

Radiologic assessment of femoral and tibial tunnel placement based on anatomic landmarks in arthroscopic single bundle anterior cruciate ligament reconstruction

Sandeep Kumar Nema, Gopisankar Balaji, Sujiv Akkilagunta¹, Jagdish Menon, Murali Poduval, Dilip Patro

ABSTRACT

Background: Accurate tibial and femoral tunnel placement has a significant effect on outcomes after anterior cruciate ligament reconstruction (ACLR). Postoperative radiographs provide a reliable and valid way for the assessment of anatomical tunnel placement after ACLR. The aim of this study was to examine the radiographic location of tibial and femoral tunnels in patients who underwent arthroscopic ACLR using anatomic landmarks. Patients who underwent arthroscopic ACLR from January 2014 to March 2016 were included in this retrospective cohort study.

Materials and Methods: 45 patients who underwent arthroscopic ACLR, postoperative radiographs were studied. Femoral and tibial tunnel positions on sagittal and coronal radiographic views, graft impingement, and femoral roof angle were measured. Radiological parameters were summarized as mean \pm standard deviation and proportions as applicable. Interobserver agreement was measured using intraclass correlation coefficient.

Results: The position of the tibial tunnel was found to be at an average of $35.1\% \pm 7.4\%$ posterior from the anterior edge of the tibia. The femoral tunnel was found at an average of $30\% \pm 1\%$ anterior to the posterior femoral cortex along the Blumensaat's line. Radiographic impingement was found in 34% of the patients. The roof angle averaged $34.3^\circ \pm 4.3^\circ$. The position of the tibial tunnel was found at an average of $44.16\% \pm 3.98\%$ from the medial edge of the tibial plateau. The coronal tibial tunnel angle averaged $67.5^\circ \pm 8.9^\circ$. The coronal angle of the femoral tunnel averaged $41.9^\circ \pm 8.5^\circ$.

Conclusions: The femoral and tibial tunnel placements correlated well with anatomic landmarks except for radiographic impingement which was present in 34% of the patients.

Key words: Arthroscopy, anterior cruciate ligament, single bundle, tunnel, femur, tibia, radiography

MeSH terms: Arthroscopic surgical procedure, ACL reconstruction, arthroscopy, knee, tibia, femur, radiography

INTRODUCTION

Anterior cruciate ligament reconstructions (ACLRs) fail at a small but not at an insignificant rate. Despite advances, failure rate after ACLR ranges from 0.7% to 10%.¹ Graft location, and therefore tibial

and femoral tunnel placement, is considered critical for the success of anterior cruciate ligament (ACL) reconstructive surgery.¹ Postoperative plain radiographs provide a reliable and valid way to assess anatomic graft placement.² Radiographs can assist in predicting risk factors for potential graft failure and poor outcome. These risk factors include inappropriate tunnel placement, excessive varus or valgus alignment, and increased extension or hyperextension with possible graft impingement.³ An audit study revealed inappropriate placement of femoral

Departments of Orthopedics and ¹Preventive and Social Medicine, Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry, India

Address for correspondence: Dr. Sandeep Kumar Nema, Department of Orthopedics, PMRC Block, Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry - 605 006, India. E-mail: drsandeepnema@gmail.com

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and tibial tunnels in 65% and 59% cases, respectively, on sagittal plane radiographic views.⁴

This study examined the radiographic location of tibial and femoral tunnels in a retrospective cohort of patients who underwent endoscopic anatomic ACLR using arthroscopic anatomic landmarks.

