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ORIGINAL ARTICLE

Comparisons of the radiological and functional results of femoral tunnels created in Figure-4 and 110° flexion positions in arthroscopic anterior cruciate ligament reconstruction

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ABSTRACT

Objectives: The aim of this study was to compare the radiological and functional results of femoral tunnels created in Figure-4 and 110° flexion positions in anterior cruciate ligament (ACL) reconstruction.

Patients and methods: Between January 2016 and December 2019, a total of 84 patients (78 males, 6 females; mean age: 29.2±6.1 years; range, 17 to 46 years) who underwent anatomic ACL reconstruction (ACLR) were retrospectively analyzed. The patients were divided into two groups according to femoral tunnel drilling technique: 110° knee flexion (Group 1) and the Figure-4 position (Group 2). Demographic data were recorded. Radiological measurements (femoral tunnel position, length, angles, and distances to the lateral epicondyle) were performed on postoperative Day 1 computed tomography (CT) scans. Functional scores (Lysholm, Cincinnati, IKDC-SKF, Tampa Kinesiophobia, Return to Sport) were assessed at 12 months postoperatively. Radiological and functional outcomes were compared between groups.

Results: The mean anterior distance and axial tunnel angle were higher in the 110° flexion group than in the Figure-4 group (AD: p=0.001; ATA: p=0.035). The superior distance, femoral tunnel length, coronal tunnel angle, and femoral tunnel positioning measurements were significantly higher in the Figure-4 group (SD: p=0.001; FTL: p=0.006; CTA: p=0.001; FTP deep-shallow: p=0.001; FTP high-low: p=0.001). The Cincinnati Knee Rating System scores were also significantly higher in the Figure-4 group (p=0.001).

Conclusion: Anterior cruciate ligament reconstruction using the Figure-4 method provides satisfactory and comparable results with the conventional method. The Figure-4 position allows for 130 to 140° flexion of the knee and tunneling closer to the anatomical ACL insertion owing to the ease of application without creating any operational difficulties.

Keywords: Anterior cruciate ligament reconstruction, arthroscopic, femoral tunneling position, Figure-4 position, 110° flexion position, radiological and functional results.

The anterior cruciate ligament (ACL) is one of the most frequently injured ligaments in the knee joint and plays a key role in maintaining joint stability.[1] With the growing popularity of high-intensity physical activities, the incidence of ACL injuries has significantly increased, and these injuries may also occur as part of multiligamentous injuries.[2] In the literature, the incidence of ACL rupture has been reported as 85 per 100,000 person-years.[3] In addition, injuries

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during childhood and adolescence have increased by 147.8% over the past decade, with an annual incidence reaching 6.79 per 100,000 in individuals aged between 5 and 14 years.[4,5]

Anterior cruciate ligament reconstruction (ACLR) is widely recognized as the gold standard for restoring knee stability and function in active individuals. Numerous factors affect surgical outcomes, including patient-specific characteristics such as sex, notch width, ligamentous laxity, ligamentum mucosum, and graft choice, tunnel placement, graft fixation, and postoperative rehabilitation.[6-8] Of these, the anatomical placement of the femoral and tibial bone tunnels is considered one of the most critical determinants of success. Improper tunnel placement can compromise graft integration, thereby leading to surgical failure.[9]

It has been reported that 70 to 80% of ACLR failures are due to technical errors, most commonly related to incorrect femoral tunnel positioning (FTP).[10,11] An excessively anterior tunnel placement may result in graft impingement or rotational laxity, whereas a posteriorly positioned tunnel may cause posterior cortical blowout and inadequate graft fixation.[9,12] Therefore, several techniques have been proposed to optimize the tunnel trajectory. One such technique is the Figure-4 position, which provides external femoral rotation and varus stress, thereby enhancing visualization of the lateral femoral condyle.[13,14]

Although several studies have compared different knee flexion angles during ACLR, to the best of our knowledge, no previous study has specifically compared the Figure-4 position with the standard 110° flexion position in terms of radiological and functional outcomes.[15,16]

In the present study, we hypothesized that the improved exposure provided by the Figure-4 position could facilitate more precise and anatomical tunnel creation, which may contribute to better graft orientation, enhanced knee stability, and ultimately improved functional outcomes. We, therefore, aimed to compare FTP, radiological alignment, and clinical outcomes between the Figure-4 and 110° flexion positions during ACL reconstruction.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Muğla Sıtkı Koçman University Faculty of Medicine, Department of Orthopedics and Traumatology between January 2016 and December 2019. From the hospital database, the clinical and radiological data were recorded of a total of 104 patients who were diagnosed with a full-thickness ACL tear, were aged between 17 and 46 years, underwent single-bundle anatomic ACLR with four layers of hamstring autograft, and had at least 12 months of follow-up. Exclusion criteria were as follows: having a previous knee surgery, the presence of arthritis, combined ligament injury, and cartilage damage. After implementation of the exclusion criteria, a total of 84 patients (78 males, 6 females; mean age: 29.2±6.1 years; range, 17 to 46 years) who met the inclusion criteria were recruited. Written informed consent was obtained from each patient. The study protocol was approved by the Muğla Sıtkı Koçman University Human Research Ethics Committee (Date: 14.02.2020, No: 17). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The surgical position was not based on preoperative clinical or anatomical criteria, but rather reflected a shift in the surgeon's routine technique over time. Specifically, all patients operated on between January 2016 and June 2018 underwent ACL reconstruction in the 110° flexion position, while those operated on between June 2018 and December 2019 underwent the procedure in the Figure-4 position, based on the surgeon’s evolving preference and experience. This natural division was used to form the two study groups in a retrospective manner (Figure 1). The demographic data of age, sex, height, and weight were noted for all patients, and two-dimensional (2D) and three-dimensional (3D) images were obtained from CT sections performed on the postoperative first day. The anterior distance (AD) and superior distance (SD) of the femoral tunnel exit to the lateral epicondyle (Figure 2), FTP (deep% *vs.* shallow, high *vs.* low%) (Figure 3) were measured by two blinded observers on the postoperative 3D computed tomography (CT) sections and mean values were recorded. The femoral tunnel length (FTL) (Figure 4), coronal tunnel angle (CTA) (Figure 5), and axial tunnel angle (ATA) (Figure 6) were measured on 2D sections. At the end of 12 months postoperatively, the Lysholm Knee Scores (LKS), Cincinnati Knee Rating System (CKRS) scores, IKDC-Subjective Knee Form (IKDC-SKF) scores, Tampa Kinesiophobia Scale (TKS) scores, and Return to Sport after ACL Injury Scale Functional Test (RST) scores, together with the Lachman and Pivot Shift test results were recorded. The score ranges were LKS: 0-100

