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Intraosseous Femoral Tunnel Morphometry of the Distal Femur: Correlation between Tunnel Angle and Tunnel Length following Arthroscopic Anterior Cruciate Ligament Reconstruction

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Learning Point of the Article:

There is a significant but small inverse correlation between femoral tunnel angle and intraosseous tunnel length after anterior cruciate ligament reconstruction. More oblique tunnel orientations are associated with shorter intraosseous trajectories, although multiple anatomical and technical factors determine tunnel length.

Abstract

Introduction: The creation of the femoral tunnel is one of the most anatomically demanding steps in an arthroscopic anterior cruciate ligament (ACL) reconstruction. The placement of the femoral tunnel in the distal femur has a role to play in the geometry of the tunnel and in the characteristics of the fixation, its trajectory, and the length of the intraosseous tunnel. The femoral tunnel angle and the tunnel length have been studied separately in ACL reconstruction. However, the literature is limited on the anatomical relationship of these two factors in the distal femur through combined radiographic and computed tomography (CT) assessment.

Objectives: To determine the degree of relationship of the femoral tunnel angle with the intraosseous femoral tunnel length post-arthroscopic ACL reconstruction.

Materials and Methods: This observational radiological study involves 70 patients who underwent arthroscopic single-bundle ACL reconstruction using quadrupled hamstring autograft. All patients underwent post-operative radiography and CT scans. Post-operative radiographs were used to measure the femoral tunnel angle using the femoral tunnel axis and distal femoral anatomical reference line. The length of the femoral tunnel was measured using CT multiplanar reconstruction. Tunnel angle and length correlation analysis was performed using the Pearson correlation coefficient.

Results: There was a substantial association between the femoral tunnel angle and the length of the intraosseous femoral tunnel. The study findings revealed that the morphology of distal femoral bone influenced femoral tunnel geometry.

Conclusion: There are measurable anatomical relationships between femoral tunnel angle and intraosseous tunnel length of the ACL-reconstructed tunnel. Research indicates that the geometry of the femoral tunnel is a reflection of the osseous architecture of the distal femur. Gaining insight into this relationship may help surgeons in achieving an adequate tunnel length with maintenance of cortical integrity through anatomical tunnel placement.

Keywords: Anterior cruciate ligament, distal femur, femoral tunnel angle, femoral tunnel length, morphometry, radiological anatomy.

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Introduction

The methods for reconstructing the anterior cruciate ligament (ACL) have evolved from isometric reconstruction to grafts that more anatomically restore the natural morphology and biomechanics of the native ligament. Among the various technical aspects involved in ACL reconstruction, femoral tunnel creation continues to remain one of the most critical determinants of graft orientation and intra-articular biomechanics [1,2].

The femoral tunnel is a manmade intraosseous tract through the distal femur. The shape of a tunnel depends not just on the technique a surgeon uses, but also on the shape of the lateral femoral condyle, the shape of the anatomy of the intercondylar notch, and the angle of the distal femur [3]. A change in the angle of a tunnel can greatly affect the distance that it travels through the lateral femoral condyle, which affects the length of the tunnel, and the containment, fixation strength, and bending characteristics of the graft [4,5].

Anatomical ACL reconstruction is gaining increasing emphasis. To try to achieve the native anatomy of the footprint, ACL surgeons try to create more oblique femoral tunnels. However, as tunnel obliquity increases, that interferes with the intraosseous tunnel lengthening, perhaps augmenting the risk of posterior cortical compromise or inadequate graft-bone interface [6]. In contrast, overtly vertical tunnels might lengthen the tunnel but jeopardize rotational biomechanics [7].

The geometrical assessment of femoral tunnels has become quite critical. According to conventional post-operative radiographs, tunnel inclination and orientation can be assessed. However, computed tomography (CT) offers a superior visualization of the tunnel trajectory and the intraosseous dimensions of the distal femur. Despite several studies evaluating graft bending angle, tunnel widening, and tunnel positioning, limited literature exists assessing femoral tunnel angle in relation to intraosseous tunnel length anatomically.

