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Analysis of Femoral and Tibial Tunnel Positions and Functional Outcome in Anterior Cruciate Ligament Reconstruction: in a Rural Population

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Abstract
Background
The precise positioning of bone tunnels is crucial for successful anterior cruciate ligament reconstruction (ACLR), as it affects graft function, biomechanics, and long-term stability. This

prospective study aims to evaluate the association between femoral, tibial and inclination angles and functional outcomes in 27 patients who underwent arthroscopic ACLR in a in a rural tertiary care hospital.

Methods

Postoperative radiographs were analysed to measure tunnel and inclination angles; the functional outcome was assessed using the Lysholm as well as the International Knee Documentation Committee (IKDC) scores.

Results

Among 27 participants, 21 (77.8%) were male, and 6 (22.2%) were female. Patients were between 22-47 years of age, with a mean age of 33.1±7.8 years. The mean BMI was 28.7±3.5 kg/m^2. Eighteen participants (66.7%) had injury on the right knee while 9 (33.3%) had on the left knee. The mode of injury was predominantly from fall (81.5%). Most of the angles were within the anatomic range. Statistically significant improvement ($p < 0.0001$) in postoperative functional scores was observed. No significant association was found between femoral tunnel position with postoperative Lysholm scores. However, a significant association ($p < 0.03$) was observed between tibial tunnel angle and postoperative Lysholm scores.

Conclusion

This study of 27 participants found significant improvements in functional outcomes, following ACLR. While femoral and inclination angles showed no significant association with functional outcomes, tibial tunnel angle indicated significant association. Further research with larger cohorts is desired to confirm and explore the clinical significance.

Keywords: Arthroscopy, ACL reconstruction, functional outcome, femoral tunnel angle, tibial tunnel angle, radiography

Introduction

The anterior cruciate ligament (ACL) is the primary mesenchymal tissue in the knee joint. ACL injury is one of the most common knee injuries, and it is particularly prevalent among athletes that participate in pivoting activities such as soccer, basketball, and skiing **[1, 2].** These injuries cause knee instability and reduced physical activity, as well as predispose the affected individual to post-traumatic osteoarthritis **[3, 4].** Anterior cruciate ligament reconstruction (ACLR) is the primary surgical intervention to treat ACL injuries **[5]**. ACLR comprises reconstructing the deficient ACL by using a tendon-bone graft, which is then fixed in depressions made along the bone surface of the femur and tibia. There are several choices of grafts for ACLR, and these include autografts, such as peroneus tendon or hamstring tendon autografts and allografts **[6]**. ACLR was formerly treated with open surgery, but less invasive arthroscopic procedures are becoming more popular **[7, 8]**.

Despite advances in surgical procedures and rehabilitation programs, ACLR outcomes still vary greatly. The factors impacting ACLR outcome may be classified as patient-related (age, gender, body mass index, activity level, concurrent injuries), surgery-related (graft type, tunnel location, fixation techniques), and rehabilitation-related (adherence, return to sports criteria) **[9–11].** Ensuring that grafts are properly positioned within their native footprints is considered critical for restoring the original knee biomechanics to improve the outcome **[12].** Improperly positioned tunnels may cause graft impingement, abnormal kinematics, and early graft failure **[13].** Several techniques have been described for creating anatomical tunnels, including transtibial, anteromedial portal, and outside-in methods **[14]**.

The evaluation of tunnel positions is usually performed with plain radiographs and advanced imaging techniques such as 3D-computed tomography (CT) and magnetic resonance imaging (MRI) **[15].** There are several parameters that have been proposed to measure tunnel positioning, such as the angles of the femoral and tibial tunnels, the angles of graft inclination, and the positions of the tunnels in relation to bony landmarks **[16, 17].** The femoral tunnel angle, tibial tunnel angle, and graft inclination angle are often used criteria to assess the position of the graft in relation to the original ACL footprints **[18, 19].** An anatomically positioned femoral tunnel should recreate the native ACL footprint and form an acute angle with the femoral shaft. The tibial tunnel angle is the angle between the tibial tunnel and a line perpendicular to the tibial shaft axis on anteroposterior radiographs **[20].** The graft inclination angle (also known as the sagittal obliquity angle) represents the obliquity of the graft relative to the tibial plateau on lateral radiographs **[15].**

A few studies have examined the association between tunnel placement characteristics and clinical outcomes after ACLR **[21-23].** The anatomy of the ACL varies among different ethnic groups, potentially influencing surgical outcomes. While existing research has mostly focused on Chinese and Caucasian populations **[24],** there is a notable gap in knowledge regarding Indian populations. This study aims to evaluate the association between graft tunnel and inclination angles with functional outcome following ACLR.

Materials and Methods

This study is a prospective study on 27 participants who presented as patients with symptoms of ACL injury to Karpaga Vinayaga Institute of Medical Sciences & Research Centre, Chengalpattu district, Tamil Nadu, India from December 2021 to May 2023.The study was initiated with the approval from the Institutional Human Ethics Committee (Reference: KIMS/F/2021/12), and getting informed consent from the participants who were assessed for the functional outcome and complications following arthroscopic ACLR.