MATERIALS AND METHODS

This retrospective cohort study was conducted from January 2014 to March 2016, and records of patients who underwent ACLR were collected from the hospital database. Seventy nine patients were operated during the study period. We searched the postoperative radiographs of these patients in the hospital database. Our hospital uses the picture archiving and communication system (PACS) (General Electric Healthcare Centricity version 12 Chicago, Illinois, United States). We could retrieve postoperative radiographs of 65 patients from PACS. Postoperative full-extension anteroposterior and lateral radiographs of the knee were included in the study. Radiographs with poor quality (inappropriate penetration), extreme obliquity for laterals (more than 5 mm lack of femoral condyle overlap), or inappropriately angled were excluded from the study. Postoperative radiographs of 45 patients which met the inclusion and exclusion criteria were included for measurements. Aperture fixation using titanium screws was used for all the cases included. The position of femoral and tibial tunnels on the postoperative radiographs was independently assessed by two of the readers.

The parameters measured were as follows:

Anteroposterior radiograph (coronal measurements)

1. The coronal position of the tibial tunnel was determined by dividing the distance from the medial border of the tibial plateau to the midpoint of the tibial tunnel (ab) by the distance from the medial border to the lateral border of the plateau (AB) and expressing it as a percentage. The midpoint of the tibial tunnel in anteroposterior view was determined at the aperture of the tunnel by measuring the positions of the medial and lateral borders of the tibial tunnel relative to the medial border of the tibial plateau [Figure 1]
2. The coronal angle (α) was determined by the angle formed by a line drawn parallel to the tibial tunnel (C) and another line along the tibial plateau (AB) [Figure 2]
3. The coronal angle (obliquity) of the femoral tunnel (β) was determined by drawing a line parallel to the femoral tunnel (F) and another line tangent to distal femoral condyles at the level of knee joint (T) and measuring the angle between them [Figure 2].

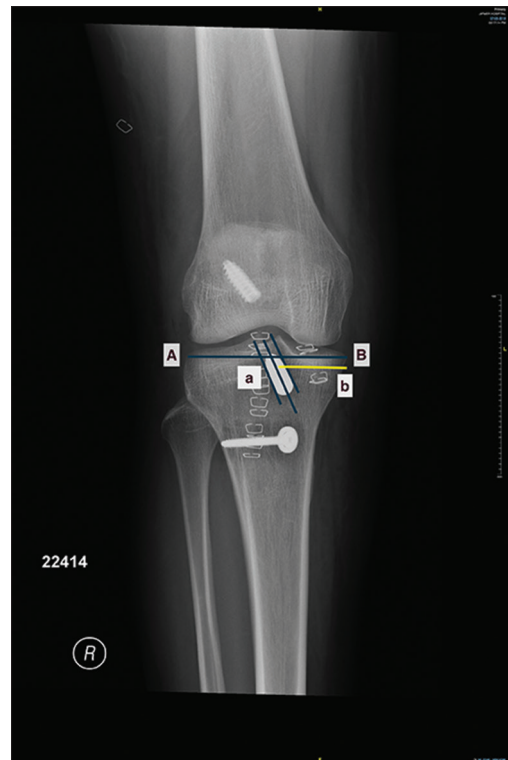


Figure 1: X-ray of knee joint with distal thigh and proximal leg anteroposterior view showing illustration of the method to measure the distance of center of tibial tunnel from medial edge of tibia (yellow line ab) on anteroposterior radiograph. Black line AB is the distance from the medial border to the lateral border of the tibial plateau

Lateral radiograph (sagittal measurements)

1. Sagittal tibial tunnel position on the lateral radiograph was obtained at the aperture of the tunnel by dividing the distance from the center of the tibial tunnel to the anterior edge of the tibia (cd) and dividing it by the distance from the anterior edge to the posterior edge of the tibial plateau (CD) and expressing it as a percentage. The midpoint of the tibial tunnel in the lateral view was determined by measuring positions of the anterior and posterior borders of the tibial tunnel relative to the anterior edge of the plateau [Figure 3]
2. Impingement of the graft was measured as the percentage of the tibial tunnel that was anterior to Blumensaat's line extended on a full-extension lateral X-ray [Figure 4]
3. The femoral roof angle was measured by the angle subtended by a line drawn along the posterior femoral cortex and a line drawn along Blumensaat's line [Figure 5]
4. The position of the femoral tunnel on the lateral radiograph was measured along the Blumensaat's line (B) from the posterior cortex. The length of Blumensaat's line was measured, and the points of intersection between it and the anterior and posterior borders of the femoral tunnel were identified. Based on these measurements, the