The current study was undertaken to assess the anatomical relationship between femoral tunnel angle and intraosseous tunnel length within the distal femur following arthroscopic ACL reconstruction using radiographic and CT evaluation.

Table 1: Femoral tunnel length

Femoral tunnel length	Frequency	Percentage	Cumulative frequency	Cumulative percentage
35	11	15.71	11	15.71
36	12	17.14	23	32.86
37	11	15.71	34	48.57
38	10	14.29	44	62.86
39	10	14.29	54	77.14
40	16	22.86	70	100

Materials and Methods

Study design

This was a hospital-based radiological observational study conducted in patients who underwent arthroscopic ACL reconstruction.

Study population

A total of 70 patients who underwent arthroscopic ACL reconstruction using quadrupled hamstring autograft were included in the study.

Inclusion criteria

- Patients aged between 18 and 45 years
- Primary ACL tear confirmed clinically and radiologically
- Patients who underwent arthroscopic single-bundle ACL reconstruction
- Availability of post-operative radiographs and CT scans.

Exclusion criteria

- Revision ACL reconstruction
- Multiligamentous knee injuries
- Previous distal femoral fractures
- Severe osteoarthritis
- Inadequate radiological imaging.

Surgical technique

All surgeries were performed arthroscopically using standard anteromedial and anterolateral portals. Femoral tunnel drilling was performed through the anteromedial portal with the knee in hyperflexion. The native femoral ACL footprint was identified arthroscopically before tunnel creation. Quadrupled hamstring autograft was used in all patients.

Radiological assessment

Measurement of femoral tunnel angle

The femoral tunnel angle was determined from the true lateral radiograph as the angle formed between:

- The long axis of the distal femoral shaft and the axis of the femoral tunnel, which is the centreline drawn through the shadow of the tunnel (Fig. 1) [1,5,8,9].
- We recorded angles in degrees and grouped them along the reported corridor (50°-57°). This made it possible to look at clustering patterns and the consistency of the surgical tunnel's orientation.

Measurement of femoral tunnel length

The length of the femoral tunnel was mainly measured by CT multiplanar reconstruction. This gave the most precise estimate of the length of the tunnel in millimeters [8,9].

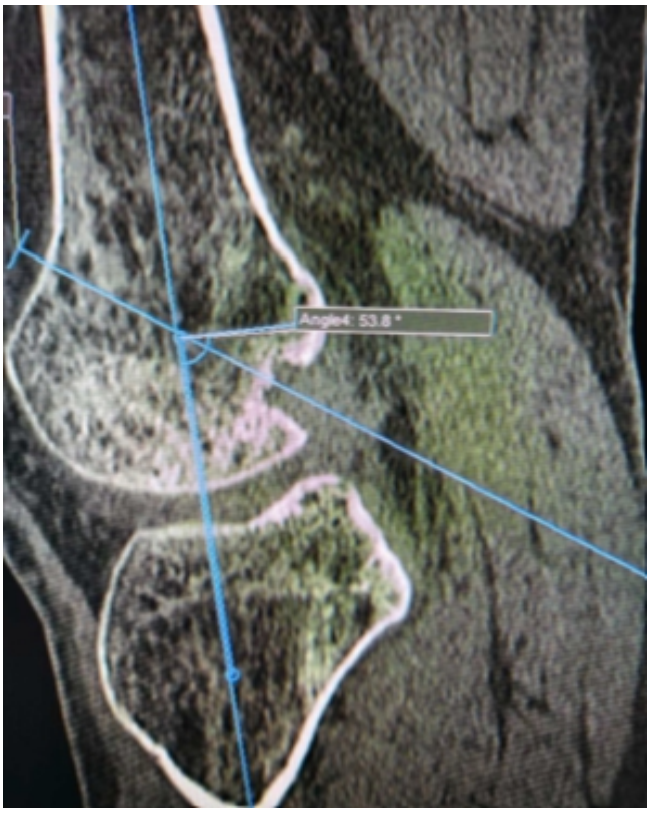


Figure 1: Measurement of femoral tunnel angle.