Inclusion criteria: The study enrolled individuals (both male and female) aged 22 to 47 years who were diagnosed with ACL injuries and confirmed through clinical examination.

Exclusion criteria: The study excluded individuals with lower-limb fractures, advanced osteoarthritis causing joint axis displacement, knee malalignment, previous ligament surgeries, or multi-ligament knee injuries.

Surgical procedure

An experienced surgeon performed all surgeries using general anaesthesia and the arthroscopic ACLR method. Bioscrews made of PLLA — BTCP (Poly- L- Lactide) & Beta tricalcium phosphate composite (HELYSIS interference screw, SIRONIX) were used in the surgery. Hamstring tendon as well as peroneus tendon autograftswere used for ACLR. All the patients were recommended to a similar standard ACL rehabilitation protocol at their residence after discharge from the hospital. Patient's knees were captured on radiography (X-ray) in anteroposterior (AP) and lateral views. The photographs were taken while the patients were standing, bearing weight on their knees, and using parallel supports for stability.

Radiographic angle measurements

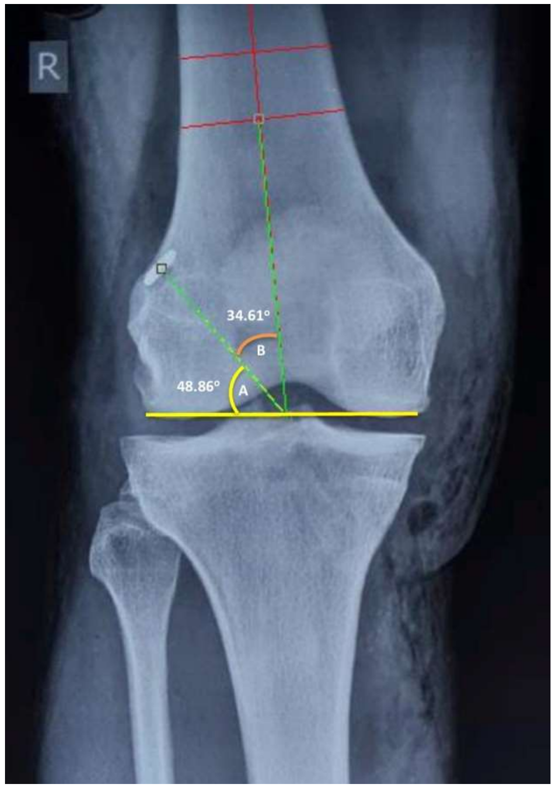

FIGURE 1. Femoral tunnel (A) and inclination (B) angles from anteroposterior radiographs

Following the procedures give in **[15 and 25]** the tunnel and graft inclination angles were computed from anteroposterior and lateral radiographs, using an image processing software (Digi imaging, EVOS® FL and FL Color Cell Imaging Systems). The midpoint of the femoral tunnel in the anteroposterior view was calculated by analyzing the positions of the medial and lateral borders of the tunnel in relation to the medial edge of the plateau at its initial point (**Figure. 1**). A line was marked parallel to the femoral tunnel (B), and another line was drawn tangent to the distal femoral condyles at the level of the knee joint. The angle formed by these two lines was then measured to determine the position of the femoral tunnel. A line was drawn to connect the medial walls of the femoral and tibial tunnels to measure the graft inclination angle. The graft inclination angle was determined as the angle between this line and a perpendicular line to the tibial plateau**.** Similarly, the tibial tunnel position was calculated from the lateral radiograph.

The clinical evaluation score at follow-up

The Lysholm score and IKDC subjective scores were evaluated for all patients preoperatively and 6 months postoperatively, to arrive at the functional outcome.

Statistical analysis

Graph pad Prism 9.0.0 version was used for statistical analysis. Descriptive data like range, mean, median and standard deviation (SD) were entered as numbers and percentages. Inferential statistics were done using paired and unpaired t-tests. Statistical significance was determined by considering P values < 0.05.

Results

The demographic characteristics and study parameters of 27 participants who underwent ACLR are presented in **Table 1**. Among the 27 participants, 21(77.8%) were male, and 6 (22.2%) were female. The mean age of the participants was 33.1 ± 7.8 years, with the range of 22-47 years.17 participants (62.9%) were above 30 years and 10 (37.1%) were below 30 years. The mean BMI was 28.7 ± 3.5 kg/m². Majority of the participants (85.2%) had BMI >25 kg/m², eighteen (66.7%) had injury in the right knee, and 9 (33.3%) had in the left knee. Hamstring grafts were utilized in 15 cases (55.6%), and peroneus grafts were used in 12 cases (44.4%). The time from injury to surgery varied widely, ranging from 7 to 730 days. The median time was 60 days and the mean was 139.3±159.8 days. Ten participants (37.1%) underwent ACLR after 90 days from the time of injury, while 17 participants (62.9%) had the surgery within 90 days of sustaining the injury. The screw implants utilized in the surgeries had an average length of 27.8±2.3mm and an average width of 8.9±0.8 mm.

