Original Research Article

Assessment of femoral tunnel after arthroscopic anterior cruciate ligament reconstruction

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Abstract

Background: The knee joint is the most commonly injured of all joints and the anterior cruciate ligament (ACL) is the most commonly injured ligament. Anatomical graft placement is one of the major challenges in ACL reconstruction. Three-dimensional (3D) reconstruction of computed tomography (CT) images is currently the best method to determine whether the ACL tunnel and graft is positioned correctly. This study was done to calculate parameters of femoral tunnel in terms of femoral tunnel diameter, femoral tunnel length, femoral tunnel position based on Bernard and Hertel grid (Quadrant method) and the angle between a line drawn along the femur diaphysis and the femoral tunnel (femoral tunnel-femur diaphyseal angle/coronal angle/coronal obliquity) and to compare the results of femoral tunnel parameters measured with current literature.

Aims and Objectives: To Evaluate the Femoral Tunnel After Arthroscopic Anterior Cruciate Ligament Reconstruction.

Materials and Methods: This is an observational cross-sectional study conducted in the Department of Orthopaedics, H.B.T. medical college and Dr. R.N. Cooper municipal general hospital, Mumbai, on 39 patients of age group of 19-52 year who underwent arthroscopic ACL reconstruction over a period of 1 year.

Results: Most of patients had femoral tunnel diameter between 7.5-8.5 mm and length of 3-4 cm and femoral tunnel-femur diaphyseal angle of 30-40 degree. Most patients had position of femoral tunnel along high to low axis of 28-34% and position of femoral tunnel along deep to shallow axis of >27%. Femoral tunnel position along high to low axis and deep to shallow axis warren anatomical.

Conclusion: Low percent of ACL reconstruction were in recommended anatomical position. CT scan is a very good tool to analyse tunnel position after ACL reconstruction.

Keywords: ACL, 3D-CT scan, arthroscopy, femoral tunnel, ACL reconstruction

Introduction

The Anterior Cruciate ligament (ACL) is the primary stabilizer of the knee and prevents the knee against anterior translation. Surgical management of ACL deficient knee has progressed from the earlier primary repair to extra capsular augmentation to ACL reconstructions utilizing tendon grafts. Anatomical graft placement is one of the major challenges in ACL reconstruction. Anatomic ACL reconstruction improves joint laxity and prevents degeneration of cartilage. The concept of anatomic ACL reconstruction advanced at the beginning of the 21st century. Studies reported that the lower femoral tunnel position in the notch, closer to the femoral footprint, provided greater control of rotatory laxity.

Tunnel misplacement is the most common technical error, which leads to graft failure, femoral tunnels placed too anterior, appearing to be the most critical of these errors. Three-dimensional (3D) reconstruction of computed tomography (CT) images is currently the best method to determine whether the ACL tunnel and graft is positioned correctly. The aim of this study is to assess the femoral tunnel positioning in patients after arthroscopic ACL reconstruction using CT scans.

Materials and Methods

The study was an observational study conducted in the Department of Orthopaedics, H.B.T. medical college and Dr. R.N. Cooper municipal general hospital, Mumbai, a tertiary level hospital on patients treated arthroscopically for ACL injuries over a period of 1 year.

Inclusion criteria included

1. Patients with isolated ACL tears with or without associated meniscal injuries.
2. Between the age group of 18-50 years.

Exclusion criteria included

1. With associated posterior cruciate ligament injury and medial and lateral collateral ligament injuries.
2. ACL re-injury.
3. An associated ipsilateral lower limb fracture around knee.
4. Patient not willing to undergo post-operative CT scan.
5. Previous surgery on or around the same knee.

