RESEARCH ARTICLE

Comparison of Clinical Outcomes between Different Femoral Tunnel Positions after Anterior Cruciate Ligament Reconstruction Surgery

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Abstract

Background: It has been shown that the proper placement of ACL graft during the ACL reconstruction surgery significantly improves the clinical outcomes. This study investigated whether a change in the femoral tunnel position in both axial and coronal planes can significantly alter the postoperative functional and clinical outcomes of the patients.

Methods: This comparative, retrospective, single-center study was performed on 44 patients undergone single-bundle anterior cruciate ligament reconstruction (ACLR). Radiographic assessments were done to evaluate the tunnel position in coronal and axial planes. Patients were classified into 4 groups based on radiographic data. The time interval between surgery and last visit averaged 23.6 ± 2.2 months (18-30 mos.). Lysholm knee score and Cincinnati score were completed for all of the patients. Furthermore, the Lachman, anterior drawer and pivot-shift tests were performed.

Results: Of the 44 patients included in the study, 9 patients (20.4%) were classified as the low-anterior group, 17(38.6%) were classified as the low-posterior group and 18(40.9%) were classified as the high-posterior group. None of the patients were included in high-anterior group. A greater mean Lysholm score (96±3) in low-posterior group was the only significant difference between the three groups (*P<0.001*).

Conclusion: Findings of the current study demonstrated that low-posterior placement of the ACL graft through the intercondylar notch, based on both antero-posterior (AP) and tunnel-view x-rays, is associated with better clinical outcomes in short-term compared to the routine tunnel placements.

Keywords: Anterior cruciate ligament, Anterior cruciate ligament reconstruction, Outcome, Radiography

Introduction

Recent investigations have been focused on proper placement of the ACL graft. Some factors may affect ACL reconstruction (ACLR) results. Evidences show that anatomic ACL graft positioning can restore rotational stability, resulting in better functional outcomes (1-4). Incorrect placement of femoral and tibial tunnels are known causes of failure in ACL reconstruction and has been reported as 4%-63% in recent studies (5, 6).

Recently, the superior role of femoral to tibial tunnel has been emphasized (7). Technically, the assessment of femoral tunnel position is difficult, especially when a double-bundle ACLR is considered (8-10). Femoral tunnel misplacement may result in a loss of flexion, an elongated graft, and knee joint instability as the results of the substantial forces applied on the reconstructed tissue (11-16).

There is no robust consensus on whether a more

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oblique femoral tunnel position offers better results than standard surgical technique in term of postoperative knee laxity. Moreover, there are few studies concerning the impact of femoral tunnel position in both coronal and axial planes.

In this regard, it is important to determine the correct position of the tibial and femoral tunnels. The purpose of this study was to investigate whether a change in the femoral tunnel position in both axial and coronal planes could change the postoperative knee joint laxity including anteroposterior and rotational instability in addition to functional outcomes of the patients.

Materials and Methods

This comparative, retrospective, single-center study was performed on 60 patients undergone single-bundle ACLR using semitendinosus autografts by an expert surgeon in 2013. Transportal technique had been used for all cases.

All 60 patients were recalled for further evaluations. The patients had to be over 18 years old and with no history of multi-ligament injury, inflammatory arthritis, and osteoarthritis. Also patients with non-anatomic femoral tunnel position in CT-scans and lateral view plain knee radiographs were excluded from study. The criteria for acceptable placement of the femoral tunnel based on the CT images included:

Placing the posteromedial surface of the lateral condyle on the axial plane as the correct position; the origin of femoral tunnel should be at 10 o'clock on the right and 2 o'clock on the left knee; tunnel insertion should be on anterolateral, lateral or posterolateral of femur with 3-4 cm distant from the lateral condyle (17, 18); and the thickness of the posterior cortex should be 1-2 mm in axial slice. Also, using quadrant method on lateral view plain radiographs, we defined the anatomic tunnel positions in sagittal plane. Thus, 44 patients (37 male - 7 male) aged 27.2±5.6 years were eligible for the study and 16 patients were excluded.

To evaluate the femoral tunnel position in both coronal and axial planes, anteroposterior (AP) and tunnel-view plain knee radiographs were taken. The knee was placed in 60° flexion for the tunnel view.

The tunnels were classified into two groups regarding their location in the coronal plane according to the AP x-rays. In the low-position group the femoral tunnel was located at 10 o'clock for the right knee or 2 o'clock for the left knee (30° from vertical line over the anatomic axis of femur), while the femoral tunnel was located at 11o'clock for the right knee or 1o'clock for the left knee (was oriented 60° from vertical line over the anatomic axis of femur) in the high-position group.