Figure 2: Measurement of femoral tunnel length.

Radiographically, the length of the femoral tunnel was secondarily corroborated by verifying the position of the Endobutton at the lateral femoral cortex and evaluating the anticipated tunnel trajectory on the lateral radiograph. For the sake of consistency in the analysis, femoral tunnel length values were grouped into millimeter ranges (35–40 mm) (Fig. 2).

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences software. Both Pearson and Spearman correlation analyses were performed. Because the variables were not normally distributed, Spearman correlation was considered the primary analysis. Continuous variables were expressed as mean ± standard deviation. $P < 0.05$ was considered statistically significant.

Results

Femoral tunnel length and tunnel angle on sagittal

The length of the femoral tunnel ranged from 35 mm to 40 mm, with most (22.86%) measuring 40 mm. The more uniform distribution across the remaining length categories indicates consistent proximal femur intraosseous tunnel morphology. The angles of the femoral tunnels were mostly found between 51° and 55° (58.6%), indicating a possible reproducible orientation of the tunnel through the lateral femoral condyle. To sum up, findings reveal that femoral tunnel geometry, as indicated by tunnel length and tunnel angle, remains relatively unchanged following anatomical ACL reconstruction and may reflect distal femoral osseous morphology rather than a mere technical consequence of tunnel drilling [Tables 1, 2, 3, 4, 5, 6].

Regression equation:

Length = 51.455 – 0.256 × Angle

Descriptive analysis of femoral tunnel morphometry

The study included 70 patients who underwent arthroscopic ACL reconstruction. The mean femoral tunnel angle as measured on sagittal radiographs was 53.36 ± 2.17° (50°–57°). On post-operative computed tomography, the average intraosseous femoral tunnel length was found to be 37.819 ± 1.64 mm (35–40 mm). The median angle of the tunnel was 53°. The median tunnel length was 38 mm. The tunnel angle's interquartile range is 3.75°, indicating moderate scatter around the average. The distribution of the length of the tunnel is most closely related to the interquartile range of 2 mm. The angle of the tunnel, with a 95% confidence interval, was 52.84°–53.88°, and the length of the tunnel, with a 95% confidence interval, was 37.42 –38.21 mm, indicating satisfactory precision.

Table 2: Tunnel angle on sagittal				
Tunnel angle on sagittal	Frequency	Percentage	Cumulative frequency	Cumulative percentage
50	8	11.43	8	11.43
51	10	14.29	18	25.71
52	8	11.43	26	37.14
53	11	15.71	37	52.86
54	8	11.43	45	64.29
55	12	17.14	57	81.43
56	7	10	64	91.43
57	6	8.57	70	100

Table 3: Descriptive statistics		
Statistic	Tunnel angle (°)	Tunnel length (mm)
n	70	70
Mean±standard deviation	53.36±2.17	37.81±1.64
Median	53	38
Minimum–Maximum	50–57	35–40
Range	7	5
Q1 (25%)	51.25	37
Q3 (75%)	55	39
Interquartile range	3.75	2
95% confidence interval	52.84–53.88	37.42–38.21

Assessment of data distribution

The normality of the data was assessed using the Shapiro–Wilk test. Tunnel angle demonstrated a W statistic of 0.937 (P = 0.0016), whereas tunnel length showed a W statistic of 0.911 (P = 0.0001). Both variables exhibited statistically significant deviation from a normal distribution. Consequently, non-parametric correlation analysis was considered appropriate for evaluating the relationship between tunnel angle and tunnel length.