According to above criteria,39 patients were included in the study. After taking informed and written consent of the patient, immediate post-operative CT scan with 3D reconstruction using 128 slice of all the patient were done and were assessed. The length, diameter, angle and position of femoral and tibial tunnel were calculated using OsiriX software. All the data was entered and compiled in MS Excel and was analysed using Statistical Package for Social Sciences (SPSS, Inc., Chicago, Illinois). Patients presenting to the orthopaedic department based on our inclusion and exclusion criteria and who agreed to participate in the study were included in the study after taking written and informed consent. ACL reconstruction was performed using an arthroscopic procedure. Immediate post-operative CT scans (within 5 days) of the patients were done. Aim was to assess the placement of femoral tunnel after arthroscopic ACL reconstruction through immediate post-operative CT scan.

Data collection included age, sex and CT scan findings of femoral tunnel measurements were done using 3D reconstruction images. Subtracting the tibia, fibula and patella digitally in 3D mode was done in all cases.

The following parameters of the femoral tunnel were recorded-

a) Femoral tunnel diameter.
b) Femoral tunnel length.
c) femoral tunnel-femur diaphyseal angle/coronal angle/coronal obliquity.
d) Femoral tunnel position based on Bernard and Hertel grid.

Results

Total of 39 patients were included in the study as per inclusion and exclusion criteria.

Femoral tunnel diameter

Average diameter of the femoral tunnel was 7.74 mm with range from 6.035 mm to 9.129 mm. Out of 39 tunnels, diameter of 18 of the tunnels were in the range of 7.5-8.5mm (46.15%), while 13 of the tunnels were in the range of 6.5-7.5mm (33.33%). (Table 1, Figure 1).

Table 1: Distribution of study participants according to femoral tunnel diameter

Femoral tunnel Diameter (mm) (Range)	Frequency	%
5.5-6.5	2	5.13
6.5-7.5	13	33.33
7.5-8.5	18	46.15
>8.5	6	15.39
Total	39	100
Mean Femoral tunnel Diameter = 7.74 mm		

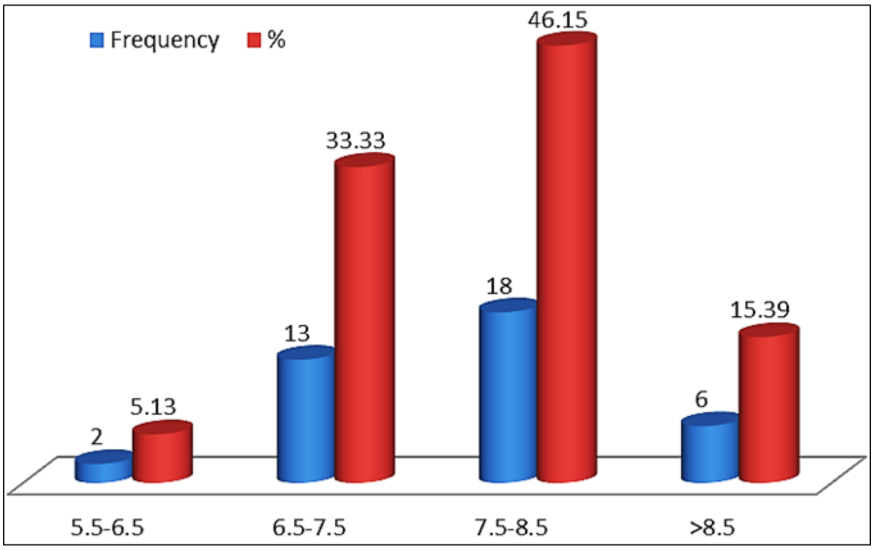


Fig 1: Segregation of cases as per the femoral tunnel diameter

Femoral tunnel length: The average length of the femoral tunnel was 3.058 cm ranging from 2.053 cm to 4.013 cm. 16 tunnels were in the range of 2-3 cm (41.03%) while 22 were in the range of 3-4 cm (56.41%) and only one tunnel of length of more than 4 cm. (Table 2 and Figure 2).