However, the tunnel was located between these values in many of the cases. Thus, the low and high positions were considered between 30°-45° and 45°-60°, respectively.

Furthermore, we determined the tunnels position based on the tunnel-view radiographs and the patients were assigned into one of the following groups: the high-position group (anterior group) with the femoral tunnel located at 11 o'clock for the right knee or 1 o'clock for the left knee (60° from a line parallel to femur condyles) [Figure 1]; and the low-position group (posterior group) with the femoral tunnel located at 10

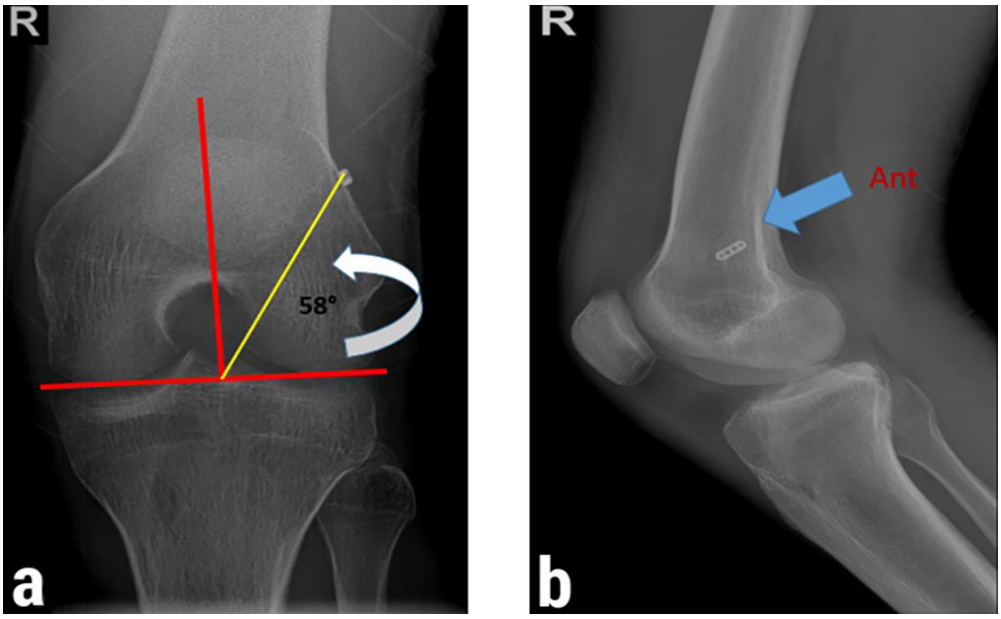

Figure 1. Correlation between the clock-face reference and the tunnel position in plain radiographs. (a) One o'clock position (high-position tunnel) in tunnel-view x-ray of the left knee. (b) The more anterior placement of the high-position femoral tunnel in comparison with low-position tunnel. (Note the endobutton insertion site.)

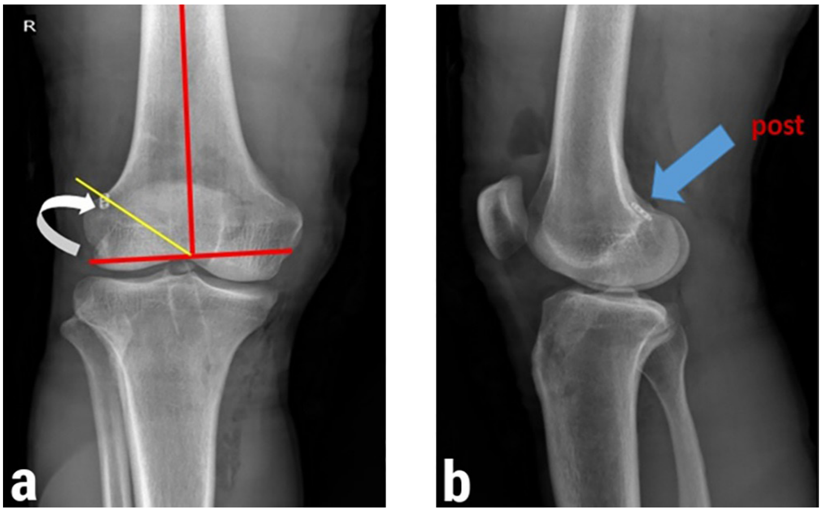

Figure 2. Correlation between the clock-face reference and the tunnel position in plain radiographs. (a) Ten o'clock position (low-position tunnel) in tunnel-view x-ray of the right knee. (b) The more posterior placement of the low-position femoral tunnel in comparison with high-position tunnel. (Note the endobutton insertion site.)

o'clock for the right knee or 2 o'clock for the left knee (30° from a line parallel to femur condyles) [Figure 2]. (In fact, tunnels with this position would be located deeper in sagittal view of the notch than the anterior group.)