The time of recovery also showed variation, ranging from 90 to 150 days, with a median recovery time of 120 days. On average, participants recovered in 113.9±18.3 days, with 74.1% taking more than 90 days for recovery. Postoperative pain lasted for a mean of 87.8±21.5 days. Majority of participants (74.1%) reported pain for less than 90 days, while 25.9% experienced pain for more than 90 days. Postoperative swelling ranged from 30 to 60 days, with median 45 days and an average duration of 41.1±12.2 days. Fourteen participants (51.9%) experienced swelling for more than 30 days and 13 (48.1%) had swelling for less than 30 days. The hospital stay duration ranged from 3 to 16 days, with an average of 8.3±3.8 days.

TABLE 1. Demographic characteristics of participants (N = 27)

Study Parameters	Values	n, (%)
Gender		
Male	-	21 (77.8)
Female	-	6 (22.2)
Age (Years)		
Range (max - min)	47 - 22	-
Median	32	-
Mean ± SD	33.1 ± 7.8	-
> 30	-	17 (62.9)
< 30	-	10 (37.1)
BMI (kg/m^2)		
Range (max - min)	34 -21	-
Median	29	-
Mean ± SD	28.7 ± 3.5	-
>25	-	23 (85.2)
<25	-	4 (14.8)
Side of injury		
Right	-	18 (66.7)
Left	-	9 (33.3)

Graft		
Hamstring	-	15 (55.6)
Peroneus	-	12 (44.4)
Mode of Injury		
Fall	-	22 (81.5)
RTA	-	5 (18.5)
Screw implant (mm)		
Length (Mean ± SD)	27.8 ± 2.3	-
Width (Mean ± SD)	8.9 ± 0.8	-
Time from injury to surgery (Days)		
Range (max - min)	730 - 7	-
Median	60	-
Mean ± SD	139.3 ± 159.8	-
> 90days	-	10 (37.1)
< 90 days	-	17 (62.9)
Time of recovery (Days)		
Range (max - min)	150 - 90	-
Median	120	-
Mean ± SD	113.9 ± 18.3	-
> 90 days	-	20 (74.1)
< 90 days	-	7 (25.9)
Postoperative pain (Days)		
Range (max - min)	120 - 60	-
Median	90	-
Mean ± SD	87.8 ± 21.5	-
> 90 days	-	7 (25.9)
< 90 days	-	20 (74.1)
Postoperative swelling (Days)		
Range (max - min)	60 - 30	-
Median	45	-
Mean ± SD	41.1 ± 12.2	-
> 30 days	-	14 (51.9)
< 30 days	-	13 (48.1)
Duration of hospital stay (Days)		
Range (max - min)	16 - 3	-
Median	8	-
Mean ± SD	8.3 ± 3.8	-
> 7 days	-	14 (51.9)
< 7days	-	13 (48.1)

Box plots illustrating the pre-operative and post-operative functional outcome,using the two widely used knee evaluation scales, the Lysholm score and the IKDC score, are shown in **Figure. 2.** Thepre-operative (a_1) Lysholm score had a mean ± SD of 57.4 ± 4.9, while the post-operative (b_1) Lysholm score was 85.1 ± 4.4, with a p-value of 0.0001, indicating a statistically significant improvement **(Figure. 2A)**.

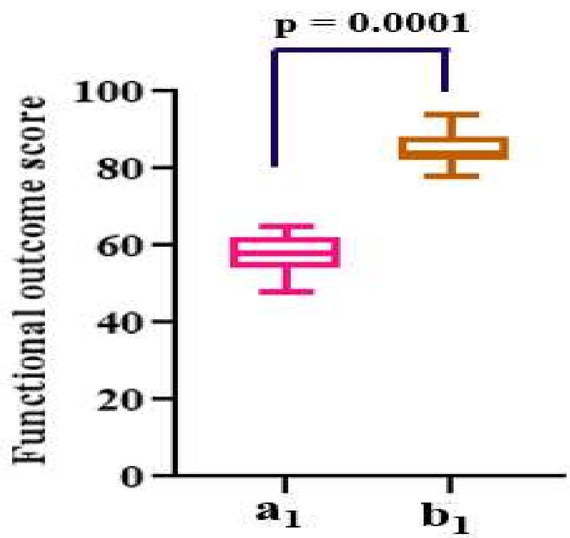

FIGURE 2A. Box plots showing pre operative (a_1) and post- operative (b_1) Lysholm score.

The pre-operative (a_2) (35.1 ± 4.8), and post-operative (b_2) (69.1 ± 2.8) IKDC scores with a p-value of 0.0001, also indicated statistically significant improvement **(Figure. 2B)**.

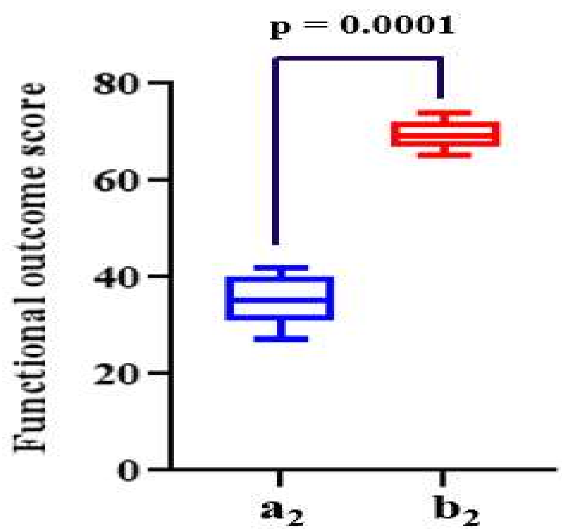

FIGURE 2B. Box plots showing pre operative (a_2) and post- operative (b_2) International Knee Documentation Committee score.

