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Evaluation of the Effect of Femoral Tunnel Direction on Clinical Outcomes After ACL Reconstruction

Abstract

Background: Anterior cruciate ligament (ACL) reconstruction is a commonly performed procedure to restore the stability of the knee. However, there is still no consensus on the optimal approach for determining the position of the tibial and femoral tunnels. In this study, we aimed to evaluate the effect of endobutton positioning on the clinical outcomes of the patients who underwent ACL reconstruction.

Methods: The adult patients who underwent single-bundle ACL reconstruction surgery within 1.5 years at our institution were studied. The patients were categorized based on the position of the femoral endobutton observed in AP radiographs and lateral radiographs as anterior, intermediate, and posterior. We investigated the relationship between the position of the femoral endobutton in lateral and AP radiographs with the clinical outcomes of range of motion (ROM), Pivot Shift examination, and knee function scores at the 6-month follow-up.

Results: We studied 100 cases (90 males, 10 females). The Intermediate group based on lateral radiographs had the largest number of patients, but there were no significant differences in the clinical examination results and knee function among these groups. Although the majority of individuals fell into the <39% group, there was no significant difference in clinical outcome and knee function across these groups.

Conclusion: In conclusion, our study found no significant relationship between the radiographic position of the femoral endobutton and the clinical examination and knee function results. Further research is needed to better understand the optimal approach and position of tibial and femoral tunnels and the appropriate grip for ACL reconstruction.

Keywords: Anterior Cruciate Ligament Reconstruction, Anterior Cruciate Ligament, Radiography, Treatment Outcome

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Introduction

Anterior cruciate ligament (ACL) is the primary restraint against anterior tibial displacement, contributing to approximately 85% of this resistance, particularly when the knee is positioned at 90 degrees of flexion without rotation[1,2]. ACL is crucial for maintaining knee stability and preventing excessive anterior tibial translation and rotational instability. It functions synergistically with other ligaments, such as the posterior cruciate ligament (PCL) and collateral ligaments, to maintain joint stability and proper function during dynamic activities like running, jumping, and pivoting[1]. The decision to pursue surgical treatment for an ACL tear depends on several factors, including the time elapsed since the injury, patient's activity level, type of tear, the presence of additional knee pathologies, and the degree of instability[3]. Surgical treatment options for ACL tears include single-bundle, double-bundle, and even triple-bundle reconstruction techniques[4]. Accurate tunnel placement during ACL reconstruction is critical for replicating the function of the native ACL and preventing anterior tibial translation and rotational instability[5]. Despite the variety of available methods and techniques, the optimal choice of treatment, graft selection, tunnel positioning, and fixation methods for ACL reconstruction remain topics of ongoing research[1,4,6]. Optimal tunnel placement enables the reconstructed ACL graft to effectively mimic the function of the native ACL, thereby preventing anterior tibial translation and rotational instability[6]. Accurate tunnel placement necessitates the consideration of multiple factors, including patient anatomy, graft selection, fixation methods, and surgeon expertise[7]. Improper tunnel positioning can lead to various complications, such as graft impingement, residual instability, joint stiffness, and eventually the

development of premature osteoarthritis. Recent advancements in preoperative planning techniques, including 3D planning and navigation systems, provide surgeons with valuable information in achieving more precise tunnel placement[4,8].

Previous studies have not extensively explored the relationship between endobutton position on radiographs and clinical outcomes, particularly regarding the pivot shift test during follow-up. Therefore, this study aims to investigate the impact of endobutton position on flexion and hyperflexion radiographs on pivot shift test results and knee function outcomes at a 6-month follow-up period.

Methods

In this observational study, we evaluated the radiologic and clinical outcomes of patients who had undergone ACL reconstruction using the single-bundle technique at our institution from 2021 to 2023. Inclusion criteria for the study were patients aged 18 to 40 years and those who received single-bundle ACL reconstruction. Exclusion criteria included history of previous ACL surgery, multiple knee injuries, knee osteoarthritis with a severity stage of 2 or above, according to Kellgren-Lawrence criteria, and systemic inflammatory diseases such as rheumatoid arthritis.

All ACL reconstructions were performed by an experienced orthopedic surgeon using the single-bundle technique. A transportal technique was employed to create the femoral tunnel. The tibial tunnel's starting point was superior to the pes anserinus, and the intraarticular site was centered at the femoral and tibial footprint. Femoral fixation was achieved using Endobutton fixation. Patients were categorized into three groups based on the anatomical position of the endobutton in the lateral radiograph of the knee as anterior, intermediate, and posterior (Figure 1).