Similar to AP x-rays, in many of the cases, the tunnel was located between these values in tunnel-view x-rays. Thus the low and high positions were considered between 30°-45° and 45°-60°, respectively.

Finally, the patients were classified into 4 groups including: low-anterior, low-posterior, high-anterior and high-posterior.

The time interval between the surgery and the last visit averaged 23.6 2.2 ± months (18-30 mos.). Lysholm knee score, and Cincinnati score as well as the Lachman, anterior drawer and pivot-shift tests were performed for all patients (19). The results of Lachman and anterior drawer tests were considered positive if there was an anterior tibial translation > 5mm compared to the normal knee. Pivot-shift test results were graded as follows: 0 (absent), grade I (gentle slide), grade II (definite subluxation), and grade III (subluxation and momentary locking) (20). All tests were performed by an expert orthopedist out of the investigation team and blind to the group assignments. Also, the intraobserver reliability of the examiner, based on a pilot study, was 0.9.

In addition, the anterior tibial translation was assessed using the KT-1000 knee arthrometer for both operated and normal knees (21-23). The maximum score for Lysholm knee score was 100 points, while higher scores indicated better outcomes.

The Cincinnati score was categorized in 4 groups: excellent (80–100 points), good (55-79), fair (30-54), and poor (fewer than 30).

Statistical analysis was performed using SPSS statistical software version 15.0 (Chicago, IL). One-way ANOVA and post-hoc tests were utilized to compare the quantitative data. Besides, chi-square test was employed for comparing the qualitative data. A $P<0.05$ was considered as statistically significant.

Results

Among the total 44 patients, 9 patients (20.4%) were classified as the low-anterior group, 17 patients (38.6%) as the low-posterior group, and 18 patients (40.9%) as the high-posterior group. None of the patients were included in high-anterior group. Table 1 shows that there was no significant difference between the 3 groups in terms of age ($P=0.411$) and gender ($P=0.353$). The mean Lysholm score was significantly higher in the low-posterior group ($P<0.001$) [Table 2]. However, the mean Cincinnati score was same in all three groups [Table 2]. Of interest, only one patient in high posterior group was categorized as fair based on Cincinnati score, while all other patients were classified as good or excellent [Table 2]. Additionally, the anterior tibial translation did not differ significantly between the three groups ($P=0.444$) [Table 3]. Lachman test was negative in

Table 1. Age-Sex distribution of the patients

	LA Group	LP Group	HP Group	*P value*
Age, yr	25.7±4.2	28.4±4.4	27.5±8.3	0.411
Gender, n				
Male	7 (77.8%)	16 (94.1%)	14 (77.8%)	0.353
Female	2 (22.2%)	1 (5.9%)	4 (22.2%)	

Table 2. Comparison of Lysholm and Cincinnati scores in different tunnel positions

		LA Group n=9	LP Group n=17	HP Group n=18	*P value*
Mean Lysholm Score		89±5 (82-100)	96±3 (88-100)	87±4 (84-94)	<0.001
Lysholm Score Grading	Excellent	7(77.8%)	9(53%)	14(77.8%)	0.296
	Good	1(11.1%)	8(47%)	4(22.2%)	
	Fair	1(11.1%)	0	0	
	Poor	0	0	0	
Mean Cincinnati Score		87±4	91±7	90±8	0.859
Cincinnati Score Grading	Excellent	8(88.8%)	16(94.2%)	12(66.7%)	0.275
	Good	1(11.2%)	1(5.8%)	5(27.7%)	
	Fair	0	0	1(5.6%)	
	Poor	0	0	0	

Table 3. Comparison of clinical tests in different tunnel positions

		LA Group n=9	LP Group n=17	HP Group n=18	*P value*
Lachman test	Positive	0	0	0	-
	Negative	9(100%)	17(100%)	18(100%)	
Anterior drawer test	Positive	1(11.2%)	0	1(5.5%)	0.418
	Negative	8(88.8%)	17(100%)	17(94.5%)	
Pivot shift test	I	5(55.5%)	8(47.5%)	7(38.8%)	0.939
	II	3(33.3%)	7(41.2%)	9(50%)	
	III	1(11.2%)	2(11.8%)	2(11.2%)	
	IV	0	0	0	
Anterior tibial translation* (mm)		2.2±0.4	2.5±0.7	2.4±0.5	0.444

*measured by KT-1000 arthrometer.

all patients. The anterior drawer test was negative in the low-posterior group; while, it was positive in 1 patient in the low-anterior (11.2%) and 1 patient in the high-posterior groups (5.5%). Pivot shift test was graded IV in none of the patients [Table 3].