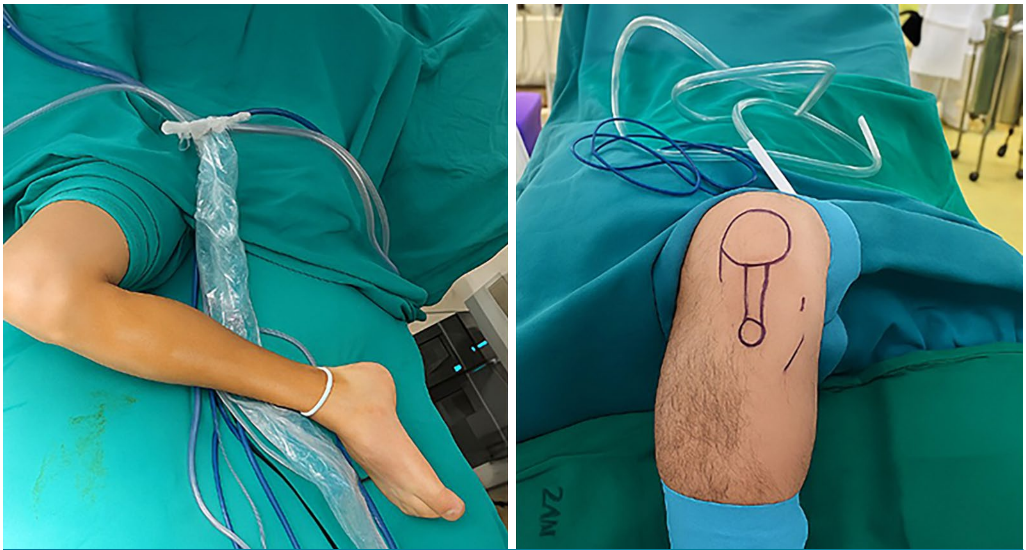

FIGURE 1. Figure-4 and flexion position applied in the surgery.

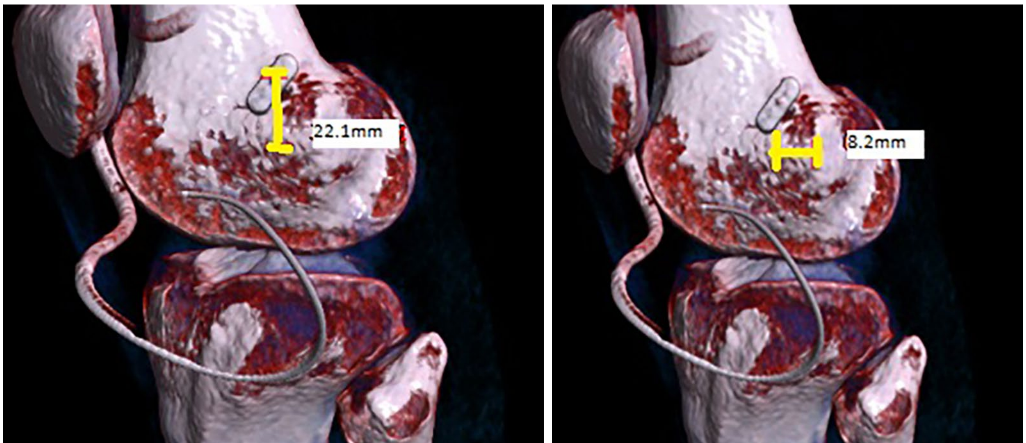

FIGURE 2. 3D CT reconstruction showing measurement of the superior distance and anterior distance of the femoral tunnel exit from the lateral epicondyle.
3D CT: Three-dimensional computed tomography.

points, IKDC-SKF: 0-97 points, CKRS: 0-30 points, TKS: 17-68 points, and RST: 0-120 points.

Surgical procedure

All patients were operated under spinal anesthesia with a tourniquet after standard sterilization of the extremity (Figure 1). Diagnostic arthroscopy was performed to confirm the ACL tear; meniscal repair or debridement was performed when necessary. The gracilis and semitendinosus tendons were identified via palpation over the pes anserinus fascia, and hamstring autografts were harvested. The tibial tunnel was positioned adjacent to the anterior horn of the lateral meniscus, approximately 7 mm anterior to the posterior cruciate ligament (PCL). The femoral footprint was debrided and marked based on the lateral intercondylar ridge.