TABLE 2. Various angles calculated from post-operative radiographs

	Femoral tunnel angle (°)	Femoral inclination angle (°)	Tibial tunnel angle (°)	Tibial inclination angle (°)
Range (max-min)	49 - 18.9	64.2 - 32	45.4 - 18.9	64.9 - 40.6
Median	28.7	53.8	32.8	53.9
Mean ± SD	29.4 ± 6.3	53.1 ± 6.4	32.4 ± 5.4	54.0 ± 5.3

The range, median, and mean ± SD of various angles calculated from post-operative X-rays, are given in **Table 2.** The femoral tunnel angles were in the range of 49-18.9, with a median of 28.7 and a mean ± SD of 29.4 ± 6.3degrees. The femoral inclination angles were in the range of 64.2-32 degrees with a median of 53.8 and a mean ± SD of 53.1 ± 6.4 degrees. The tibial tunnel angle range was 45.4-18.9 degrees, with a median of 32.8and a mean ± SD of 32.4 ± 5.4 degrees. The tibial inclination angle had a range of 64.9-40.6 degrees, a median of 53.9, and a mean ± SD of 54.0 ± 5.3 degrees.

TABLE 3. Association between femoral angles and functional outcome*

Outcome*	Number of samples in category, n (%)	Femoral tunnel angles(°) Mean ± SD	p value	Number of samples in category, n (%)	Femoral tunnel inclination angles(°) Mean ± SD	p value
Excellent	0	-	0.41	0	-	0.44
Good	18 (66.7)	28.7 ± 5.0		18 (66.7)	53.8 ± 5.3	
Fair	9 (33.3)	30.9 ± 8.5		9 (33.3)	51.7 ± 8.3	
Poor	0	-		0	-	

Note: Excellent (95-100), Good (84-94), Fair (65-83), Poor (<65) classification is based on Lysholm score*

TABLE 4. Association between tibial angles and functional outcome*

Outcome*	Number of samples in category, n (%)	Tibial tunnel angles(°) Mean ± SD	p value	Number of samples in category, n (%)	Tibial tunnel inclination angles (°) Mean ± SD	p value
Excellent	0	-	**0.03**	0	-	0.31
Good	18 (66.7)	33.9±4.8		18 (66.7)	53.2±5.9	

Fair	9 (33.3)	29.3±5.5		9 (33.3)	55.5 ±3.8	
Poor	0	-		0	-	

Lysholm scores were used to analyzethe association of the graft orientation with the ACLR outcome. Based on earlier studies **[26, 27],** using Lysholm scores, the functional outcome was classified as excellent (95-100), good (84-94), fair (65-83) and poor (<63). For a six-month follow-up period, there were no cases under the poor as well as excellent categories. The outcome details and the mean angles corresponding to these categories are given in **Tables 3 and 4,** for femoral and tibial angles, respectively. Results of paired t-test analysis of the tunnel and inclination angles of the good and fair groups are also presented in these tables.

The correlations between the femoral tunnel angle, femoral tunnel inclination angle, with the functional scores, presented in **Figure. 3A, 3B, 3C** and **3D.** The scatter plot of angle vs post-operative six-month Lysholm score demonstrates a week association between the femoral tunnel angle and the Lysholm score, with a correlation coefficient (CC) of -0.13, indicating a weak negative correlation (**Figure. 3A**). **Figure. 3B** represents the correlation between the femoral inclination angle and the six-month Lysholm score. CC of 0.18, indicates a weak positive correlation. IKDC score also showed similar trends (**Figure.3C** and **3D**).

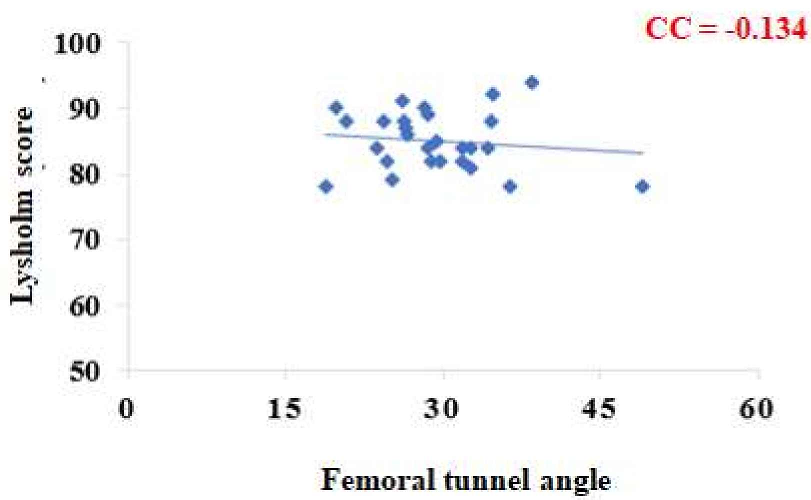

FIGURE 3A. Association of femoral tunnel angle with post operative Lysholm scores

