatomical tunnel placement and graft positioning after ACLR, as the inserted graft makes an angle proportional to the basic anatomy of the patient's tibia and femur (13).

Considering the importance of the anatomical graft positioning in the success of ACLR surgery, this study aimed at evaluating how femoral tunnel angle, tibial tunnel angle, and graft inclination angle are associated with the outcome of reconstruction surgery in patients with an ACL tear.

2. Methods

This study was approved by the Institutional Review Board and informed consent was obtained from patients before their participation in the study. In a retrospective design, patients, who had undergone ACLR surgery from April 2015 to December 2017 at Rasool Akram Hospital of Iran University of Medical Sciences and were available for final evaluation, were included. The inclusion criteria were age of > 18 years and a follow-up of > six months. Patients with a multi-ligament knee injury, knee malalignment, previous knee ligament surgeries, and fractures of the femur or tibia were excluded. Finally, a total of 37 patients were identified as eligible for this study.

The patients' demographic data were extracted from their medical data. Due to the high cost of computed tomography (CT) scan, plain radiographs were used for the assessment of femoral tunnel angle, tibial tunnel angle, and graft inclination angle. To this aim, on the Anteroposterior (AP) and lateral radiographs, the tibial and femoral angles were measured by calculating the angle between the axis of tunnels and the anatomical axis of the bones (Figure 1). The percentage of femoral tunnel was assessed through drawing a line from the axis of the femoral tunnel crossing the length of Blumensaat's line and expressed as a percentage of the total length of Blumensaat's line that was crossed. The percentage of tibial tunnel was assessed by drawing a line from the axis of the tibial tunnel crossing the length of the proximal tibial plateau on either AP or lateral view and expressed as a percentage of the total length proximal tibial plateau that was crossed (Figure 2A). For measuring graft inclination angle, a line was drawn to connect the medial wall of the femoral and tibial tunnels. The angle between this line and a line perpendicular to the tibial plateau was considered as the graft inclination angle (Figure 2B). All evaluations were performed by two independent knee surgery fellowships and in case of discordance, a senior orthopedic professor re-measured the case.

The Persian version of the International Knee Documentation Committee (IKDC) form was used for the subjective evaluation of the patients' outcome on a scale of 0 to 100. A maximum of 100 was indicative of no limitation or symptoms (14). The joint function and ACL integrity were assessed by the Lachman test and the pivot shift test on a scale of zero to three. A score of zero was indicative of no instability, and positive scores of 1+, 2+, 3+, were indicative of mild, moderate, and severe laxity, respectively (15). KT-1000 arthrometer score was used for the assessment of the potential knee instability, where a greater score was indicative of a greater laxity (16).

2.1. Surgical Technique

All surgeries were performed by one surgeon under general anesthesia and tourniquet application by transportal arthroscopic reconstruction technique, as previously described (17). Briefly, after the establishment of high anterolateral and standard anteromedial portals, the diagnostic arthroscopy was performed. Semitendinosus and gracilis tendons were harvested. A guide pin was inserted and its position was verified by placing the scope in the standard medial portal. The femoral tunnel was drilled while keeping the scope in the anteromedial portal up to the size of the graft diameter. Subsequently, tibial guide pin was passed in an outside-in fashion and at an angle of 55° from the tibia. The tibial tunnel was reamed according to the graft size. The graft was passed with the aid of passing sutures from tibial to the femoral tunnel and fixed with endobutton (Smith and Nephew) on the femoral side with bio-absorbable interference screw (Smith and Nephew) on tibial side. The final position of the graft was verified afterwards.

2.2. Postoperative Protocol

No drains or braces were used after the surgery. Physiotherapy was started the day after the surgery. Partial weight-bearing was allowed immediately after the operation. Early closed kinematics chain exercises and full range of motion was started after two weeks.

2.3. Statistical Analyses

Descriptive data were presented as the mean ± standard deviation (SD) for quantitative variables and frequency (percentage) for categorical variables. One-way analysis of variance (ANOVA) test was used to evaluate the association between the angles and the Lachman or pivot shift test. The association between the categorical variables was evaluated using the chi-square test. The potential correlations were tested by Pearson's or Spearman's correlation coefficient test. The IBM SPSS Statistics for Windows version 21.0 (2012. Armonk, NY: IBM Corp.) was used for all statistical evaluations. P values of 0.05 or less were considered statistically significant.