In Group 1, the femoral tunnel was created through the anteromedial portal with the knee in 110° flexion. In Group 2, the same technique was applied in the Figure-4 position (Figure 7). A femoral tunnel with an average length of 35 mm was created. The previously marked and measured proximal portion of the graft was trimmed to approximately 25 mm in length to ensure that it would remain entirely within the femoral tunnel.

After both tunnels were prepared, the graft-suspension system was inserted into the

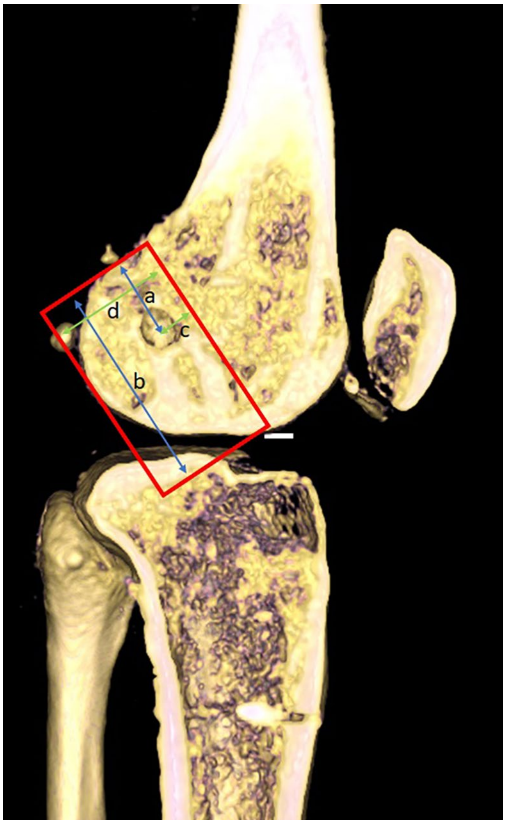

FIGURE 3. Measurement of femoral tunnel position using the Bernard-Hertel quadrant method. A rectangle was drawn on the lateral femoral condyle, with the superior border aligned with the Blumensaat line, the inferior border aligned with the distal end of the lateral condyle, and the anterior and posterior borders defined by the anterior and posterior cortical margins. The femoral tunnel exit point was mapped within this quadrant and its position was expressed as a percentage along the deep-shallow (anterior-posterior) and high-low (superior-inferior) axes.

FIGURE 4. Measurement of femoral tunnel length on 2D CT images. The linear distance between the tunnel's entry and exit points along the femoral cortex was calculated.
2D CT: Two-dimensional computed tomography.

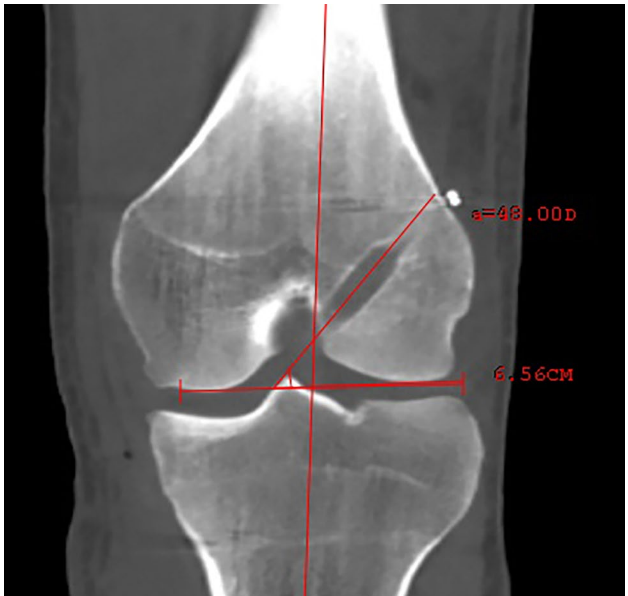

FIGURE 5. Measurement of the coronal tunnel angle. The angle between the femoral tunnel and the longitudinal axis of the femur in the coronal plane was recorded.

femoral tunnel using a looped suture, and the graft was pulled to secure the Endobutton™ (Acufex Microsurgical, Inc., MA, USA) on the lateral cortex. The graft was fixed in the tibial tunnel with an interference screw matching the tunnel diameter. Graft tension and joint mobility were evaluated arthroscopically. Stability tests were repeated, excessive graft material was trimmed, and the pes anserinus fascia was closed.

Drains were removed on postoperative Day 2. An angle-adjustable knee brace was used for six weeks, and mobilization was allowed under physiotherapist supervision with progressive range of motion exercises.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency,

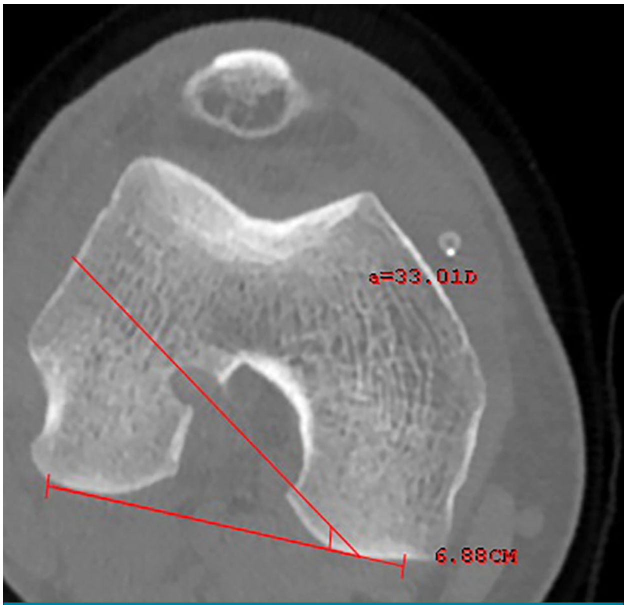

FIGURE 6. Measurement of the axial tunnel angle on axial CT images. The angle formed between the femoral tunnel and the posterior cortical surface in the axial plane was measured.
CT: Computed tomography.

where applicable. Normally distributed data were analyzed with parametric tests and compared using the Student t-test. Non-normally distributed data were analyzed using the non-parametric Kruskal-Wallis test. A p value of <0.05 was considered statistically significant.