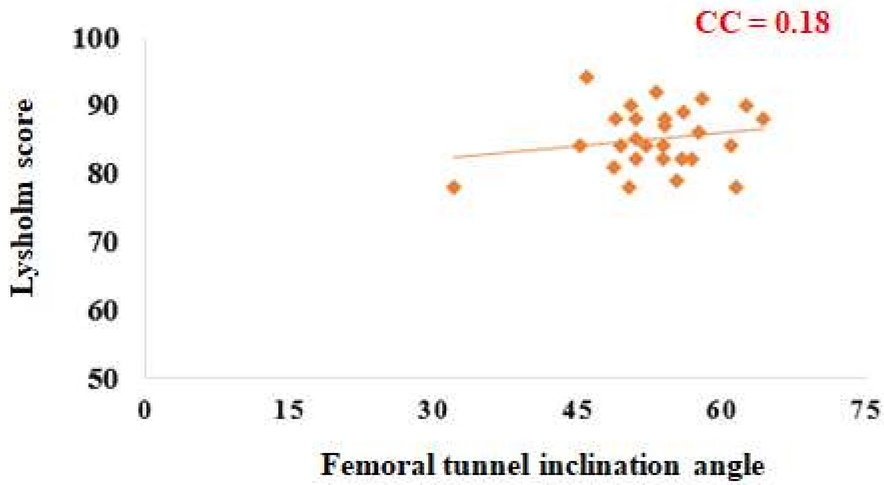

FIGURE 3B. Association of femoral tunnel Inclination angles with post operative Lysholm scores

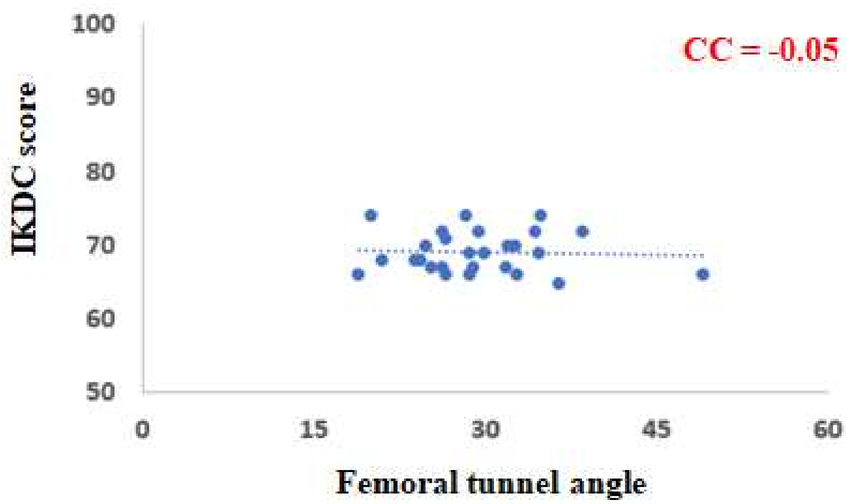

FIGURE 3C. Association of femoral tunnel with post operative International Knee Documentation Committee scores

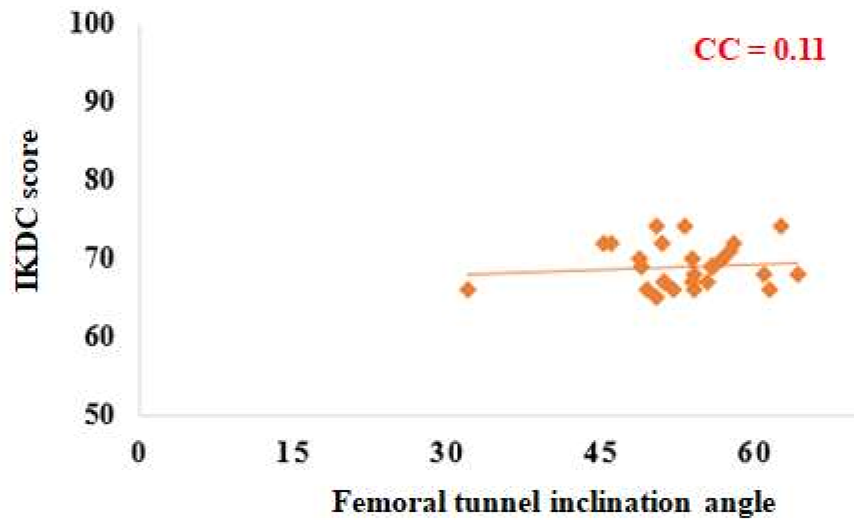

FIGURE 3D. Association of femoral tunnel Inclination angles with post operative International Knee Documentation Committee scores

The correlations between the tibial tunnel angle, tibial tunnel inclination angle, with the functional scores, presented in **Figure. 4A, 4B, 4C and 4D,** shows a slight positive correlation (CC=0.29) **(Fig.4A)** and negative correlation (CC = -0.31) **(Figure. 4B)** between the tibial tunnel and inclination angles, respectively IKDC scores also showed similar trends (**Figure 4C** and **4D**).