Correlation between femoral tunnel angle and tunnel length

Spearman rank correlation analysis revealed a statistically significant negative correlation between femoral tunnel angle and intraosseous femoral tunnel length (P = –0.329, P = 0.005). This finding indicates that increasing tunnel obliquity was associated with a reduction in the intraosseous tunnel length within the distal femur.

Pearson correlation analysis produced similar findings, demonstrating a significant inverse relationship between tunnel angle and tunnel length (r = –0.338, P = 0.004). Although the magnitude of the correlation was modest, the consistency of the findings across both parametric and non-parametric methods supports the existence of a genuine anatomical association between tunnel orientation and tunnel length.

Linear regression analysis

Table 4: Shapiro–Wilk normality test			
Variable	W Statistic	*P*-value	Interpretation
Tunnel angle (°)	0.937	0.00161	Not normally distributed
Tunnel length (mm)	0.911	0.000108	Not normally distributed

The relationship between tunnel angle and tunnel length was further investigated through linear regression analysis. The regression model revealed a significant negative correlation (P = 0.004), with a coefficient of determination of 0.114. Thus, tunnel angle explains only about 11.4% of the variation in tunnel length. Thus, variations in tunnel angle and tunnel length are poorly predictable.

The negative coefficient of the regression slope means that more oblique tunnels were associated with shorter intraosseous tunnels. While changes to the tunnel angle were sufficient to cause variation in tunnel length, the low coefficient of determination indicates that other anatomical factors related to the distal femur may influence the tunnel geometry.

Radiological anatomical interpretation

We found a weak correlation between the femoral tunnel angle and the available intraosseous corridor in the distal femur. Higher tunnel obliquity correlated with shorter tunnel length, but tunnel angle accounted for only 11.4% of the variation seen, suggesting other anatomical and technical factors also contribute substantially to tunnel length. Shorter intraosseous trajectories through the lateral femoral condyle were associated with more oblique tunnel orientations. This relationship may be explained by interaction between tunnel trajectory, distal femoral morphology, and technical factors during tunnel creation. Conversely, less oblique tunnels had a longer intraosseous course. The fact that femoral tunnel morphometry is directly related to distal femoral bone morphology and not merely due to surgical techniques could be seen from these observations.

Discussion

The present study evaluated the anatomical relationship between femoral tunnel angle and intraosseous femoral tunnel length within the distal femur following arthroscopic ACL reconstruction. The key finding was a statistically significant

Table 5: Correlation analysis	
Parameter	**Value**
Pearson correlation	
Pearson r	−0.3379
R^2	0.1142
t -statistic	−2.961
Degrees of freedom	68
P -value	0.00422
Spearman rank correlation	
Spearman ρ	−0.3285
t -statistic	−2.868
P -value	0.00549
Interpretation	Significant negative rank correlation

negative correlation between tunnel angle and tunnel length, indicating that increasing tunnel obliquity was associated with a reduction in the available intraosseous tunnel corridor. Although the strength of correlation was modest, the finding is anatomically meaningful, as it suggests that femoral tunnel length is influenced not only by surgical drilling technique but also by the osseous geometry of the distal femur. Table 7 compares the present study with previously published studies evaluating femoral tunnel geometry, tunnel length, and tunnel orientation in ACL reconstruction.

Modern ACL reconstruction has moved toward anatomical femoral tunnel placement, with the intention of restoring the native femoral footprint and improving rotational control. Bedi et al. demonstrated that anteromedial portal drilling allows more anatomical and oblique femoral tunnel placement when compared with the transtibial technique [5]. Their work supports the current understanding that tunnel orientation is central to anatomical ACL reconstruction. However, our study adds a further anatomical perspective by showing that such tunnel orientation has a measurable relationship with intraosseous tunnel length. In other words, the tunnel is not only a surgical pathway but also a morphometric expression of the lateral femoral condylar corridor.