The position of the femoral tunnel in the frontal plane was evaluated using anteroposterior (AP) radiography, reported as the ratio of the distance from the center of the femoral tunnel to the outer condyle, relative to the distance between the outermost points of the femoral condyles (Figure 2). Range of motion (ROM) and knee function were assessed using the International Knee Documentation Committee (IKDC), Lysholm, and Modified Cincinnati scores, as well as the clinical pivot shift test at six months post-surgery[7-9].

Figure 1 Femoral Endobutton in lateral radiograph

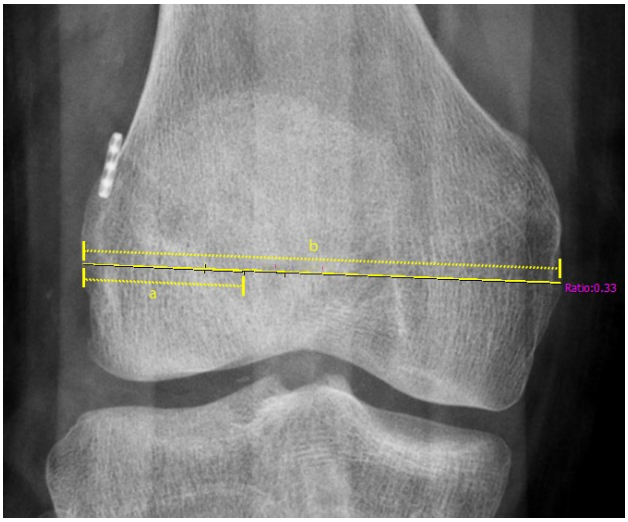

Figure 2 Femoral Endobutton Position assessment in the anteroposterior radiograph:

a= Distance of Tunnel Center to Outer Cortex of lateral condyle,

b= Diameter of femoral condyle, a/b= ratio of the two diameters

Pivot Shift Test

To perform the pivot shift test, the patient is positioned supine. The examiner grasps the patient's heel with one hand while slightly flexing the hip. The other hand is placed on the lateral aspect of the proximal tibia. The examiner then applies an axial

load and valgus stress to the knee while internally rotating the tibia and moving the knee from full extension to 90 degrees of flexion. The test is considered positive when a subluxation of the lateral tibial plateau occurs, typically between 30-40 degrees of knee flexion.

Data Analysis

Quantitative variables were expressed as mean ± standard deviation, while qualitative variables were reported as percentages. The Kolmogorov-Smirnov test was used to assess the normal distribution of variables. Comparison of means between groups was performed using one-way analysis of variance (ANOVA). Qualitative data were compared between study groups using the Chi-square test and Fisher's exact test. All statistical analyses were conducted using IBM SPSS Statistics version 26 and statistical significance was set at $p < 0.05$.

Results

A total of 100 patients who had undergone single-bundle ACL reconstruction during 2 years were evaluated. The average age was 29.49 ± 8.06 years, and 90% were male. The demographic characteristics of the patients are summarized in Table 1. Most patients (n=67) were in the intermediate group based on lateral radiograph endobutton positioning, with 22 in the anterior group and 11 in the posterior group.

Table 1 Demographic Characteristics of Included Patients

Variables		Mean ± SD or n (%)
Age (year)		29.49 ± 8.06
Gender	Male	90 (90)
	Female	10 (10)
Height		165.41 ± 7.97
Weight		73.49 ± 7.84
BMI		26.77 ± 1.34

BMI: Body Mass Index

The average range of motion (ROM) was 127.48 ± 49.06, 128.67 ± 5.41, and 129.34 ± 4.15 in the anterior, intermediate, and posterior groups respectively (p-value=0.248). The pivot shift was positive in 4 cases of the anterior group, 12 cases of the intermediate group, and 2 cases of the posterior group (p=0.399). There were no significant differences in IKDC, Lysholm, Modified Cincinnati scores, or pivot shift test results among the three groups based on lateral radiograph endobutton positioning (Table 2).

Furthermore, when patients were categorized by femoral tunnel position on AP radiographs, 83% fell into the less than 39% group, 17% in the 39-45% group, and none in the greater than 45% group. Again, no significant difference was observed in knee ROM, IKDC, Lysholm, Modified Cincinnati scores, or pivot shift test results between these groups (Table 3).