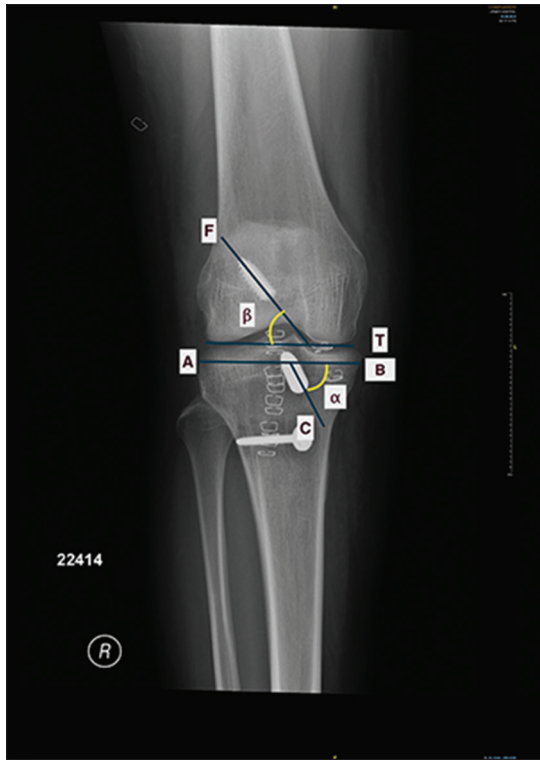


Figure 2: X-ray of knee joint with distal thigh and proximal leg bones showing illustration of method to measure tibial tunnel coronal angle (α) and femoral tunnel inclination (β)

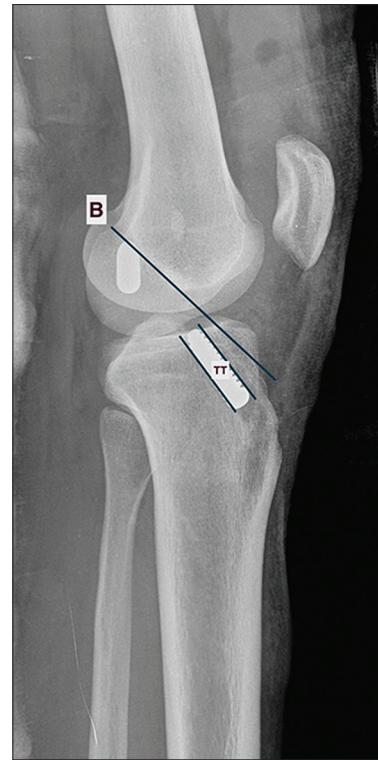


Figure 4: X-ray of knee joint with proximal leg and distal thigh showing illustration of method to measure graft impingement on lateral radiograph. B represents the Blumensaat's line extended and TT represents the tibial tunnel

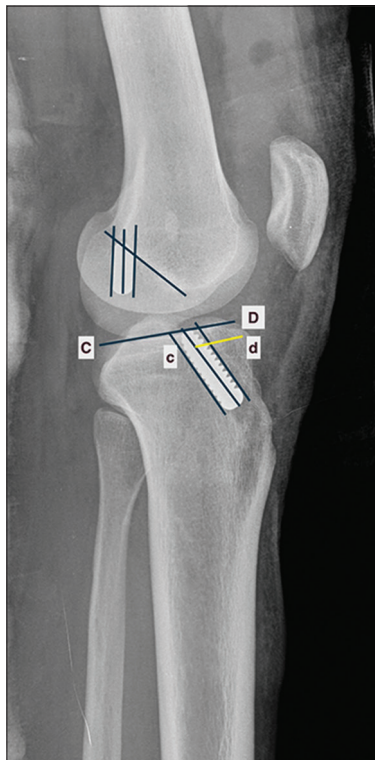


Figure 3: X-ray of knee joint with proximal leg and distal thigh lateral view showing illustration of the method to measure the distance of center of tibial tunnel from the anterior edge of the tibia (yellow line cd) on lateral radiograph. Black line CD is the distance from the anterior border to the posterior border of the tibial plateau