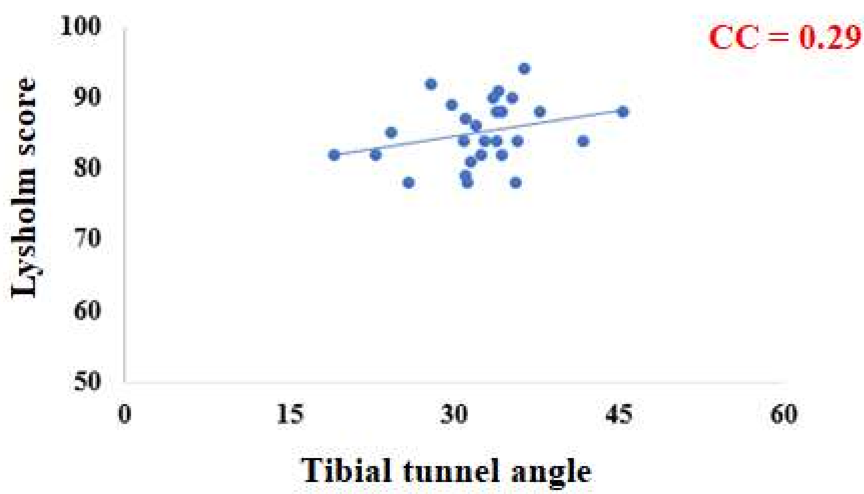

FIGURE 4A. Association of tibial tunnel angle with post operative Lysholm scores

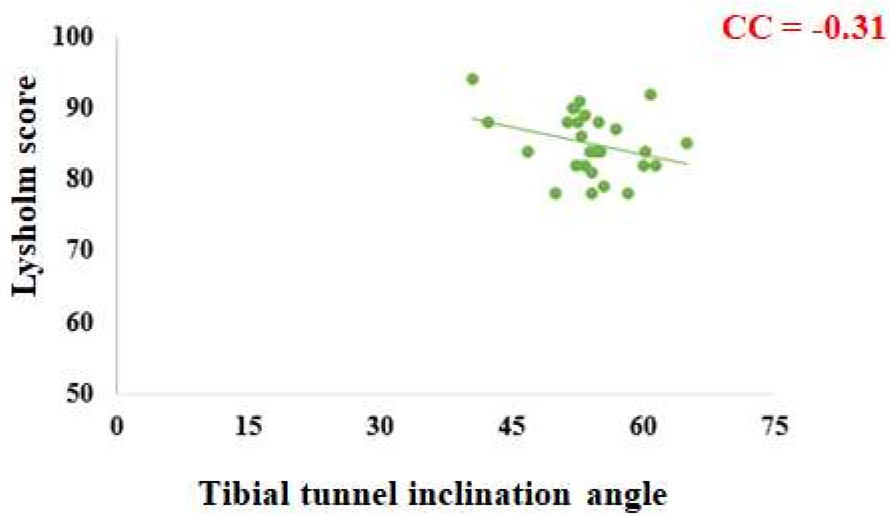

FIGURE 4B. Association of tibial tunnel Inclination angles with post operative Lysholm scores

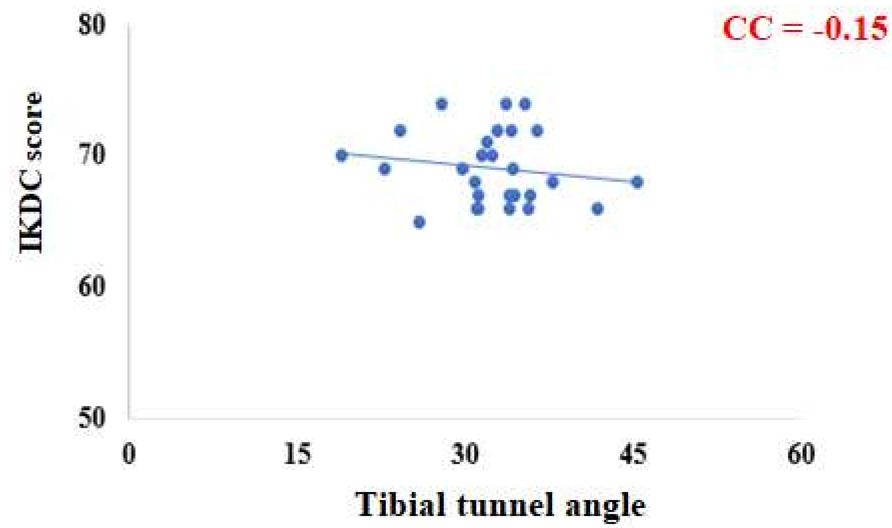

FIGURE 4C. Association of tibial tunnel with post operative International Knee Documentation Committee scores