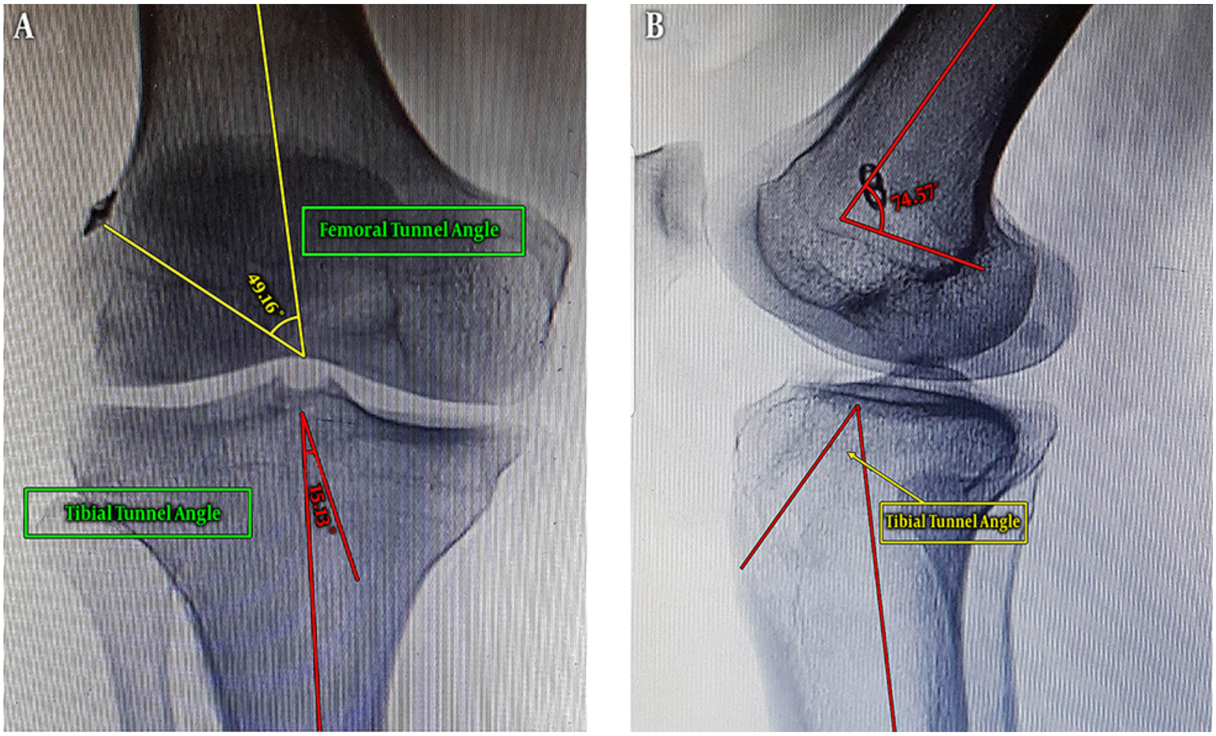

Figure 1. A, Evaluation of the tibial and femoral tunnel angles on the anteroposterior radiograph; B, Evaluation of the tibial and femoral tunnel angles on the lateral radiograph

3. Results

A total of 37 patients, including 36 males and only one female, with the mean age of 30.1 ± 9.4 years (range 18 to 50 years) were assessed. The ACLR surgery was successful in 36 patients and failed in only one patient. The mean KT-1000 score was 8 ± 2.45 (range: 2 to 12). The mean IKDC score was 70.7 ± 16.4 (range 31 to 97.7). The Lachman score of the ipsilateral knee was zero in 16 patients (43.2%), score 1+ in 19 patients (51.4%), and score 2+ in two patients (5.4%). The Lachman score of the contralateral knee was zero in 34 patients (91.9%) and 1+ in three patients (8.1%). The pivot shift test of the ipsilateral knee was zero in 20 patients (54.1%), score 1+ in 16 patients (43.2%), and score 2+ in one patient (2.7%). The pivot shift test of the contralateral knee was zero in 35 patients (94.6%) and 1+ in two patients (5.4%). The clinical outcome and demographic characteristics of the patients are demonstrated in Table 1.