Table 2: Distribution of study participants according to femoral tunnel length

Femoral tunnel length (cm) (Range)	Frequency	%
2-3cm	16	41.03
3-4cm	22	56.41
>4cm	1	2.56
Total	39	100
Mean Femoral tunnel Length = 3.058 cm		

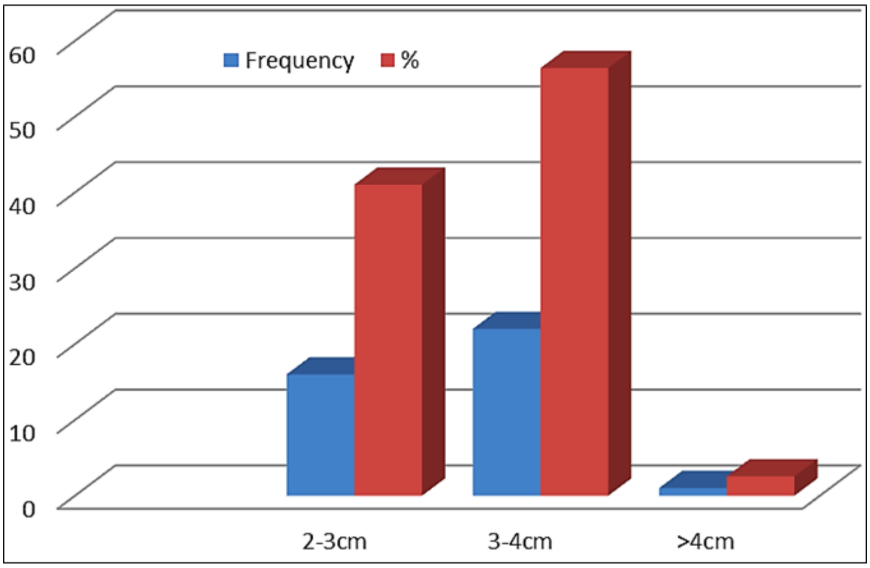


Fig 2: Segregation of cases as per the femoral tunnel length

Femoral tunnel-femoral diaphyseal angle (coronal angle/obliquity): The femoral tunnel-femoral diaphyseal angle (coronal angle/coronal obliquity) had a range from 28.475 to 58.865 degree. Average coronal angle was 42.09 degree. 17 were in the range of 30-40 degree (43.59%) and 16 were in the range of 40-50 degree (41.03%), 5 tunnels having more than 50 degree of coronal obliquity (12.82%) and only 1 tunnel with less than 30 degree of coronal obliquity. (Table 3 and Figure 3).

Table 3: Distribution of study participants according to Femoral tunnel-femoral diaphyseal angle

Femur tunnel-femur diaphyseal angle (in degree)	Frequency	%
< 30	1	2.56
30-40	17	43.59
40-50	16	41.03
>50	5	12.82
Total	39	100
Mean femur tunnel-diaphyseal angle = 42.09 degree		

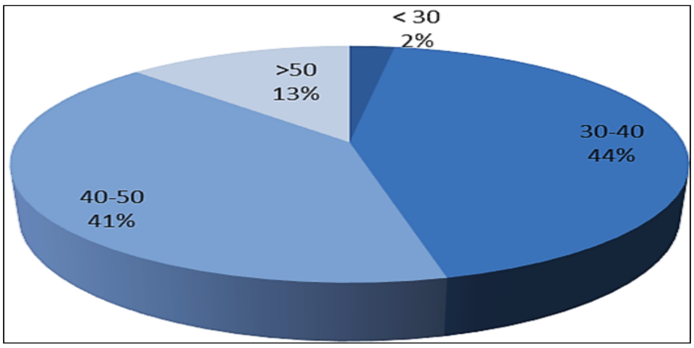


Fig 3: Segregation of cases as per the femur tunnel-diaphyseal angle

Quadrant method

a) **Measurements along high to low axis:** The average calculated total low to high distance as per quadrant method was 22.28 mm. The lowest calculated value was 17.49 mm while the highest was 27.34 mm. The average distance of centre of femoral tunnel from the Blumensaat line along high to low was 6.92 mm. The calculated high to low percent as per Bernard and Hertel grid had a range from 18% to 50.44% with mean percentage of 31.23%. Out of 39 tunnels, 20 of the tunnels i.e. 51.28% were in recommended anatomical position while 19 were not. (Table 4 and Figure 4).