RESULTS

The median height of the patients was 176 (range, 164 to 186) cm in Group 1 and 177 (range, 164 to 184) cm in Group 2, indicating no statistically significant difference between the groups (p=0.281). The median weight was 76 (range, 56 to 90) kg in Group 1 and 82 (range, 53 to 94) kg in Group 2, indicating a statistically significant difference (p=0.004) (Table I). There was no statistically significant difference between the two groups in terms of age, sex, or height (p>0.05).

Radiological analysis showed statistically significant differences between the two groups in terms of AD, SD, ATA, and FTP values (p=0.001, p=0.001, p=0.035, and p=0.001 (Table II). Statistically significant differences were observed between the two groups in terms of FTL, CTA, and FTP values (p-value range: 0.001-0.006) (Table II).

According to the functional scores, only the CKRS scores showed a statistically significant difference between the two groups (p=0.001). There was no significant difference between the groups in terms of LKS, TKS, IKDC-SKF, and RST scores (p=0.416, p=0.380, p=0.201, and p=0.793, respectively) (Table III).

There was no statistically significant difference between the two groups in terms of the Lachman test and Pivot shift test results in the follow-up examinations performed at 12 months postoperatively (p=0.903 and p=1.000, respectively).

DISCUSSION

In the present study, we compared FTP, radiological alignment, and clinical outcomes between the Figure-4 and 110° flexion positions during ACL reconstruction. To the best of our knowledge, this is the first study in the literature comparing the Figure-4 position with the standard 110° flexion position in terms of both radiological alignment

FIGURE 7. Guidewire targeting the femoral tunnel exit.

TABLE I
Demographic characteristics of the patients according to femoral tunnel drilling technique

	Group 1	Group 2	
Variables	Mean±SD	Mean±SD	*p*
Age (year)	28.6±6.2	29.7±5.9	0.771
Height (cm)	176.4±5.3	177.1±4.6	0.281
Weight (kg)	74.2±7.9	81.5±8.3	0.004

SD: Standard deviation. Statistical analysis was performed using independent samples t-tests. A significant difference between the two groups was observed only in body weight (p<0.05).

TABLE II
Radiological measurements of the femoral tunnel between the 110° flexion and Figure-4 groups

	Group 1	Group 2	
Measurement	Mean±SD	Mean±SD	*p*
AD (mm)	8.65±0.20	8.16±0.46	0.001
SD (mm)	22.23±1.23	24.78±1.53	0.001
ATA (°)	34.86±1.61	33.97±2.18	0.035
FTP (high-low %)	25.48±1.31	26.6±0.5	0.001
FTL (mm)	36.4±1.1	37.0±1.5	0.006
CTA (°)	39.6±1.4	43.4±2.2	0.001
FTP (grid %)	29.6±2.0	32.5±1.2	0.001

SD: Standard deviation; AD: Anterior distance from lateral epicondyle; SD: Superior distance from lateral epicondyle; ATA: Axial tunnel angle; FTP: Femoral tunnel position; FTL: Femoral tunnel length; CTA: Coronal tunnel angle. Statistical comparisons were performed using independent samples t-tests.

TABLE III
Comparison of postoperative functional scores at 12 months between the two groups

	Group 1	Group 2	
Measurement	Mean±SD	Mean±SD	*p*
LKS	93.2±3.4	94.1±4.3	0.416
CKRS	26.4±1.9	28.2±1.3	0.001
TKS	61.3±2.5	62.5±2.1	0.380
IKDC-SKF	90.5±4.1	89.4±6.2	0.201
RST	99.2±5.6	100.3±6.0	0.793

SD: Standard deviation; LKS: Lysholm Knee Score; CKRS: Cincinnati Knee Rating System; TKS: Tampa Kinesiophobia Scale; IKDC-SKF: International Knee Documentation Committee Subjective Knee Form; RST: Return to Sport test. Between-group differences were evaluated using t-tests.

and functional outcomes in ACL reconstruction. The main finding of the study was that the Figure-4 position allowed for a more anatomical femoral tunnel placement, as demonstrated by grid-based measurements on postoperative 3D CT. Furthermore, the Figure-4 group exhibited significantly longer tunnel lengths and improved Cincinnati scores, which may reflect better dynamic knee performance. These results suggest that the Figure-4 position can enhance surgical exposure and precision during tunnel creation, potentially leading to more stable graft fixation and superior clinical outcomes.