The mean femoral tunnel angle on AP view was 40.2° ± 8.6° (range 20.2° to 56.2°). The mean tibial tunnel angle on AP view was 21.8° ± 8.1° (range 6° to 36.9°). The mean graft inclination angle on the AP view was 23.8° ± 6.9 (range 9.3° to 36°). In case of failed ACLR surgery, the femoral tunnel angle, the tibial tunnel angle, and the graft inclination angle on AP view were 56.2°, 36.8°, and 24.5°, respectively.

The mean femoral tunnel angle on lateral view was 46.4° ± 11.8° (range 23° to 74°). The mean tibial tunnel angle on lateral view was 35.7° ± 7.5° (range 18.7 to 49.9). In case of failed ACLR surgery, the femoral tunnel angle and the tibial tunnel angle on lateral view were 55.5° and 35.6°, respectively.

No significant association was found between the Lachman scores and the femoral/tibial tunnel angles, femoral/tibial tunnel percentages, and the graft inclination angle. No significant association was found between the pivot shift scores and femoral/tibial tunnel angles, femoral/tibial tunnel percentages, and the graft inclination angle, as well (Table 3).

No significant correlation was found between the IKDC scores and femoral tunnel angle on both AP and lateral view (P = 0.48, r = 0.071, and P = 0.66, r = -0.021, respectively). No significant correlation was found between the IKDC score and tibial tunnel angle on both AP and lateral view as well (P = 0.27, r = 0.052, and P = 0.38, r = 0.039, respectively). A negative significant correlation was found between the IKDC score and the graft inclination angle (P = 0.049, r = -0.326). To further evaluate the association of the graft inclination angle and outcome measures, it was