Table 4: Distribution of study participants according to position of femoral tunnel along high to low axis (in percentage)

Position of femoral tunnel along high to low axis (in percentage)	Frequency	%
< 28%	10	25.64
28%-34% (recommended range)	20	51.28
>34%	9	23.08
Total	39	100
Mean position of femoral tunnel along high to low axis = 31.23%		

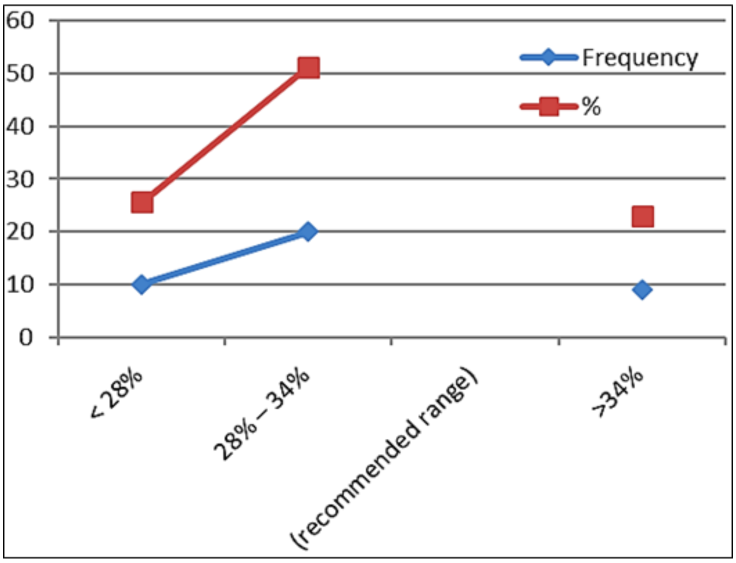


Fig 4: Segregation of cases as per the position of femur tunnel-along high to low axis

b) Measurements along deep to shallow axis: The total distance measured along deep to shallow axis as per quadrant method ranged from 34.33 mm to 52.2 mm with mean distance of 43.25 mm. The average distance from the deep end to the centre of the femoral tunnel along deep to shallow axis was 13.38 mm with range of 8.8 mm to 19.54 mm. The average percentage calculated along deep to shallow axis for femoral tunnel was 30.95% with maximum and minimum percentages of 42.73 and 22.80 respectively. 13 of the tunnels, accounting to one third of the total (33.33%), were in recommended anatomical position while 26 were not. (Table 5 and Figure 5).

Table 5: Distribution of study participants according to Position of femoral tunnel along deep to shallow axis (in percentage)

Position of femoral tunnel along deep to shallow axis (in percentage)	Frequency	%
< 24%	1	2.57
24%-27% (recommended range)	13	33.33
>27%	25	64.10
Total	39	100
Mean position of femoral tunnel along deep to shallow axis = 30.95 %		

