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RADIOLOGICAL EVALUATION OF FEMORAL AND TIBIAL TUNNEL POSITION IN SINGLE BUNDLE ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AND ITS RELATION WITH FUNCTIONAL OUTCOME

Orthopaedics

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ABSTRACT

Background: Anterior cruciate ligament (ACL) injuries are prevalent in active individuals and often lead to instability and early osteoarthritis if untreated. Anatomical tunnel placement is crucial for restoring knee function post-ACL reconstruction. However, limited Indian data exist correlating radiological tunnel positioning with functional outcomes. **Objectives:** To evaluate femoral and tibial tunnel positions postoperatively using CT and assess their relationship with functional outcomes using IKDC and Lysholm scores. **Methods:** A prospective observational study was conducted on 30 patients (18–50 years) undergoing single-bundle ACL reconstruction. Tunnel positions were measured postoperatively via CT scans. Functional outcomes were assessed at 12 and 24 weeks using Lysholm and IKDC scores. Statistical analysis was performed using SPSS v21.0. **Results:** Mean tibial distance was 15.47 ± 1.15 mm, and femoral distances were 13.72 ± 1.76 mm (posterior) and 14.12 ± 1.78 mm (inferior). Significant negative correlations ($p < 0.05$) were observed between tunnel distances and functional scores, with most patients showing marked improvement by 24 weeks. **Conclusion:** Precise tunnel placement significantly influences functional recovery. Radiological evaluation aids in optimizing outcomes post-ACL reconstruction.

KEYWORDS

ACL reconstruction; Tibial tunnel; Femoral tunnel; Functional outcome; IKDC; Lysholm score

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are common in active individuals and, if untreated, often lead to joint instability, meniscal damage, and early osteoarthritis.[1] ACL reconstruction is the standard treatment, yet many patients report suboptimal outcomes due to technical factors—most notably, tunnel placement. Precise positioning of femoral and tibial tunnels is essential to restore knee biomechanics and prevent graft failure. Techniques such as transtibial and anteromedial portal approaches have been used, but both show variability in tunnel placement, often affecting long-term function.[2] Despite technological advances, malposition remains a key cause of poor surgical outcomes, including graft impingement and instability. Anatomical reconstruction aims to replicate native ACL insertion sites, but literature primarily reflects Western data.[3] There is limited evidence specific to the Indian population, where anatomical variations may affect tunnel positioning and, subsequently, clinical outcomes. Radiological evaluation, especially via X-ray and MRI, offers a reliable method to assess tunnel location postoperatively. However, studies correlating radiographic tunnel placement with functional outcome in Indian patients are scarce.[4] This study aimed to evaluate the femoral and tibial tunnel positions radiologically in single-bundle ACL reconstruction and assess their relationship with functional outcomes, thereby guiding improved surgical accuracy and patient recovery.

MATERIAL AND METHODS

A prospective observational study was conducted in the Department of Orthopaedics, SRMS Institute of Medical Sciences, Bareilly, from May 1, 2023, to October 31, 2024. Institutional ethical clearance (Ref. SRMS IMS/ECC/2023/125) was obtained, and informed consent was secured from all participants.

Study Design And Participants

This study included 30 patients with isolated ACL tears, aged between 18 and 50 years, selected through complete enumeration during the study period. Inclusion criteria required clinical and radiological confirmation of ACL injury. Patients with associated meniscal injury, multi-ligament instability, condylar fractures, previous surgeries, or generalized ligamentous laxity were excluded.

Preoperative Evaluation

Detailed demographic data, history, and physical examination findings were recorded. Range of knee motion was categorized, and functional assessment was done using the Lysholm Knee Score and 2000 IKDC Subjective Knee Evaluation Form.

Radiological Assessment

- **X-ray (AP & Lateral views):** To rule out bony injuries.
- **MRI Knee:** To confirm isolated ACL tear and rule out associated injuries.

Surgical Technique

Under anesthesia, arthroscopic single-bundle ACL reconstruction was performed using quadrupled hamstring autografts (gracilis and semitendinosus). Femoral tunnels were created via anteromedial transportal technique, and tibial tunnels using angle-guided drilling. Fixation was done using an Endobutton on the femoral side and interference screw on the tibial side.

Postoperative Care and Rehabilitation

Patients received intravenous antibiotics post-surgery followed by oral antibiotics. ROM knee braces were used, and weight-bearing progressed gradually. A five-phase rehabilitation protocol spanned over 24 weeks. Clinical follow-ups were done at 6, 12, and 24 weeks.

Radiological Evaluation

Postoperative CT scans were used to measure:

- **Tibial tunnel:** Distance from anterior margin of the tibial plateau.
- **Femoral tunnel:** Distance from the posterior and inferior lips of the medial surface of the lateral femoral condyle.

Outcome Measures

Final functional outcomes were evaluated using IKDC and Lysholm scores at 12 and 24 weeks.

Statistical Analysis

Data were entered in Microsoft Excel 2019 and analyzed using SPSS v21.0. Descriptive statistics were applied. Paired t-tests assessed changes in functional scores over time, with $p < 0.05$ considered statistically significant.