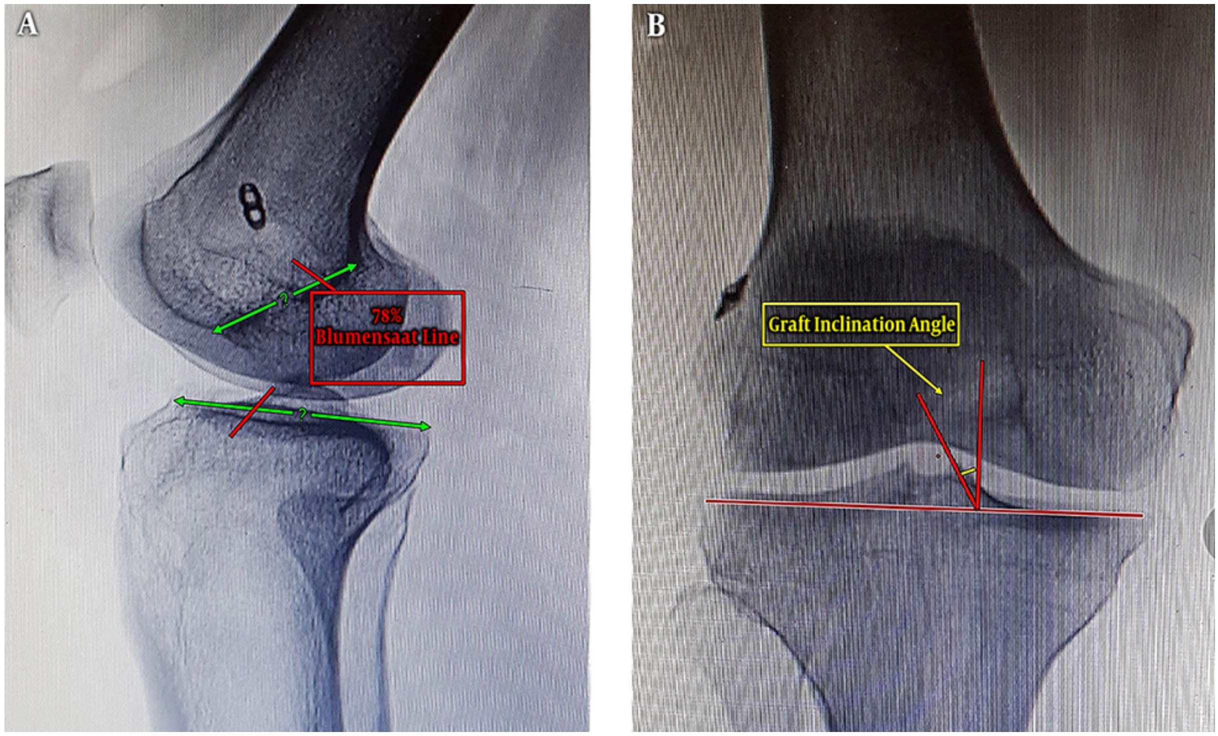

Figure 2. A, Evaluation of the tibial and femoral tunnel percentages on the lateral radiograph; B, evaluation of the graft inclination angle on the anteroposterior radiograph

categorized to two groups of < 20° and > 20°. Accordingly, with graft angle of 20° to 36°, the more horizontal graft was associated with better IKDC score. No significant correlation was found between KT-1000 scores and tunnels angle as well as graft inclination angle.

4. Discussion

In conclusion, ACL injuries are amongst the most frequent knee injuries and identification of factors capable of predicting the outcome of ACLR surgery is of critical value. Failure rates of ACLR have been reported to be between 3.6% and 15% (18). The anatomic positioning of the graft has been suggested to play a major role in the success of the surgery. Recently, several studies have attempted to find an association between graft angles and ACLR results (3, 18, 19). Accordingly, the current research evaluated the potential association between the ACLR outcome and femoral tunnel angle, tibial tunnel angle, and graft inclination angle in this study.

Based on the results, the femoral tunnel angle on AP view ranged from 20.2° to 56.2°. The tibial tunnel angle on AP view ranged from 6° to 36.9°. The graft inclination angle ranged from 9.6° to 36°. At these ranges, the failure rate of the patients was 2.7%, which was lower than earlier investigations (18). No significant association was found between ACLR results and tunnels' angle in the current study. However, a negative significant correlation was found between IKDC scores and graft inclination scores, suggesting that with graft angle between 20° and 36°, a more horizontal graft could result in a better ACLR outcome.

Illingworth et al. evaluated femoral tunnel angle and inclination angle in 50 patients, who had received single-bundle ACLR surgery. Based on their results, a femoral tunnel angle of < 32.7° and inclination angle of greater than 55° was considered as a threshold to determine whether the ACL reconstruction fell within an anatomic range. Moreover, patients with tunnel positions within an anatomic range had a smaller inclination angle than patients, who fell outside an anatomic range (12). They did not evaluate the association of the angles with the clinical outcome of the patients.

Padua et al. assessed the influence of graft positioning on the clinical outcome of ACLR surgery in 30 patients. Based on their results, tibial tunnel position on the lateral view correlated significantly with both the IKDC score and the Lysholm score. Tibial tunnel position on the lateral view also correlated with KT-1000 arthrometer scores

Table 1. The Demographic and Clinical Outcome of Patients Following the ACLR Surgery

Variable	Mean ± SD or No. (%), N = 37
Age	30.08 ± 9.36
Gender	
Male	36 (97.3)
Female	1 (2.7)
Involved knee	
Right	18 (48.6)
Left	19 (51.4)
ACLR result	
Successful	36 (48.6)
Failed	1 (2.7)
KT-1000 score	70.7 ± 16.4
IKDC score	8 ± 2.45
Lachman test	
0	16 (43.2)
+1	19 (51.4)
+2	2 (5.4)
+3	0 (00)
Pivot shift test	
0	20 (54.1)
+1	16 (42.3)
+2	1 (2.7)
+3	0 (00)

Abbreviations: ACLR, anterior cruciate ligament reconstruction; IKDC, International Knee Documentation Committee; SD, standard deviation.

at 30 N of force. No significant correlation was observed between the femoral tunnel position on view and Lysholm score, IKDC score, and Tegner activity level. In the AP view, Padua et al. found no significant correlation with the tunnels' angle and the outcome of the surgery, which was in accordance with the current results (20). The current research found no association between the patients' outcome and femoral/tibial tunnel angles on both AP and lateral views.