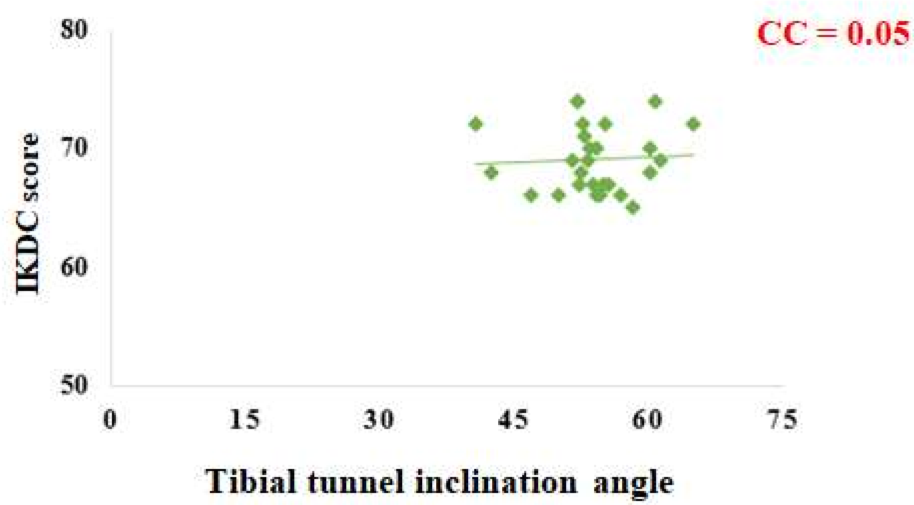

FIGURE 4D. Association of tibial tunnel Inclination angles with post operative International Knee Documentation Committee scores

The study further explored the association between the angles and participants characteristics such as gender, age, BMI, side of injury, and mode of injury **(Tables 5-9)**. No significant differences were observed in angles with gender **(Table 5)**, age **(Table 6)**, BMI **(Table 7)**, side of injury **(Table 8)** and mode of injury **(Table 9)**. However, the tibial tunnel angle was slightly larger for the right side compared to the left (p = 0.02).

TABLE 5. Association between angles and gender

Angles	Gender		p value
	Male	Female	
Femoral tunnel angle*	30.0±6.8	27.4 ±4.0	0.4
Femoral tunnel inclination angle*	52.7±6.8	54.4 ±5.0	0.6
Tibial tunnel angle*	31.6 ±4.8	35.2±6.8	0.2
Tibial tunnel inclination angle*	54.1±4.9	53.5 ±7.1	0.8

Note: * Values given as mean ±SD

TABLE 6. Association between angles and age

Angles	Age (years)		p value
	>30	<30	
Femoral tunnel angle*	29.3 ± 7.1	29.6 ± 5.2	0.9
Femoral tunnel inclination angle*	53.4 ± 7.4	52.4 ± 4.6	0.7
Tibial tunnel angle*	32.5 ± 6.2	32.3 ± 4.1	0.9
Tibial tunnel inclination angle*	54.0 ± 6.4	54.0 ± 3.1	0.9

Note: * Values given as mean ±SD

TABLE 7. Association between angles with BMI

Angles	BMI (kg/m^2)		p value
	> 25	< 25	
Femoral tunnel angle*	29.2 ± 6.2	30.4 ± 8.1	0.8
Femoral tunnel inclination angle*	53.0 ± 6.4	53.0 ± 7.0	0.9
Tibial tunnel angle*	32.2 ± 5.7	33.3 ± 3.8	0.7
Tibial tunnel inclination angle*	54.4 ± 4.7	51.4 ± 8.3	0.3

Note: * Values given as mean ±SD

TABLE 8. Association between angles with side of injury

Angles	Side of injury		p value
	Right side	Left side	
Femoral tunnel angle*	28.4 ± 6.9	31.5 ± 4.5	0.2
Femoral tunnel inclination angle*	52.8 ± 7.5	53.7 ± 3.7	0.7
Tibial tunnel angle*	34.0 ± 4.5	29.1 ± 5.8	**0.02**
Tibial tunnel inclination angle*	53.5 ± 4.8	55.0 ± 6.4	0.5

Note: * Values given as mean ±SD

TABLE 9. Association between angles with mode of injury

Angles	Mode of injury		p value
	Fall	RTA	
Femoral tunnel angle*	30.5 ± 6.2	26.2 ± 4.8	0.2
Femoral tunnel inclination angle*	51.8 ± 5.8	56.1 ± 6.2	0.2
Tibial tunnel angle*	32.1±5.9	33.1 ± 1.9	0.7
Tibial tunnel inclination angle*	53.9 ± 5.7	54.2 ± 3.4	0.9

Note: * Values given as mean ±SD

Discussion

ACLR is a widely performed surgical procedure aimed at restoring knee stability and function after an ACL tear. The success of this procedure is reported to be influenced by positioning of the bone tunnels for graft placement. This study aimed to the association between femoral, tibial tunnel and inclination angles, and functional outcomes ACLR. The study population consisted predominantly of a male (77.8%), which aligns with the general trend observed in ACL injuries, where males tend to be more affected than females **[28-30].** Previous studies have reported a higher prevalence of ACL injuries in younger age groups, typically between 17 and 30 years **[29, 30].** However, in this study about 63% were above 30 years.

The mean BMI of the participants was 28.7 ± 3.5 kg/m², with 85. 2% being overweight or obese (BMI > 25 kg/m²). Elevated BMI has been associated with an increased risk of ACL injuries and potential challenges during surgical procedures and rehabilitation **[31-33].** Additionally, previous studies have suggested that obese patients may experience lower functional outcomes after ACLR, as evidenced by lower IKDC scores **[32, 34].** The mode of injury was predominantly falling (81.5%), followed by road traffic accidents (18.5%), which is consistent with the literature, highlighting these as common mechanisms of ACL injuries **[35-37]**.