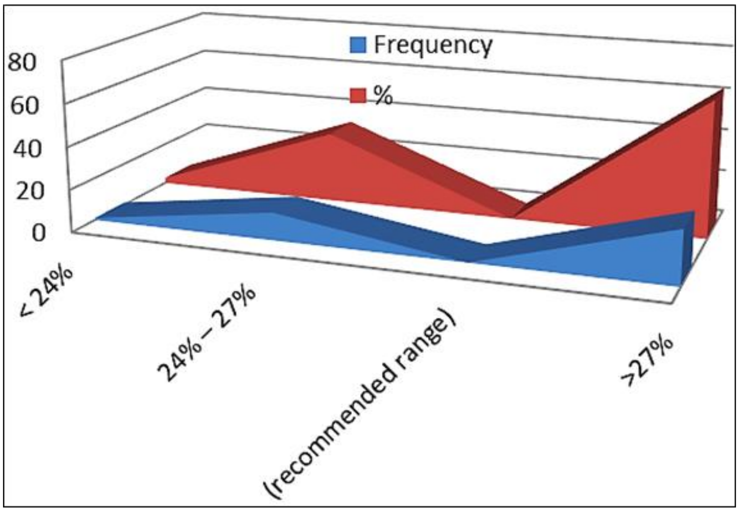
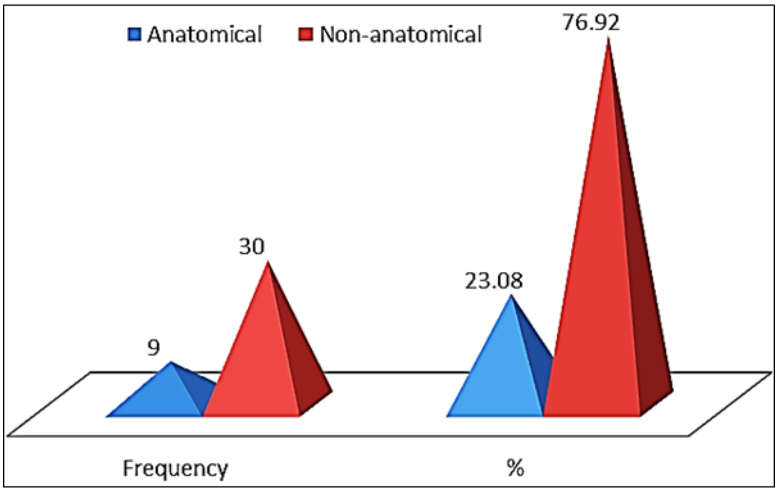


Fig 5: Segregation of cases as per the position of femoral tunnel along deep to shallow axis

c) **Tunnel position in both anterior to posterior and medial to lateral axis:** When considering both the measurements (measurements along high to low axis and along deep to shallow axis), 9 out of total 39 were in recommended anatomical position (23.08%). (Table 6 and Figure 6).

Table 6: Distribution of study participants according to recommended anatomical range of high to low percentage and deep to shallow percentage of femoral tunnel based on Bernard and Hertel grid

Femoral tunnel position along high to low axis and deep to shallow axis	Frequency	%
Anatomical	9	23.08
Non-anatomical	30	76.92
Total	39	100.0



Fi 6: Segregation of cases as per the Femoral tunnel position along high to low axis and deep to shallow axis

Discussion

Average diameter of the femoral tunnel was 7.74 mm with range from 6.035mmto 9.129 mm. Out of 39 tunnels, diameter of 18 of the tunnel were in the range of 7.5-8.5mm (46.15%), while 13 of the tunnels were in the range of 6.5-7.5mm (33.33%). This correlates with the clinical experience of 8mm drill bit being most commonly used for drilling of the tunnel followed by 7 mm drill bit. The average length of the femoral tunnel in present study was 3.058 cm with 16 tunnels in the range of 2-3 cm (41.03%) while 22 were in the range of 3-4