Discussion

In this study, we investigated the impact of femoral endobutton positioning on radiologic and clinical outcomes in patients who underwent ACL reconstruction. Patients were categorized based on endobutton position in lateral radiographs, with most patients falling into the intermediate group. Clinical outcomes were assessed using ROM and pivot shift tests, showing no significant differences among the three groups. Additionally, knee function was evaluated using the Modified Cincinnati, Lysholm, and IKDC scores, with results indicating that endobutton position in lateral radiographs does not significantly affect knee function or clinical outcomes.

Patients were also classified based on the ratio of the femoral tunnel center distance from the lateral condyle edge to the outermost points of the femoral condyles on AP radiographs. Most patients had a ratio of less than 39%. The study found no significant impact of femoral tunnel positioning on clinical examinations and knee function outcomes.

Several studies have examined the relationship between femoral tunnel positioning and clinical outcomes in ACL reconstruction. Arthur et.al. in a study of 1214 cases of ACL reconstruction using Endobutton fixation demonstrated a malpositioning rate of 3.5%[10]. Their results emphasized the importance of accurate intraoperative technique, such as fluoroscopy, to minimize misplacement[10]. In another study by Lee et al., the authors investigated the influence of femoral tunnel position on postoperative outcomes, concluding that non-anatomic tunnel placement was linked to increased revision rates[11]. They found that a shallow femoral tunnel could negatively impact knee stability, yet

Table 2 Comparison of Knee Function in 3 Groups based on Lateral Radiograph (Mean ± SD)					
Variables		Anterior Group n= 11	Intermediate Group n= 67	Posterior Group n= 22	p-value
ROM		127.48 ± 49.06	128.67 ± 5.41	129.34 ± 4.15	0.248
Pivot Shift	Positive Negative	3 (27.3) 8 (72.7)	12 (17.91) 55 (82.09)	2 (9.09) 20 (90.91	0.399
IKDC		76.39 ± 11.56	74.06 ± 11.17	71.48 ± 15.19	0.510
Lysholm		78.75 ± 13.67	81.27 ± 9.88	83.63 ± 9.93	0.422
Modified Cincinnati		86.98 ± 6.88	85.60 ± 6.65	84.06 ± 9.05	0.511
ROM: Range of Motion, IKDC: International Knee Documentation Committee					

Table 3 Comparison of Knee Function in 3 Groups based on Anteroposterior Radiograph (Mean ± SD)					
Variables		<39% Group n= 83	39-45% Group n= 17	>45% Group n= 0	p-value
ROM		128.15 ± 4.92	127.38 ± 3.65	-	0.541
Pivot Shift	Positive Negative	14 (16.90) 69 (83.1)	3 (17.65) 14 (82.35)	-	0.938
IKDC		74.66 ± 12.16	72.47 ± 9.16	-	0.484
Lysholm		81.85 ± 10.71	79.85 ± 8.37	-	0.469
Modified Cincinnati		85.96 ± 7.24	84.65 ± 5.46	-	0.405
ROM: Range of Motion, IKDC: International Knee Documentation Committee					

they did not observe significant differences in functional outcomes between various tunnel positions in their cohort[11]. This suggests that while anatomical positioning is strived for to prevent complications, it may not always translate into improved functional outcomes, at least in short term.

Radiological studies, such as those by Nema et al., evaluated the femoral tunnel position in ACL reconstruction, finding an average position of 30% posterior to the Blumensaat line in 45 patients[12]. This study classified endobutton positions according to the criteria established by Gunaydin et al.[13], with most subjects falling into the intermediate category. Gunaydin's study on 130 patients also found no significant differences in knee function across different endobutton positions when assessed using IKDC, Lysholm, and Cincinnati questionnaires[13]. Our findings are consistent with these results, as no significant differences in clinical examination or knee function were observed among the different endobutton position groups.

This study has several limitations that may affect the interpretation and generalization of the results. Firstly, the relatively small sample size of 100 subjects may limit the statistical power and precision of the findings. A larger sample size could enhance the robustness and generalizability of the results to a broader patient population. Secondly, the follow-up period of six months is relatively short. Long-term follow-up is essential to assess the durability and sustainability of the observed outcomes. Future studies with extended follow-up periods could provide insights into potential long-term complications or adverse effects that may arise over time.

Conclusion

Our findings demonstrated that the position of the femoral tunnel in AP radiography does not significantly impact clinical outcomes or knee function post-ACL reconstruction in short term follow-up. Further research with larger sample sizes and longer follow-up periods is recommended to validate these findings and provide a more comprehensive understanding of the influence of femoral tunnel positioning on ACL reconstruction outcomes

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