The radiological measurements of this study, comparing the 110-degree flexion and Figure-4 positions are compatible with the literature.[17,18] The most important factors affecting the success of ACLR are the proximity of the bone tunnels to the anatomical positions and the fixation stability.[19] It has been reported that 70 to 80% of technical errors in ACL reconstruction are incorrect tunnel placement.[20,21] Excessive anterior positioning can cause rotational laxity or graft compression, while a posteriorly placed femoral tunnel can lead to a fracture of the posterior femoral cortex and consequent failure of femoral graft fixation.[22,23]

The main goal of the previous studies in the literature evaluating the position of the femoral tunnel exit point on the grid drawn on the lateral femoral condyle is to avoid inappropriate femoral tunnel placement and to determine the optimal exit point.[24] The grid is formed by drawing a quadrant using anatomical markers such as the edge of the lateral condyle and the Blumensaat line.[25] In those studies, the ideal tunnel exit point was calculated by measuring the height, the lateral and SD and depth of the tunnel exit point according to the lines drawn in the quadrant method.[25-27] Kosy et al.[1] compared the degrees of 100° flexion and maximum flexion, and reported the femoral tunnel location to be deep-shallow 32.9±0.1%, and high-low 26.6±0.1%. Yahagi et al.[28] compared grid methods, and showed the femoral tunnel placement to be 42.1±5.8% deep-shallow%, and 42.6±4.8% high-low%. In a study of cadaveric knees, Lee et al.[29] reported the average ACL insertion position as 33.9% in the anteromedial deep-shallow position and 26.5% in the high-low position. Parkar et al.[30] examined 218 knees and reported the femoral localization center to be 29% in the deep-shallow direction and 35% in the high-low position. The weighted 5th and 95th percentiles were 24% and 37% for deep-shallow and 28% and 43% for high-low, respectively. In the current study, according to the conventional femoral tunnel grid method, the tunnel location was deep-shallow 29.6% (25-33), high-low 25.4±1.3% in Group 1, and deep-shallow 32.4% (30-33), high-low 26.5% in Group 2. Both groups were found to be compatible with the literature in the deep-shallow evaluation of the tunnel. In the high-low evaluation, the values in Group 2 being closer to the values in the literature was due to the better visibility in the lateral compartment due to the varus stress created in the Figure-4 position and, accordingly, the better adjustment of the drilling angle. Moreover, according to Bernard and Hertel's quadrant method, the ideal FTP is usually considered to be between 25 and 35% on the deep-shallow axis and 25 and 40% on the high-low axis.[26] These ranges are considered to reflect anatomical footprint placement, which is associated with optimal graft integration and biomechanical function. The values obtained in the current study were closely aligned with these ranges, and the Figure-4 group in particular showed greater consistency with the literature, supporting the conclusion that this technique may result in more precise anatomical tunnel placement.

There are various studies examining the FTL in the literature. In those studies, emphasis has been placed on ensuring sufficient contact between the tendon graft and the surrounding bone tunnel walls, as this interface plays a key role in biological integration and healing. Therefore, an adequate tunnel length is considered essential for successful graft fixation.[31] Hensler et al.[32] conducted a study examining the correlation between FTL and tunnel position and concluded that non-anatomical femoral tunnels were longer than tunnels created with reference to anatomical footprints. In the aforementioned study, the mean length of the tunnels fitted to the anatomical footprint was reported to be 31.0±6.3 mm. Basdekis et al.[33] observed that femoral tunnels created at 90° were significantly shorter than those created at 110°, 130°, and maximal flexion. In contrast, Bedi et al.[34] evaluated the effect of knee flexion angle on tunnel length and determined that tunnels created at higher flexion angles resulted in shorter tunnels. The parameters of knee flexion angle and tunnel position are probably not independent; both affect FTL, making it difficult to compare data from different studies of tunnel length. The anatomical position of the tunnel should usually precede concerns about tunnel length, as the literature has shown that anatomical tunnel position better restores physiological knee kinematics.[32] Although there is a common agreement that adequate bone-tendon contact within the tunnel is critical for proper graft integration and fixation, there is no consensus on the appropriate tunnel length for good biological fixation. In the current study, the median tunnel length was 36.4 (range, 34.8 to 38.2) mm in Group 1 and 37 (range, 32 to 39.4) mm in Group 2. Although there was a statistically significant difference in favor of Group 2 forming longer tunnels, both groups were found to be compatible with the literature. There was also seen to be consistency with the correlation between tunnel depth and tunnel length, as stated by Hensler et al.[32]

The CTA and ATA were other parameters examined in this study. It has been demonstrated in the literature that while the CTA can be measured on conventional radiographs, the ATA is typically assessed using three-dimensional imaging modalities. In a randomized 3D CT study by Kosy et al.,[1] in which the femoral tunnel was created in a hyperflexion position using a rigid reamer, the mean CTA was reported to be 42.8±5.3°, and the mean ATA to be 37.4±7.5°. No significant difference was found between the hyperflexion and 100° flexion groups. Muller et al.[35] reported a mean CTA of 42.0±7.2° in measurements performed using a rigid reamer. In a radiological study by Dong et al.[36] on 30 cadavers to evaluate the FTP, the median CTA was reported to be 48.53°. The current study results showed a median CTA of 39.6° (range, 36.40° to 42.00°) in Group 1, and 43.4° (range, 35.3° to 47.4°) in Group 2. The mean ATA was determined to be 34.8±1.6° in Group 1 and 33.9±2.1° in Group 2. According to these measurements, Group 2 showed higher CTA values, and the ATA values were higher in Group 1, with both differences at a statistically significant level. Although there is no consensus in the literature about these measurements, the values for both groups in the current study were consistent with the literature.