Table 7: Comparison of the present study with previously published studies evaluating femoral tunnel geometry, tunnel length, and tunnel orientation in ACL reconstruction

Study	Primary focus	Verified finding	Relationship to present study
Ahn *et al* . [1]	Post-operative graft angle and tunnel orientation	Quantified graft angle and tunnel placement after ACL reconstruction using imaging	Supports the importance of radiological evaluation of tunnel orientation, which was also analyzed in the present study.
Gali *et al* . [8]	Effect of knee flexion angle on femoral tunnel length	Demonstrated that femoral tunnel length varies according to drilling conditions and knee flexion angle during tunnel creation	Consistent with our finding that tunnel geometry influences intraosseous tunnel length. Our study further evaluated this relationship using post-operative tunnel angle measurements.
Bedi *et al* . [5]	Anteromedial portal versus transtibial drilling	Demonstrated that tunnel orientation changes with drilling technique and influences anatomical tunnel placement	Supports the concept that tunnel trajectory is a major determinant of femoral tunnel geometry.
Nishimoto *et al* . [2]	Graft bending angle at femoral tunnel aperture	Showed that tunnel orientation affects graft bending angle at the femoral aperture	Supports the anatomical relevance of tunnel geometry beyond tunnel creation alone.
Tashiro *et al* . [6, 7]	Dynamic graft bending angle and tunnel orientation	Demonstrated that graft bending behavior changes according to tunnel orientation and reconstruction technique	Indicates that femoral tunnel orientation influences graft mechanics and tunnel-related biomechanics.
Wein *et al* . [9]	Tunnel anteversion and tunnel length	Demonstrated that tunnel direction and instrumentation influence femoral tunnel length	Similar to our findings showing that tunnel orientation affects intraosseous tunnel length within the distal femur.
Tompkins *et al* .	Femoral tunnel length and lateral femoral condylar dimensions	Demonstrated that tunnel length correlates with lateral femoral condylar morphology and anthropometric parameters.	Strengthens our interpretation that tunnel length reflects distal femoral osseous anatomy rather than being solely a technical measurement.
Present study	Distal femoral tunnel morphometry	Significant negative correlation between tunnel angle and tunnel length (ρ = −0.329, *P* = 0.005)	One of the few studies specifically evaluating tunnel angle and tunnel length as a distal femoral morphometric relationship using combined radiographic and computed tomography assessment.

ACL: Anterior cruciate ligament

Table 6: Linear regression analysis

Parameter	Value
Slope (b)	−0.2556
Intercept (a)	51.4545
R^2	0.1142
Standard error of estimate	1.559
Standard error of slope	0.0863
t- statistic	−2.961
P-value	0.00422

Gali et al. reported that femoral tunnel length changes with knee flexion angle during anatomical ACL reconstruction [8]. Their findings suggested that tunnel length is sensitive to the direction of drilling and the spatial orientation of the femur at the time of tunnel creation. The present study is in agreement with this concept, as more oblique tunnels were associated with shorter intraosseous tunnel lengths. However, while Gali et al. focused mainly on the influence of knee flexion angle, the present study specifically examines the relationship between post-operative tunnel angle and CT-measured tunnel length as a distal femoral morphometric phenomenon.

Wein et al. also highlighted the relationship between femoral tunnel anteversion, instrumentation, and tunnel length in ACL reconstruction [9]. Their study supports the idea that femoral tunnel geometry is affected by the three-dimensional direction of tunnel creation. The present study similarly indicates that the intraosseous path available within the distal femur is not fixed. It changes according to the angular orientation of the tunnel. This reinforces the view that femoral tunnel length should not be interpreted as a simple technical measurement. It reflects the interaction between tunnel trajectory, condylar morphology, and the cancellous osseous corridor of the lateral femoral condyle.