RESULTS

In this study of 30 patients, the most common age group was 30–40 years (40%), with a mean age of 31.77 ± 9.16 years. Males predominated, comprising 80% of cases. The leading cause of ACL injury was sports-related trauma (40%), followed by falls (36.7%) and

road traffic accidents (23.3%), highlighting the higher risk among physically active young males.

Table 1: Postoperative CT-Based Measurements of Tibial and Femoral Tunnel Parameters in ACL Reconstruction (n = 30)

Tunnel Measurement Parameter	Mean ± SD (mm)	Minimum (mm)	Maximum (mm)
Tibial distance	15.47 ± 1.15	12.70	18.00
Tibial diameter	7.89 ± 0.75	7.00	10.70
Femoral distance (inferior)	14.12 ± 1.78	7.40	16.80
Femoral distance (posterior)	13.72 ± 1.76	8.40	17.20
Femoral diameter	8.64 ± 0.56	8.00	10.30

At Pre-Op, all 30 patients were categorized as Poor, indicating that they had a low functional status before surgery.

Table 2: Change in LYSHOLM score distribution post-operatively at 12th and 24th week

LYSHOLM SCORE		LYSHOLM SCORE			p value
post-op 12th week		**post-op 24th week**			
		EXCELLENT	**FAIR**	**GOOD**	
FAIR	16	7	0	9	0.001
	53.3%	43.8%	0.0%	56.3%	
GOOD	8	8	0	0	
	26.7%	100.0%	0.0%	0.0%	
POOR	6	0	4	2	
	20.0%	0.0%	66.7%	33.3%	
Total	30	15	4	11	
	100.0%	50.0%	13.3%	36.7%	

Before surgery, all patients (100%) had poor IKDC scores, indicating significant knee dysfunction. The changes in the IKDC (International Knee Documentation Committee) score from pre-operative levels to 12th Week post-operative, showing how scores improved across different ranges as shown in Table 3.

Table 3: Change in IKDC score post-operatively at 12th week to post-operatively at 24th week

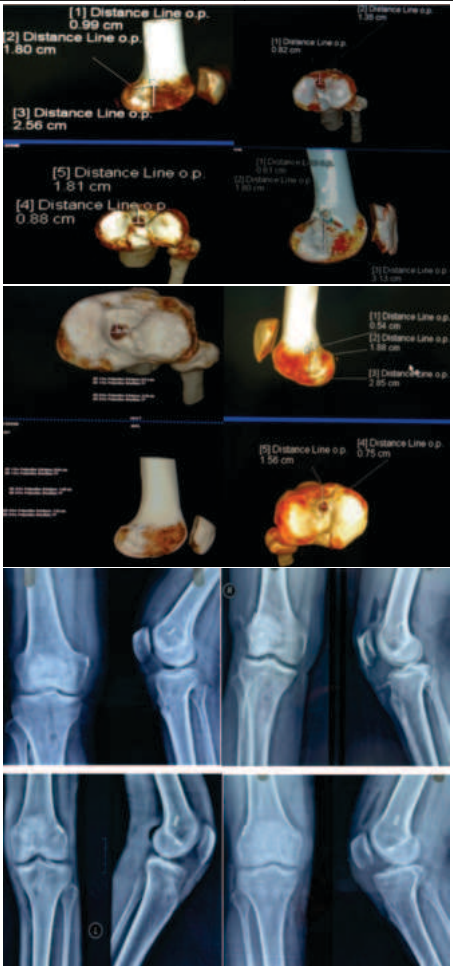
IKDC Score		IKDC Score			p value
post-op 12th week		**post-op 24th week**			
		EXCELLENT	**FAIR**	**GOOD**	
FAIR	5	5	0	0	0.002
	16.67%	100.0%	0.0%	0.0%	
GOOD	1	0	0	1	
	3.33%	0.0%	0.0%	100.0%	
POOR	24	3	4	17	
	80.00%	12.5%	16.7%	70.8%	
Total	30	8	4	18	
	100.00%	26.7%	13.3%	60.0%	

Table 4: Correlation of Tibial and Femoral Tunnel Parameters with Functional Outcomes (IKDC and Lysholm Scores) at 12 and 24 Weeks Post-ACL Reconstruction

Functional outcome	Tibial Distance	p-value	Femoral distance (inferior)	p-value
IKDC Score	**R**		**R**	
Post-Op 12th week	-0.263	0.041	-0.176	0.048
Post-Op 24th week	-0.507	0.004	-0.299	0.037
LYSHOLM SCORE				
Post-Op 12th week	-0.599	0.00	-0.346	0.035
Post-Op 24th week	-0.768	0.00	-0.39	0.033
IKDC Score	**Tibial Diameter**	**p-value**	**Femoral distance(posterior)**	**p-value**
Post-Op 12 weeks	-0.591	0.002	-0.297	
Post-Op 24 weeks	-0.409	0.008	-0.529	0.036
LYSHOLM SCORE				0.003
Post-Op 12 weeks	-0.647	0.000	-0.525	0.003
Post-Op 24 weeks	-0.487	0.006	-0.627	0.000