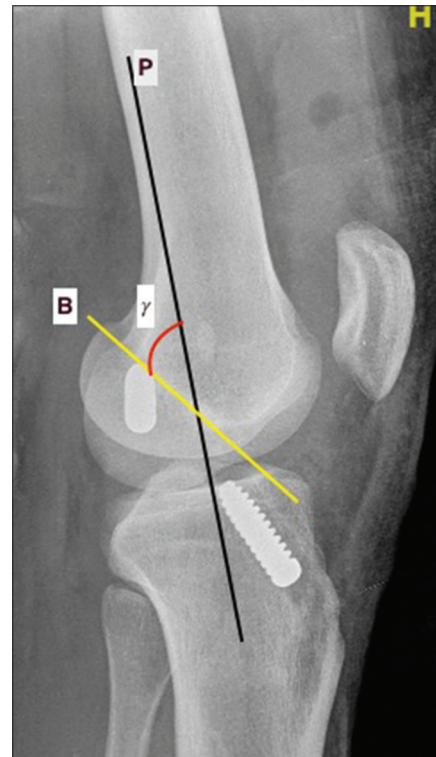


Figure 5: X-ray of knee joint with proximal leg and distal thigh showing illustration of method to measure the femoral roof angle (γ) on lateral radiograph. Black line P represents a line parallel to the posterior cortex of femur. Yellow line B represents the Blumensaat's line

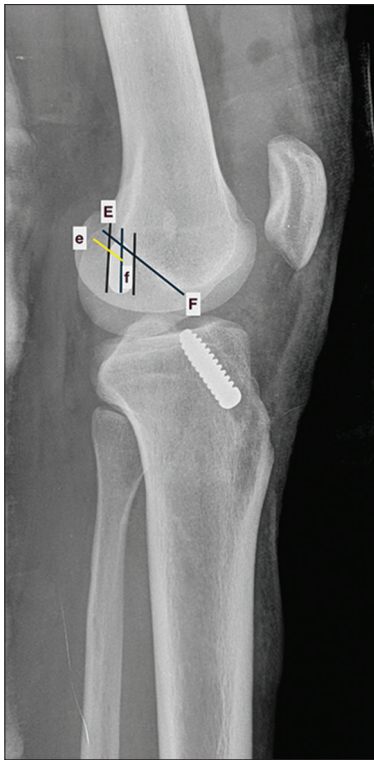


Figure 6: X-ray of knee joint lateral view with distal thigh and proximal leg showing illustration of method to measure the position of femoral tunnel on the lateral radiograph. Black line EF represents the Blumensaat's line. Yellow line ef represents the distance from posterior cortex of the lateral femoral condyle to the center of the femoral tunnel

position of the center of the femoral tunnel was calculated and then expressed as a percentage of the total length of Blumensaat's line [Figure 6].

The interobserver agreement for continuous variables was assessed by measuring the intraclass correlation coefficient (ICC). ICC is a statistical measure used to find the interobserver agreement for quantitative data. In our study, ICC was measured using two way random effects model since there were two readers. ICC above 0.7 was considered strong agreement. Interobserver agreement was obtained for the two readers, and intraobserver reliability was achieved by having the readers repeat measurements more than 4 weeks following the initial measurements.

RESULTS

A total of 45 radiographs were included in the study. The distribution of radiological parameters in the study done is presented in Table 1. Nearly 22% of the patients were operated between 0 and 6 months, 36% between 6 and 12 months, and 42% more than 12 months after injury.