The distal femur has a complex anatomical architecture. The femoral tunnel begins at the anatomical femoral ACL footprint, passes through cancellous bone in the lateral femoral condyle, and exits toward the lateral cortex. As tunnel obliquity increases, the tunnel takes a more horizontal course through the condyle. This reduces the available intraosseous distance and may bring the tunnel closer to the posterior cortical boundary. This anatomical explanation is consistent with our observation that greater tunnel obliquity was associated with shorter tunnel length. It also explains why a balance is required between anatomical footprint restoration and maintenance of an adequate tunnel length for graft containment.

Tunnel geometry also has implications for graft bending. Nishimoto et al. analyzed the graft bending angle at the femoral tunnel aperture in anatomical double-bundle ACL reconstruction and demonstrated that tunnel orientation affects graft bending at the aperture [2]. Tashiro et al. further showed that graft bending angle varies during knee motion and differs according to reconstruction technique [6,7]. These studies indicate that femoral tunnel orientation does not end as an isolated bony measurement. It affects the course of the graft, the bending angle at the aperture, and potentially the stress distribution across the graft-tunnel interface. The present study complements these observations by showing that the same tunnel orientation also affects the intraosseous length available within the distal femur.[10].

The biomechanical implications of femoral tunnel orientation are not limited to tunnel length. Graft bending angle was shown by Chen et al. to affect early allograft tendon maturation after ACL reconstruction [11]. Zaffagnini et al. investigated the influence of the orientation of the femoral tunnel on knee stability and the relevance of the positioning of the graft for the restoration of the biomechanics of the joint [12]. Similarly, Kato et al. demonstrated that different femoral graft positions result in different biomechanical responses, indicating the importance of anatomical tunnel placement [13]. The findings suggest that the geometry of the femoral tunnel should not only be considered as an anatomical measurement, but also in relation to the behaviour of the graft and postoperative knee biomechanics.

Chung et al. further showed that the knee flexion angle during transportal femoral tunnel drilling affects the graft bending angle, tunnel length, and risk of posterior cortical compromise [14]. Guglielmetti et al. investigated the influence of femoral tunnel length on graft rupture after ACL reconstruction and emphasised the clinical significance of measuring tunnel length [15]. Collectively, the results of these studies emphasise the need to balance anatomical graft positioning with sufficient intraosseous tunnel length and good graft mechanics. However, the present study was confined to radiological morphometry and did not assess graft maturation, fixation strength, clinical stability, or graft failure. Therefore, the relationship between tunnel angle and tunnel length observed here should not be interpreted as direct evidence of altered graft biomechanics or clinical outcomes.

CT was useful in the present study because it allowed better assessment of the tunnel course within the distal femoral bone.

Conventional radiographs provided a practical method for assessing tunnel angle, but CT defined the intraosseous tunnel length and its relationship to the distal femoral cortex more clearly. This combined radiographic and CT-based approach strengthens the anatomical relevance of the study. It allows the femoral tunnel to be studied as a three-dimensional osseous corridor rather than merely as a post-operative surgical mark.

An important strength of this study is its anatomical framing. Most previous studies have discussed femoral tunnel position, tunnel length, graft bending angle, or drilling technique mainly from a surgical or biomechanical perspective [2,5,6,7,8,9]. The present study specifically examines the correlation between femoral tunnel angle and tunnel length as a distal femoral morphometric relationship. This makes the work relevant to applied anatomy, particularly because the femoral tunnel is created within the lateral femoral condyle and is directly influenced by the osseous architecture of the distal femur (Table 7).

The modest correlation observed in this study also deserves attention. Tunnel angle explained only part of the variation in tunnel length. This is expected, as tunnel length may also be influenced by individual variation in condylar size, intercondylar notch morphology, lateral femoral wall thickness, knee flexion during drilling, and subtle differences in portal placement. Therefore, the findings should not be interpreted as a purely mechanical rule. Rather, they suggest that tunnel angle is one important anatomical determinant of intraosseous tunnel length within a broader distal femoral morphometric framework.