Table 5: Comparison of range of motion knee pre-op, at 6th week, 12th week and 24th week

Pair	Range of Motion	Mean	Std. Deviation	Paired Differences	p value#
1	Pre-Op	97.00	10.875	40.667	0.000
	Post-Op 6th week	56.33	6.149		
2	Pre-Op	97.00	10.875	-9.333	0.004
	Post-Op 12th Week	106.33	11.592		
3	Pre-Op	97.00	10.875	-23.000	0.000
	Post-Op 24th Week	120.00	12.034		



DISCUSSION

In our study, demographic, radiological, and functional parameters in patients undergoing single-bundle ACL reconstruction. The mean age of participants was 30.73 ± 8.3 years, with the majority in the 30–40-year group and a male predominance (80%). These findings are consistent with Sharma et al.[5] who reported 96% male prevalence, Ko et al.[6] reported a mean age of 31.8 years with 68.7% males, and Nascimento et al.[7] noted a mean age of 27.1 years. In contrast, Fernandes et al.[8] observed a younger cohort (mean 23 years) with a higher female representation (38%).

Sports injuries accounted for the most common etiology (40%), followed by falls (36.7%) and RTAs (23.3%), similar to the pattern reported by Kaarre et al.[9] However, the findings contrast with Dhillon et al.[10] and Jain et al.[11], who found RTAs to be the predominant cause pre-COVID-19 (74.2% in Jain et al.), indicating possible regional or temporal variations in injury mechanisms.

Functionally, all patients in our study began with poor Lysholm and IKDC scores preoperatively. By 12 weeks, 53.3% had fair Lysholm scores, improving to 86.7% achieving good-to-excellent scores by 24 weeks. Similar improvement was seen in IKDC scores, with 60%

reaching good and 23.3% reaching excellent scores at 24 weeks. These outcomes align with Fernandes et al.[8], who reported IKDC improvements from 75 to 84 between 6 and 12 months. Mathai et al.[12] and Yoon et al.[13] also noted significant Lysholm and IKDC improvements postoperatively, supporting the reliability of these scoring systems in tracking recovery.

Radiologically, the mean tibial tunnel position was 15.47 ± 1.15 mm (range: 12.7–18 mm), consistent with Mathai et al.[12] (15.55 mm), suggesting appropriate mid-range tunnel placement. Similarly, femoral tunnel positions were in the optimal range: posteriorly at 13.72 ± 1.76 mm (8.4–17.2 mm) and inferiorly at 14.12 ± 1.78 mm (7.4–16.8 mm), closely matching findings by Mathai et al.[12] and aligning with Pinczewski et al.[14]'s emphasis on anatomical positioning.

Statistical analysis revealed significant negative correlations between tunnel distances and functional outcomes. At 12 weeks, tibial distance negatively correlated with IKDC ($r = -0.263$, $p = 0.041$), and this correlation strengthened by 24 weeks ($r = -0.507$, $p = 0.004$). Lysholm scores showed stronger correlations, particularly at 24 weeks ($r = -0.768$, $p < 0.001$). Femoral tunnel positions (both posterior and inferior) also showed moderate negative correlations with functional outcomes at both time points. These findings underscore the role of precise tunnel placement in optimizing surgical outcomes.

Comparable results have been reported by Fernandes et al.[8] and Yan Xu et al.[15], who linked tunnel malpositioning with poorer outcomes and increased tunnel enlargement. Our findings affirm that anatomical tunnel placement is essential for improving stability and enhancing recovery. Postoperative ROM also showed steady improvement—from a mean of 97° preoperatively to 120° at 24 weeks. This trend is similar to Debnath et al.[4] and Zhang et al.[16], who demonstrated early restoration of motion with structured rehabilitation.

Limitations

The study was limited by its small sample size and single-center design, which may restrict generalizability. Short-term follow-up of 24 weeks limits insight into long-term graft survival and functional stability. Additionally, radiological assessment was limited to CT-based linear measurements without 3D orientation, which may not fully capture tunnel alignment or rotational discrepancies.

Strengths

This study utilized objective CT-based measurements and validated functional outcome scores (Lysholm, IKDC), ensuring reliable correlation analysis. The prospective design, standardized surgical technique, and consistent rehabilitation protocol enhanced internal validity. Moreover, it contributes region-specific data, addressing the paucity of Indian literature on anatomical tunnel positioning and its impact on functional recovery in ACL reconstruction.

CONCLUSION

We concluded that precise anatomical placement of femoral and tibial tunnels plays a pivotal role in determining functional recovery after single-bundle ACL reconstruction. Strong inverse correlations between tunnel positioning and functional outcomes highlight that even subtle deviations can compromise results. Meticulous surgical technique, supported by radiological evaluation, is essential to optimize graft performance, restore joint stability, and ensure superior long-term outcomes.

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