Anteroposterior radiograph (coronal measurements)

The position of the tibial tunnel was found at an average of 44.16% ± 3.98% from the medial edge of the tibial

Table 1: Distribution of radiological parameters in the study

Parameter	Mean±SD	Category	n (%)
Position of the tibial tunnel on sagittal radiograph from anterior edge of tibia (%), n=45	35.17±7.41	0-10	0
		11-20	4
		21-30	20
		31-40	60
		41-50	9
Position of the femoral tunnel on sagittal radiograph along the Blumensaat's line (%), n=43	30.59±10.77	51-60	6
		0-25	40
		26-50	53
		51-75	7
Impingement of the graft on sagittal radiograph (%), n=45	34	76-100	0
		0	66
		1-25	2
		26-50	22
		51-75	7
Angle of the tibial tunnel on coronal radiograph (°), n=44	67.56±8.9	76-100	3
		≤59	16
		60-64	17
		65-69	16
		70-74	31
Position of the tibial tunnel on coronal radiograph (%), n=43	44.16±3.98	75-79	9
		80-84	11
		85-89	0
		35-40	14
		41-45	53
Obliquity of the femoral tunnel on coronal radiograph (°), n=43	41.97±8.58	46-50	21
		>50	12
		≤35	12
		36-40	14
		41-45	21
Femoral roof angle on sagittal radiograph (°), n=43	34.30±4.39	46-50>50	20
		33	33
		≤30	14
		31-35	61
		36-40	24
		>40	1

SD=Standard deviation

plateau. The angle of the tibial tunnel was demonstrated at an average of 67.56° ± 8.9°. The angle of the tibial tunnel was <75° in 80% of cases. Obliquity of the femoral tunnel was found at an average of 41.97° ± 8.58°.

Lateral radiograph (sagittal measurements)

The position of the tibial tunnel on sagittal radiograph was found at an average of 35.17% ± 7.41% posterior from the anterior edge of the tibia. In 94% of the cases, the tibial tunnel was demonstrated to be <50% posterior from the anterior edge of the tibial plateau. The average position of the femoral tunnel was found to be 30.59% ± 10.77% anterior to the posterior femoral cortex along the Blumensaat's line. The position of the femoral tunnel was <50% anterior along the Blumensaat's line from the posterior femoral cortex in 93% of the cases. Almost 34% of the cases showed graft impingement. Impingement was 1%–25% in 2%, 26%–50% in 22%, 51%–75% in 7%, and

Table 2: Interobserver agreement for the radiological parameters in the study

Radiological parameter	ICC	95% CI
Position of the tibial tunnel on sagittal radiograph (%)	0.95	0.91-0.97
Position of the tibial tunnel on sagittal radiograph (mm)	0.96	0.92-0.98
Coronal position of the tibial tunnel (%)	0.82	0.66-0.90
Angle of the tibial tunnel on coronal radiograph (°)	0.83	0.68-0.91
Angle of the tibial tunnel on sagittal radiograph (°)	0.95	0.90-0.97
Impingement of the graft on sagittal radiograph (%)	0.96	0.92-0.98
Femoral tunnel position on sagittal radiograph along the Blumensaat's line (%)	0.71	0.45-0.85
Femoral roof angle on sagittal radiograph (°)	0.83	0.68-0.91
Obliquity of the femoral tunnel on coronal radiograph (°)	0.85	0.72-0.92

ICC=Intraclass correlation coefficient, CI=Confidence interval

76%–100% in 3% of cases. The average femoral roof angle was found to be $34.30^\circ \pm 4.39^\circ$.

ICCs were obtained from the readings of two readers [Table 2]. These demonstrated consistently high ICCs for the two readers for the measurements with all of them higher than 0.7.