The study demonstrated a statistically significant improvement in postoperative functional outcome scores, as assessed by the Lysholm and IKDC scales, compared to preoperative scores **(Table 2).** This finding aligns with previous studies that have reported enhanced knee function and patient-reported outcomes following ACLR **[38-40]**. The significant improvement in functional scores suggests that ACLR can effectively restore knee function and stability in the postoperative period.

The position of femoral and tibial tunnels is a very important indicator for good functional outcome postoperatively **[41,42].** Incorrect positioning of tunnels incoronal and sagittal planes causes complications that modify the clinical outcome and often it becomes the most common cause of ACLR failure **[43, 13, 44].** The non-anatomic positioning of the graft may cause graft failure. The ideal femoral tunnel position in ACLR is between 9 and 10 o'clock on the lateral wall of the knee, with the knee flexed to 90degrees. Illingworth et al. evaluated femoral tunnel angle and inclination angle in 50 patients, who had received single bundle ACLR surgery **[15]**. However, they did not evaluate the association of the angles with the clinical outcome of the patients. 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. Patients with tunnel positions within an anatomic range had a smaller inclination angle than patients, who fell outside an anatomic range.

This study suggested that an inclination angle greater than 55 is a good predictor of a nonanatomic femoral tunnel. In another study, Peres et al.(2018) **[45]** it was observed that the patients who underwent anatomical reconstruction presented a femoral tunnel angle ranging from 29.3° to 57.4°. In our study the mean femoral tunnel angle is 29.4 ± 6.3°. However, the largest value observed was 49° well below the upper limit.Moghtadaei et al.(2018) **[46]** reported the highest angle at 43.1° ± 4°, while Padua et al. (2016) **[43]** reported a similar angle to the present study at 30.0° ± 10.0°.The variation could be due to differences in surgical techniques or measurement methods.

The anatomic range of an ACL tibial tunnel angle is typically considered to be between 35.5° and 55.5° in the sagittal plane with an average around 45°. In our study the mean tibial tunnel angle is32.4 ± 5.4° and the largest angle observed is well below the upper limit. The tunnel angles observed in our study suggest that our results are within the anatomic limit. The mean femoral and tibial tunnel angles, observed in our study are < 57°. However, 6 cases had tunnel inclination angles > 57°, above the limit proposed by Illingworth et al.(2011)**[15].** The observation of no cases in the poor outcome category **(Tables 3** and **4)** perhaps renders support for near anatomical ACLR in our study.

One of the critical aspects of the present study is the evaluation of the association between various tunnel angles and the functional outcomes. Jepsen et al. (2007) **[27]**have highlighted the crucial role of tunnel placement in obtaining good clinical results, restoring rotational stability, and achieving favourable patient outcomes. In the present study, no significant association was found between femoral tunnel angle, femoral inclination angle, or tibial inclination angle and postoperative Lysholm scores. However, a statistically significant result ($p < 0.03$) **[Table 4]** was observed for association between tibial tunnel angle and postoperative Lysholm scores. Padua et al. (2016) **[43]** have studied the influence of graft positioning on the clinical outcome of ACLR surgery in 30 patients. Their results showed correlation between tibial tunnel position and the IKDC score and the Lysholm score.Similarly, Avadhani et al. (2010) **[47]** have also found a significant association between tibial tunnel position on AP view and the outcome of ACLR. Our results are in accordance with the study of Avadhani et al. (2010) **[47]** and may indicate that the position of the tibial tunnel is associated with postoperative knee function in ACL reconstruction.

Limitations and Future Directions

While our study attempts insights into the relationships between tunnel angles and functional outcomes after ACLR, the sample size and follow-up time may limit the generalizability of the findings. Additionally, the study relied on conventional radiographic measurements, which is limited in its level of accuracy and precision, as compared to advanced imaging techniques such as three-dimensional computed tomography (3D CT) or magnetic resonance imaging (MRI).

Conclusion

This study contributes to the ongoing discussion on the graft position influencing functional outcomes following ACLR. While significant improvement in postoperative functional scores aligns with previous literature, the association between tibial tunnel angle and functional outcomes, but not femoral tunnel angles, warrants further investigation. Future research incorporating larger cohorts, advanced imaging modalities, longer follow-up time and comprehensive assessments of various contributing factors will further enhance our understanding of the relationships between tunnel positioning, graft orientation, and long-term functional outcomes in ACLR patients.

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Author contribution

R. Annamalai and **Venkatramanaiah. C:** Conceptualization, Formal analysis, Investigation, Methodology, Writing-Original draft preparation and Validation. **Gopinath Duraiswamy:** Methodology and Validation. **Kanchan**. **N**: Data curation. **N. Vignesh, D.Danis Vijay** and **A.Sujhithra:** Visualization, Computation, Writing-Reviewing and Editing.

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Declaration of competing interest

The author declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and materials

All data relevant to the study are either included in the article or uploaded as supplementary information.

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