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cm (56.41%) and only one tunnel of length of more than 4 cm. Greis *et al*. [1] reported that the length of attend on placed within a bone tunnel influences tendon pull out strength and advocated maximizing tendon length inside the bone tunnel. A recent study by Zantop *et al*. [2] did not find any inferior deleterious outcome with insertion of a graft as little as 15mm in a goat model. However, graft in set of 20mm has been the general recommendation for ACL reconstruction. Very short femoral tunnels would cause difficulties while using suspensory method of fixation that is considered as the most optimal method. The ideal or minimal tunnel length remains unclear, but for nearly all forms of femoral graft fixation, the tunnel should be a long enough tunnel to hold an adequate amount of graft to foster healing of the graft. A thin cortical bridge reduces the margin of error during tunnel drilling in spite of the risk of cortical breakage. Hence, a tunnel length of at least 35 mm remains a desirable target. In the present study, ACL reconstruction was performed using an anteromedial portal for femoral tunneling and was performed with the knee maintained at 110-120 degree flexion. The femoral tunnel-femoral diaphyseal angle (coronal angle or corona obliquity) had a range from 28.475 to 58.865 degree with mean coronal angle of 42.09 degree which is comparable. The coronal obliquity of the femoral tunnel was 49.9±5.6 degree in the study done by Lee *et al*. [3]. Pascual-Garrido *et al*. [4] reported that the values were 50±6 degree, when femoral tunneling was performed via the low anteromedial portal in ACL reconstruction using an anteromedial portal, whereas the values were 58 ± 9 degree, respectively, when a transtibial tunnel was for femoral tunneling. Bedi *et al*. [5] reported the values as 45.9 ± 6.9 degree, after ACL reconstruction using an anteromedial portal for femoral tunneling that was performed with the knee maintained at 120 degree flexion. The angle measured between a line drawn along the femur diaphysis and the femoral tunnel angle must be approximately 39°. Angles of approximately ≤ 17° are associated with rotational instability. None of the tunnels in present study had angle less than 17 degrees with mean coronal angle of 42.09 degrees. Blumensaat ‘slime and’ Bernard and Hertel Grid" (Quadrant method) are commonly adopted radiographic markers to determine the location of the tunnels in the distal femoral shaft. In this grid-based technique, the optimal placement for deep-shallow direction has a ratio of 24 to 27%. For the optimal placement for the high-low direction, a ratio of 28to34%is proposed. Assuming the center of the ACL footprints is located in the middle between the anteromedial bundle and the posterolateral bundle, Tsukada *et al*. [6] reported the center of the ACL footprint was located at 30.35% from the deep margin and 29.95% from the Blumensaat’s line. The values were 27% and 29%, respectively, according to Yamamoto *et al*. [7], 26.9% and 27.5% respectively, according to Steckel *et al*. [8], 29.35% and 36.45% respectively according to Colombet *et al*. [9], 23.9% and 37.95% respectively according to Zantop *et al*. [10] and 43.1% and 38.3%, respectively according to Guo *et al*. [11]. In study by S. Kopf *et al*. [12] with the quadrant method, femoral tunnels were measured at a mean of 37.2% ± 5.5% from the proximal condylar surface (parallel to the Blumensaat line) and at a mean of 11.3% ± 6.6% from the notch roof (perpendicular to the Blumensaat line). In our study, the values were 30.95% for mean depth and 31.23% for mean height, respectively, which were similar to the mean values of other studies by different from study by S. Kopf *et al*. In present study, 9 out of total 39 femoral tunnels were in recommended anatomical position which is 23.08%. In the study by T. Vermersch *et al*. [13], partial ACL reconstruction group had 6 femoral tunnels (37.5%) in the optimal position and 10tunnels (62.5%) were not. In the complete ACL reconstruction group, 124 femoral (68.9%) were in the optimal position and 56 (31.1%) were not. While Ghaffar *et al*. [14] reported 52% of tunnels in recommended position. C. Topliss *et al*. [15] reported 65% percent of femoral tunnels and59%of the tibial tunnels were mal positioned. J. Dargel *et al*. [16] reported that 86% femoral bone tunnels were positioned close to the reference value using an antero-medial drilling technique when compared to trans tibial drilling. When femoral tunnel placement is too shallow and too high the graft is taut in flexion. If tunnel placement is too high, the graft may overstretch in extension and reduce the range of motion.

Conclusion

In the present study,9 out of 39 femoral tunnels were in recommended anatomical position. CT scan is a very good tool to analyse tunnel position after ACL reconstruction. Feedback from CT scans may help surgeons to improve in future surgeries.

Source of funding: None.

Conflict of interest: None.

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