The measurement of the SD and AD of the exit point of the femoral tunnel to the lateral epicondyle, which can be measured using 3D CT, is another parameter evaluated in this study. Wang et al.[16] examined the position of the exit point of the femoral tunnel to the lateral epicondyle in ACLR, and found that the femoral tunnel was posterior to the lateral epicondyle in all knees in 90° flexion, and anterior to the lateral epicondyle in 110°, 120°, and 130° flexion. In a randomized 3D-CT study by Kosy et al.[1] examining ACLR tunnel formation, the mean AD of the femoral tunnel exit point to the lateral epicondyle with the knee in hyperflexion was 10.4±5.6 mm, and the SD was 19.8±4.4 mm. In another cadaver study examining the position of the femoral tunnel with the anteromedial technique in ACLR by Dong et al.,[36] the mean tunnel exit point at 110° flexion was determined to be 3.4±1.4 mm proximal to the femoral lateral epicondyle and 4.3±1.3 mm anterior. Although there are no consistent numerical data about the distance from the exit point of the femoral tunnel to the lateral epicondyle, it has been emphasized in the literature that the lateral epicondyle should be anterior and superior.[37] In the current study, the mean SD of the tunnel exit to the lateral epicondyle was measured as 22.2±1.2 mm in Group 1 and 24.7±1.5 mm in Group 2. The mean AD of the tunnel exit to the lateral epicondyle was measured as 8.1±0.4 mm in Group 1 and 8.6±0.1 mm in Group 2, indicating a statistically significant difference found in favor of Group 1. The requirement for the tunnel exit to be anterior and superior to the lateral epicondyle, which is emphasized in the literature, was found to be consistent in both groups. Nevertheless, although this statistically significant difference in AD favors Group 1, it should be interpreted with caution. The current literature does not define precise thresholds for clinically optimal AD or SD; therefore, while there was seen to be a statistically significant difference, both groups can still be considered to have achieved anatomically acceptable tunnel placements.

Functional evaluation following ACLR is a critical component in assessing postoperative success. In the current study, both the Lysholm and Cincinnati scoring systems were administered at the one-year postoperative follow-up. These tools are commonly used in clinical practice, with reported utilization rates of 67% and 33%, respectively. Although both scales assess similar parameters, a statistically significant difference was observed only in the Cincinnati score, which was higher in the Figure-4 position group. Unlike the Lysholm scale, the Cincinnati scoring system includes dynamic activities such as single-leg hopping and deep squatting, which may better reflect proprioceptive control and dynamic stability of the knee. Therefore, the more anatomical placement of the femoral tunnel achieved in the Figure-4 position may have contributed to improved performance in these areas. However, no significant differences were found between the groups in respect of the Lysholm, IKDC-SKF, Tampa kinesiophobia, or return-to-sport scores. These findings suggest that, while both positions offer comparable overall functional outcomes, the Figure-4 position may provide additional benefits in aspects related to dynamic knee performance.

Establishing and maintaining knee flexion in the axial plane during ACL reconstruction can be challenging. The lower part of the standard operating table typically inhibits knee flexion beyond 100º. It has often been shown in the literature that femoral tunneling should be made in at least 110° of flexion. Therefore, many surgeons are troubled by the technical difficulty associated with anteromedial portal drilling and the required knee flexion. The Figure-4 position is used to gain access to the lateral compartment of the knee in routine knee arthroscopy. George[14] advocated that the Figure-4 position is a standard knee arthroscopy position that most surgeons are comfortable with, which can be used to easily achieve the necessary hyperflexion to create a femoral tunnel through the anteromedial portal. This position is easy to achieve and has high reproducibility. Hyperflexion of the knee up to 130 to 140º can be easily achieved in the Figure-4 position. In addition to the practicality of the Figure-4 position provided to the surgeon, there are also benefits in terms of arthroscopic view. Unlike standard flexion positions, it facilitates access to the lateral compartment due to the 30° external rotation created in the femur and the varus stress created in the knee. It is thought that cartilage damage, which is one of the disadvantages of the anteromedial portal method, would occur less due to the increased mobility in the lateral compartment. In the current study, the femoral tunnels created using the Figure-4 position were found to be compatible with both the tunnels created at 110° of flexion and with previous literature findings. Considering the technical convenience provided, creating the femoral tunnel in the Figure-4 position during ACLR surgery can be recommended. With the more anatomical tunnel placement, increased surgical field visibility, and longer tunnel length achieved in the Figure-4 group, it can be considered that this technique may contribute to more stable graft fixation and better functional outcomes in ACLR surgery.

Nevertheless, there are some limitations to this study including its single-center, retrospective design, the relatively small number of patients in each group, the lack of randomization, and the lack of long-term follow-up data. Moreover, the postoperative rehabilitation protocols were not identical across all patients, and concomitant intra-articular pathologies, such as meniscal lesions which might affect functional outcomes, could not be completely excluded. Despite these limitations, this study can be considered to make a valuable contribution by providing a unique comparison of radiological and functional outcomes, thereby addressing a notable gap in the existing literature.

In conclusion, this study is the first in the literature comparing directly the Figure-4 position with the 110° flexion position in terms of both radiological alignment and functional outcomes. These findings demonstrate that the Figure-4 position allows for more anatomical femoral tunnel placement, facilitates the creation of longer tunnels, and results in superior Cincinnati scores. These advantages are considered to stem from improved surgical access and visualization of the lateral compartment provided by the Figure-4 position. In addition, although a statistically significant difference was observed only in the CKRS score, the long-term clinical relevance of this finding remains unclear and warrants further investigation. The inclusion of the CKRS, which is not commonly reported in similar studies, represents a distinctive aspect of this study. Further large-scale, prospective, randomized studies are needed to confirm these findings.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept: F.E.T., N.H.A.; Design: F.E.T., E.G., N.H.A.; Control/supervision: N.H.A.; Data collection and/or processing: F.E.T., C.Y.K., F.İ.C., H.T., Ç.G.; Analysis and/or interpretation, literature review, writing the article: E.G., F.E.T.; Critical review: N.H.A.