Overall, the present study supports the view that femoral tunnel length should not be considered only as an intraoperative technical parameter. It is a radiological reflection of distal femoral osseous anatomy and tunnel orientation. Recognition of this relationship may help surgeons achieve a more balanced reconstruction, where anatomical tunnel placement is obtained without compromising tunnel length, graft containment, or cortical safety.

Limitations of the study

The study carries multiple limitations. The single-center observational design and relatively small sample size may limit the generalisability of the findings. The cohort was sufficient to demonstrate the observed association between femoral tunnel angle and tunnel length, but was not powered for subgroup analyses based on age, sex, graft characteristics, or variations in femoral morphology.

The study was mostly designed to evaluate the post-operative tunnel geometry. There was no pre-operative three-dimensional assessment of the distal femur nor a non-operated control group. Therefore, the relative contribution of native femoral anatomy and surgically determined tunnel orientation cannot be clearly disentangled. The analysis also did not include detailed morphometric parameters such as the dimensions of the lateral femoral condyle, notch morphology, thickness of the posterior wall, cortical thickness, and overall femoral size.

The femoral tunnel angle was measured on true lateral radiographs and therefore is a two-dimensional projection of a three-dimensional trajectory. Although only technically adequate radiographs were included, small rotational variations during imaging as well as differences in identification of the tunnel axis may have affected the measured angle. Tunnel orientation in axial and coronal planes was not quantified independently. Reliability analyses for intraobserver and interobserver were also not done. Future studies with three-dimensional CT-based measurements and formal assessment of measurement reliability would yield more comprehensive assessments of tunnel geometry.

Furthermore, the interpretation of the results has to take into account the rather limited range of tunnel angles (50°–57°) and tunnel lengths (35–40 mm). The observed relationship may not necessarily hold for substantially more vertical or more oblique tunnel orientations. Furthermore, a number of anatomical and technical variables that might influence tunnel length were excluded from multivariate analysis. Factors include knee flexion during drilling, portal position, guidewire placement, tunnel starting position, reamer trajectory, and individual skeletal morphology. The general method of reconstruction was consistent, but these individual operative variables were not standardized in a quantitative manner.

Most importantly, the correlation observed was modest, and tunnel angle explained only a small amount of the variability in tunnel length. Thus, the results should be interpreted as an association and not as a causal or predictive relationship. The length of the tunnel is probably a function of an interaction between the tunnel orientation, the distal femoral morphology, and the surgical technique.

Finally, clinical- and graft-related outcomes were beyond the scope of the present radiological morphometric study. Graft stability, post-operative laxity, functional scores, return to sport, graft bending, fixation-related parameters, tunnel widening, graft failure, and revision surgery were not assessed. However, the clinical and biomechanical implications of this morphometric relationship are yet to be established. Larger prospective multicenter studies including pre-operative three-dimensional morphometry, standardized surgical parameters, reliability testing, multivariable analysis, and longitudinal

clinical outcomes would help to clarify the clinical relevance of these findings.

Conclusion

The relationship between the intraosseous tunnel length after arthroscopic ACL reconstruction and the femoral tunnel angle was statistically significant but weakly inverse. Tunnel angle accounted for only a small proportion of tunnel-length variability, but more oblique tunnel orientations were associated with shorter intraosseous trajectories. Femoral tunnel angle demonstrated a statistically significant but modest inverse association with intraosseous tunnel length. This finding should be interpreted as a morphometric relationship rather than evidence that increasing tunnel obliquity directly causes tunnel shortening. Therefore, femoral tunnel length is a multifactorial parameter influenced both by tunnel orientation and distal femoral anatomy.

Clinical Message

In anatomical ACL reconstruction, femoral tunnel orientation should be evaluated in conjunction with available intraosseous tunnel length, not in isolation. An understanding of this relationship may assist the surgeon in achieving an anatomical tunnel placement while being aware of the anatomical limitations of the distal femoral osseous corridor.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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