Avadhani and Rao also found a significant association between tibial tunnel position on AP view and the outcome of ACLR surgery, so that the tibial tunnel of patients with a fair Lysholm outcome was significantly anterior compared to patients with an excellent and good outcome (21). The current results were not in accordance with the study of Avadhani and Rao.

Snoj et al. evaluated the femoral tunnel inclination and ACL graft inclination on MRI in sixty subjects, including 40 patients at 5.9 years after ACLR and 20 healthy controls. Femoral tunnel inclination revealed no correlation with subjective clinical measures. The ACL graft inclination angle showed no significant correlation with subjective clinical measures as well. In contrast to the study of Snoj et al., the current research found a significant correlation between the graft inclination angle and the outcome of the patients (22).

Although the impact of the anatomic graft positioning on the success of ACLR surgery is well acknowledged, it seems that there is no consensus regarding the results of different investigations. This could be attributed to the variety of confounding factors that could affect the outcome of ACLR, including surgical and non-surgical factors (23). Moreover, as tunnel positions finally define the graft inclination angle, evaluation of graft angle could be a better choice than tunnel angles. As both angles of the tibial and femoral tunnel are important in the positioning of graft, evaluation of each tunnel angle separately may not be a good representative of the anatomic alignment. To support this hypothesis, it should be noted that in failed surgery of the cohort, tibial and femoral tunnel angles were considerably higher than mean values, while the graft inclination angle was very close to the mean value. An equation of tunnel angles might be a better representative of the anatomic graft positioning.

After all, as the majority of investigations have been performed on small number of patients, in order to remove the effect of confounding bias, future studies with larger patient numbers are needed to allow multivariate analysis.

The current study had some weakness that should be mentioned. The main limitation of this study was the small sample size that did not allow multivariate analysis of the data. Moreover, while some recent studies have introduced three-dimensional computed tomography (3D CT) as the most accurate method for determining femoral and tibial tunnel position after ACL reconstruction, this research did not use CT scanning for the assessment of an-

Table 2. Descriptive Measures of the Femoral and Tibial Tunnel Angles and Percentages on Anteroposterior and Lateral Radiographs of ACLR Patients

	Anteroposterior View				Lateral View			
	Femoral Tunnel		Tibial Tunnel		Femoral Tunnel		Tibial Tunnel	
	Angle, deg	Percentage	Angle, deg	Percentage	Angle, deg	Percentage	Angle, deg	Percentage
Mean ± SD	40.2 ± 8.6	43.1 ± 4	21.8 ± 8.2	43.2 ± 4.4	46.4 ± 11.8	73.5 ± 11.8	35.7 ± 7.5	32.3 ± 7.5
Median	40.5	43	19.9	43	46.1	76	36.4	32
Minimum	20.2	37	6	31	23	33	18.7	18
Maximum	56.2	50	36.9	53	74	88	49.9	47
Case of ACLR failure	56.2	42	36.8	39	24.5	35.6	55.5	63

Abbreviations: SD, standard deviation; ACLR, anterior cruciate ligament reconstruction.

Table 3. Statistical Analysis of the Association Between the Lachman/Pivot Shift Test and Anatomical Graft Angles[a]

Angle	Lachman Test	Pivot Shift Test
Tibial tunnel angle (AP)	0.41	0.44
Tibial tunnel angle (lateral)	0.33	0.47
Tibial tunnel percentage	0.51	0.39
Femoral tunnel angle (AP)	0.18	0.21
Femoral tunnel angle (lateral)	0.25	0.71
Femoral tunnel percentage	0.16	0.64
Graft inclination angle	0.42	0.35

[a] P value < 0.05 considered significant.

gles, which could be considered as another weakness of this study.

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