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REFERENCES

1. Kosy JD, Walmsley K, Anaspure R, Schranz PJ, Mandalia VI. Flexible reamers create comparable anterior cruciate ligament reconstruction femoral tunnels without the hyperflexion required with rigid reamers: 3D-CT analysis of tunnel morphology in a randomised clinical trial. Knee Surg Sports Traumatol Arthrosc 2020;28:1971-8. doi: 10.1007/s00167-019-05709-7.
2. Martinez-Calderon J, Infante-Cano M, Matias-Soto J, Perez-Cabezas V, Galan-Mercant A, Garcia-Muñoz C. The incidence of sport-related anterior cruciate ligament injuries: An overview of systematic reviews including 51 meta-analyses. J Funct Morphol Kinesiol 2025;10:174. doi: 10.3390/jfmk10020174.
3. Ponkilainen V, Kuitunen I, Liukkonen R, Vaajala M, Reito A, Uimonen M. The incidence of musculoskeletal injuries: a systematic review and meta-analysis. Bone Joint Res 2022;11:814-825. doi: 10.1302/2046-3758.1111.BJR-2022-0181.R1.
4. Zimmerer A, Schneider MM, Semann C, Schopf W, Sobau C, Ellermann A. 17-Year results following transepiphyseal anterior cruciate ligament reconstruction in children and adolescents. Z Orthop Unfall 2022;160:393-9. doi: 10.1055/a-1352-5541.
5. Jin H, Tahir N, Jiang S, Mikhail H, Pavel V, Rahmati M, et al. Management of anterior cruciate ligament injuries in children and adolescents: A systematic review. Sports Med Open 2025;11:40. doi: 10.1186/s40798-025-00844-7.
6. Harris JD, Abrams GD, Bach BR, Williams D, Heidloff D, Bush-Joseph CA, et al. Return to sport after ACL reconstruction. Orthopedics 2014;37:e103-8. doi: 10.3928/01477447-20140124-10. PMID: 24679194.
7. Atik OŞ. The risk factors for second Anterior Cruciate Ligament (ACL) tear after ACL reconstruction. Jt Dis Relat Surg 2024;35:255-6. doi: 10.52312/jdrs.2024.57920.
8. Acevedo RJ, Rivera-Vega A, Miranda G, Micheo W. Anterior cruciate ligament injury: identification of risk factors and prevention strategies. Curr Sports Med Rep 2014;13:186-91. doi: 10.1249/JSR.0000000000000053. PMID: 24819011.
9. Jindal I, Thakur K, Singh CM, Sood C, Mahajan S, Agrawal M. Inching closer to native anatomy: A CT scan based morphometric analysis of tunnels in all-inside ACL reconstruction. J Clin Orthop Trauma 2025;68:103072. doi: 10.1016/j.jcot.2025.103072.
10. Lu VYZ, Lee DHY, Tsui SHY, Lo TCH, Chau WW, Kumar A, et ak. Risk factors for ACL revision failure and optimum graft size for revision anterior cruciate ligament reconstruction. Eur J Orthop Surg Traumatol 2025;35:260. doi: 10.1007/s00590-025-04381-7.
11. Utoyo GA, Hidayat YM, Rahim AH, Usman HA, Dirgantara T, Adachi N, et al. Arthroscopic repair for acute anterior cruciate ligament rupture results in higher failure rates and greater residual knee laxity compared to reconstruction if performed more than 3 weeks after injury: A systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2025 Jun 5. doi: 10.1002/ksa.12715.
12. Lin W, Chen X, Li D, He W, Lyu J. Anatomical features and tibial tunnel placement: Influence on graft maturity at a 2-year follow-up after anterior cruciate ligament reconstruction. Acta Radiol 2025;66:902-7. doi: 10.1177/02841851251331922.
13. Kose A, Ayas MS, Turgut MC, Altay ON. Investigation of the importance of knee position during femoral tunnel reaming; Figure 4 versus hyperflexion. Malays Orthop J 2022;16:102-9. doi: 10.5704/MOJ.2207.013.
14. George MS. Femoral tunnel drilling from the anteromedial portal using the figure-4 position in ACL reconstruction. Orthopedics 2012;35:674-7. doi: 10.3928/01477447-20120725-03.
15. Kim SH, Kim SJ, Choi CH, Kim D, Jung M. Optimal condition to create femoral tunnel considering combined influence of knee flexion and transverse drill angle in anatomical single-bundle acl reconstruction using medial portal technique: 3D simulation study. Biomed Res Int 2018;2018:2643247. doi: 10.1155/2018/2643247.
16. Wang H, Wang J, Han X, Wang W. Best knee flexion angle through anteromedial portal during anterior cruciate ligament reconstruction. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2014;28:571-5.
17. Song JH, Lee SS, Lee DH. Reliability of measuring femoral tunnel aperture location after anterior cruciate ligament reconstruction: Quadrant method versus anatomical coordinate axes method. Knee 2025;56:22-8. doi: 10.1016/j.knee.2025.05.007.