Discussion

The main goal of the study was to see whether an alteration in the femoral tunnel position in both axial and coronal planes could change the postoperative joint laxity including the antero-posterior and rotational instability in addition to functional outcomes of the patients.

As stated by literature it is possible that patients reconstructed with a higher tunnel positions have an increased laxity as a result of misplaced femoral graft that does not mimic the positioning of the intact or normal ACL. In contrast, graft placement can restore normal knee motion if it is performed in the anatomic fashion (24-28).

Our findings demonstrated a greater mean Lysholm score in the low-posterior group in terms of functional outcomes comparing the other groups of the patients. However, we did not find a significant difference in the remaining clinical evaluations including the Cincinnati score, Lachman test, pivot shift test and anterior drawer test. A study by Lee et al, showed a lower Lysholm score and a higher femoral tunnel positioning in the knees with positive pivot shift test than in the knees without pivot shift (29). This was not in accordance with the results of Tsuda et al, who found that the difference between the low- and high-positions was not enough convincing that different tunnel positions can be associated with clinical and functional outcomes (30). Beside, Markolf reported on a method for the impact of linear regression slopes for the femoral tunnels on postoperative results. He concluded that the slope difference between the above-mentioned positions was not significant enough to be a reason for any advantage of the oblique (or low) tunnel over a standard (or high) tunnel position (31). It seems that femoral tunnel obliquity may result in marked clinical outcomes if there is a great difference between tunnels linear slope.

Practically other findings in our study are not clarifying in favor of which tunnel position is preferable. In this regard, the harvested data from anterior drawer and Lachman tests support that all 3 tunnel positions are quite enough for stopping the anterior tibial translation. This maybe because of the ACLR surgery and its outcomes in which almost all anatomic reconstructed ACLs can control the anterior tibial translation (32).

It has been common to place the femoral graft at 11 o'clock position to recover the function of the AM bundle of the ACL (14, 33). Once an ACL reconstructed knee is subjected to rotatory loads, the high-position tunnel for graft placement will not avoid rotational instability anymore (4, 34, 35). Moreover, It has been revealed that the 10 o'clock position resembles the PL bundle attachment and can be more sufficient at rotatory loads and limiting the anterior tibial translation which was confirmed by other biomechanical studies (14, 36, 37). So, it can answer this question that why the mean Lysholm score in the low-posterior group could be greater compared to the two other groups and consequently justify the fact that how our remaining non-biomechanical evaluations have the same results.

We did not found a significant difference in the pivot test between the three groups. This test is the most widely used dynamic test, which correlates with instability symptoms (38). However, our results could be due to the low sensitivity of the pivot shift test (39). This is in accordance with the result of Jepsen et al, who found no difference between the high- and low-position tunnels regrading the anterior laxity and pivot shift test (40).

There are a number of potential limitations that warrant consideration. The first is that in our view the postoperative radiologic assessment of tunnel positions can be somehow challenging with the routine radiography, as this is a 2-dimensional illustration of a 3-dimensional situation (41). This is a reason why we should investigate tunnel positions in both axial and coronal planes concurrently. Furthermore, it has been found that the tunnel-view radiograph is not satisfactory to assess the femoral tunnel placement due to the variations in radiographic projection at different phases of postoperative evaluation of the same patient (40). The second limitation concerns that the mean follow-up time was about 2 years, and thus we cannot debate about the long-term surgical outcomes associated with clinical and radiologic developments. According to the literature Lysholm score was not sensitive to detect changes over time, and hence, it cannot be a precise scoring scale for long-term postoperative follow-up (42).

The final limitation was that like most related studies we did not consider the tibial tunnel position which can be one of the important factors in clinical results (40, 42, 43).

The methodological pitfalls we encountered include: first, the number of patients in this study should be more due to the study type. The second is the fact that this retrospective study investigates the tunnel positions and ACL grafts in patients with previous ACLR surgeries and consequently we had no role in their tunnel positioning.

Although the anatomic ACLR can sufficiently restore the knee stability and be associated with considerable functional improvement, the current study showed that low-posterior tunnel placement resulted in significantly higher knee scores. It is important to consider the femoral tunnel position in different planes. Further investigations are required.

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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