DISCUSSION

The goal of ACLR surgery is to provide an isometric, anatomic, impingement-free graft for the torn ligament. Recently, the Multicenter ACL Revision Study (MARS) showed some degree of technical error either in isolation or combination with trauma and/or biological issues as the major cause of failure after ACLR.¹ In the patients who were felt to have technical problems contributing to their failure, 80% believed to have femoral tunnel malposition. Various studies have described arthroscopic and anatomic landmarks for successful placement of tibial and femoral tunnels for ACLR.^{5,6} We placed femoral tunnel slightly posterior to the center of the native footprint so that the tunnel will have 3 mm of intact posterior wall and about 3 mm superior to the articular cartilage. In the absence of the native foot print, the femoral tunnel was placed inferior to lateral intercondylar ridge and slightly posterior to the bifurcate ridge. The tibial tunnel was placed 7 mm anterior to the posterior cruciate ligament (PCL) and slightly medial and posterior to the inner edge of lateral meniscus. Studies have investigated the relationship between arthroscopic anatomic landmarks and postoperative radiological and functional outcomes.^{7,8}

We placed femoral tunnels at an average of $30.59\% \pm 10.77\%$ anterior from the posterior femoral cortex along the Blumensaat's line. Studies have recommended placing the femoral tunnel at least 60% to 86% posterior along the Blumensaat's line.^{7,9} A positive correlation has been demonstrated between functional outcomes and posterior femoral tunnel placement on lateral radiographs.⁷

The angle of tibial tunnel placement in coronal plane is critical to avoid posterior cruciate ligament impingement and loss of flexion postoperatively. The angle of the tibial tunnel in coronal plane in our study was $<75^\circ$ in 80% of the patients. Howell *et al.* reported a coronal plane angle $>75^\circ$ which was associated with loss of flexion and increased laxity.¹⁰ Pinczewski *et al.* placed location of the tibial tunnel in the coronal plane in their study at a mean of 46% (standard deviation 3) lateral to the medial border of the medial tibial plateau.⁷ The location of tibial tunnel in our study was at a mean of $44.1\% \pm 3.9\%$ lateral to the medial border of the medial tibial plateau.

Anterior graft impingement has been evaluated previously and found to be associated with increased effusions, lack of extension, and increased failure rates.^{10,11} Studies have recommended placement of tibial tunnel $\leq 50\%$ (37%–47%) posteriorly along the length of the anterior tibial plateau in the 22–28 mm impingement-free zone to avoid impingement.^{7,10,11} Radiographic findings in revision ACLRs from the MARS cohort found variability in the tibial tunnel placement.⁹ We did not quantitate the distance of tibial tunnel center in millimeters in this study, but the tibial tunnel was placed at an average distance of $35.17\% \pm 7.41\%$ posterior from the anterior edge of tibia along the tibial plateau. We could not compare radiographic and clinical impingement perioperatively because of retrospective nature of the study, but we found that despite placement of the tibial tunnel using anatomic landmarks, radiographic impingement ranging from 1% to 100% was found in 34% of the patients. Sudhahar *et al.* have demonstrated that the surgeon's ability to predict the femoral tunnel location is reasonable, but less so for tibial tunnel position.¹²

The graft inclination should be measured on a 45° posteroanterior weightbearing view (Rosenberg view) of the knee. We measured inclination of the graft indirectly by measuring obliquity of the femoral tunnel on coronal radiograph because of retrospective nature of the study. The average angle of the femoral tunnel on coronal radiographs in our study was 41° . The femoral tunnel placement in our study was through an accessory anteromedial portal instead of the trans-tibial technique where femoral tunnel placement is directed by the tibial tunnel. Coronal obliquity of graft is one of the most crucial factors for rotational stability of the knee. A femoral tunnel placed obliquely is more efficient in resisting rotatory loads when compared with a vertical tunnel close to the roof of the intercondylar notch.^{13,14} The reconstructed ACL can be closer to the native ACL by the creation of a more horizontal femoral tunnel.

The limitations of the study are that the cohort was retrospective. Poor technique or inadequate X-rays may preclude accurate measurements. Though correlation

of functional outcomes and laxity measurements with radiological parameters would have been ideal, we were unable to do so because of the retrospective nature of the study.

To conclude, femoral and tibial tunnel placements correlated well with anatomic landmarks except for impingement which was present in 34% of patients radiologically.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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