18. Yin L, Liao D, Xie Q, Liu J, Deng B. Characteristics of the femoral tunnel of anatomical and isometric single bundle anterior cruciate ligament reconstruction: A modeling analysis based on quadrant method and anatomical landmarks. J Orthop Surg Res 2024;19:822. doi: 10.1186/s13018-024-05306-6.
19. Bedi A, Musahl V, Steuber V, Kendoff D, Choi D, Allen AA, et al. Transtibial versus anteromedial portal reaming in anterior cruciate ligament reconstruction: An anatomic and biomechanical evaluation of surgical technique. Arthroscopy 2011;27:380-90. doi: 10.1016/j.arthro.2010.07.018.
20. Rayan F, Nanjayan SK, Quah C, Ramoutar D, Konan S, Haddad FS. Review of evolution of tunnel position in anterior cruciate ligament reconstruction. World J Orthop 2015;6:252-62. doi: 10.5312/wjo.v6.i2.252.
21. Ilahi OA, Mansfield DJ, Urrea LH 2nd, Qadeer AA. Reliability and reproducibility of several methods of arthroscopic assessment of femoral tunnel position during anterior cruciate ligament reconstruction. Arthroscopy 2014;30:1303-10. doi: 10.1016/j.arthro.2014.05.034.
22. Giron F, Losco M, Giannini L, Buzzi R. Femoral tunnel in revision anterior cruciate ligament reconstruction. Joints 2014;1:126-9.
23. Westermann RW, Wolf BR, Elkins J. Optimizing graft placement in anterior cruciate ligament reconstruction: A finite element analysis. J Knee Surg 2017;30:97-106. doi: 10.1055/s-0036-1581137.
24. Li J, Yang J, Xu Z, Wang W. Comparison of the quadrant method measuring four points and bernard method in femoral tunnel position evaluation on 3-dimensional reconstructed computed tomography after anatomical single-bundle anterior cruciate ligament reconstruction. BMC Musculoskelet Disord 2024;25:558. doi: 10.1186/s12891-024-07678-6.
25. Masuda T, Kondo E, Onodera J, Kitamura N, Inoue M, Nakamura E, et al. Effects of remnant tissue preservation on tunnel enlargement after anatomic double-bundle anterior cruciate ligament reconstruction using the hamstring tendon. Orthop J Sports Med 2018;6:2325967118811293. doi: 10.1177/2325967118811293.
26. Bernard M, Hertel P, Hornung H, Cierpinski T. Femoral insertion of the ACL. Radiographic quadrant method. Am J Knee Surg 1997;10:14-21.
27. Morita K, Kobashi S, Kashiwa K, Nakayama H, Kambara S, Morimoto Computer-aided surgical planning of anterior cruciate ligament reconstruction in MR images. Proce. Comput. Sci 2015;60:1659-67.
28. Yahagi Y, Iriuchishima T, Horaguchi T, Suruga M, Tokuhashi Y, Aizawa S. The importance of Blumensaat's line morphology for accurate femoral ACL footprint evaluation using the quadrant method. Knee Surg Sports Traumatol Arthrosc 2018;26:455-61. doi: 10.1007/s00167-017-4501-2.
29. Lee JK, Lee S, Seong SC, Lee MC. Anatomy of the anterior cruciate ligament insertion sites: comparison of plain radiography and three-dimensional computed tomographic imaging to anatomic dissection. Knee Surg Sports Traumatol Arthrosc 2015;23:2297-305. doi: 10.1007/s00167-014-3041-2.
30. Parkar AP, Adriaensen MEAPM, Vindfeld S, Solheim E. The anatomic centers of the femoral and tibial insertions of the anterior cruciate ligament: A systematic review of imaging and cadaveric studies reporting normal center locations. Am J Sports Med 2017;45:2180-8. doi: 10.1177/0363546516673984.
31. Wein F, Osemont B, Goetzmann T, Jacquot A, Valluy J, Saffarini M, et al. Anteversion and length of the femoral tunnel in ACL reconstruction: In-vivo comparison between rigid and flexible instrumentation. J Exp Orthop 2019;6:26. doi: 10.1186/s40634-019-0198-0.
32. Hensler D, Working ZM, Illingworth KD, Tashman S, Fu FH. Correlation between femoral tunnel length and tunnel position in ACL reconstruction. J Bone Joint Surg Am 2013;95:2029-34. doi: 10.2106/JBJS.L.01315.
33. Basdekis G, Abisafi C, Christel P. Influence of knee flexion angle on femoral tunnel characteristics when drilled through the anteromedial portal during anterior cruciate ligament reconstruction. Arthroscopy 2008;24:459-64. doi: 10.1016/j.arthro.2007.10.012.
34. Bedi A, Raphael B, Maderazo A, Pavlov H, Williams RJ 3rd. Transtibial versus anteromedial portal drilling for anterior cruciate ligament reconstruction: A cadaveric study of femoral tunnel length and obliquity. Arthroscopy 2010;26:342-50. doi: 10.1016/j.arthro.2009.12.006.
35. Muller B, Hofbauer M, Atte A, van Dijk CN, Fu FH. Does flexible tunnel drilling affect the femoral tunnel angle measurement after anterior cruciate ligament reconstruction? Knee Surg Sports Traumatol Arthrosc 2015;23:3482-6. doi: 10.1007/s00167-014-3181-4.
36. Dong YL, Cai CY, Jiang GY, Qian YN, Yang GJ. Femoral tunnel positioning using an anteromedial technique for ACL reconstruction: A radiographic study with a cadaveric model. Technol Health Care 2017;25:729-37. doi: 10.3233/THC-160414.
37. Sharafatvaziri A, Tahami M, Salimi M, Rabie H, Vosoughi F, Karimpour M, et al. Radiographic acceptable zone of endobutton placement in ACL reconstruction: A prospective study. J Exp Orthop 2024;11:e70082. doi: 10.1002/jeo2.70082.