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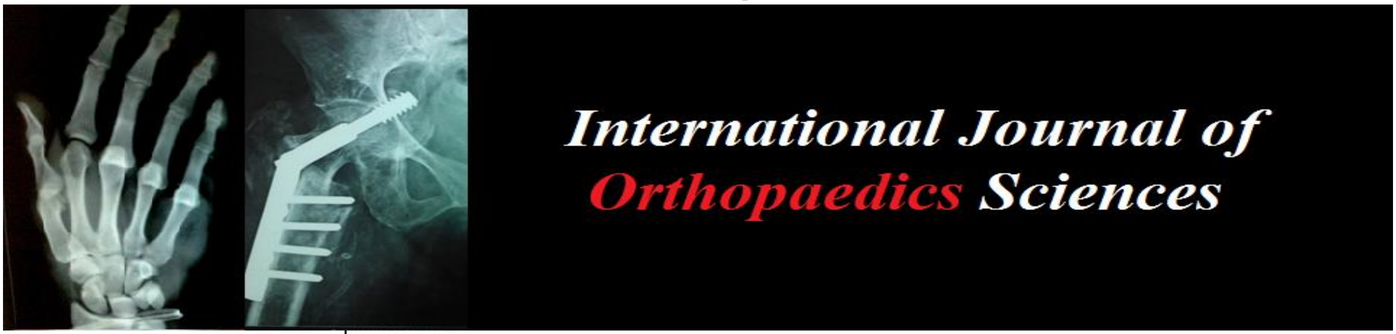

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Radiological assessment of femoral and tibial tunnel placement in arthroscopic ACL reconstruction using hamstring tendon graft

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Abstract
Background: Proper and accurate placement of tibial and femoral tunnels has a significant impact on anterior cruciate ligament (ACLR) reconstruction outcomes. After ACLR, postoperative radiographs give us a precise and valid way to evaluate anatomical tunnel positioning.
Aim of this study is to analyze the radiographic position of tibial and femoral tunnels in patients with anatomic landmarks who have undergone arthroscopic ACLR. This prospective cohort analysis included patients who underwent arthroscopic ACLR between January 2018 and May 2019.
Materials and Methods: It is a prospective study conducted on 40 patients who has undergone arthroscopic ACLR, postoperative radiographs were assessed. 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 ± standard deviation, inter-quartile range and proportions as applicable.
Results: The position of the tibial tunnel from the anterior edge of the tibia is found at an average of 44.98% ± 8.77% later. The femoral tunnel was located 36.4% ± 4.8% before the posterior femoral cortex along the axis of the Blumensaat's. Radiographic impingement was found in 32.5% of the patients. The roof angle averaged 39.8° with interquartile range of 4°. The position of the tibial tunnel was found at an average of 39.3% ± 4.19% from the medial edge of the tibial plateau. The coronal tibial tunnel angle averaged 58.7° ± 8.7°. The average femoral tunnel coronal angle was 39.8 ° ± 3.26 °.
Conclusion: Femoral and tibial tunnel placements were well associated with anatomical landmarks with the exception of radiographic impingement in 32.5% of patients.

Keywords: Arthroscopy, anterior cruciate ligament, tunnel placement, femur, tibia, radiography

Introduction

Anterior Cruciate Ligament (ACL) surgical repair is one of the most common orthopedic procedures, with approximately 100,000–175,000 procedures performed annually [1]. ACL reconstruction operation replaces a torn ACL-a major ligament of the knee. In general, ACL injuries occur when sports involve sudden stops and indirect changes such as basketball, football, downhill skiing, gymnastics, etc [2].
The damaged ligament is removed and replaced by a tendon graft from another section of the knee or from a deceased donor via ACL reconstruction. It being an ambulatory operation is performed by tiny incisions around the knee joint [2].
Ligaments are tight tissue bands that bind one bone to another. The ACL, one of two ligaments that cross the middle of the leg, links the thighbone (femur) to the shinbone (tibia) and serves to support the knee joint [2]. The 4 main ligaments in the knee that connect the femur to the tibia include the following [3]. Anterior Cruciate Ligament (ACL)
which is located in the center of the knee, and controls rotation and forward movement of the tibia, Posterior Cruciate Ligament (PCL) which is located in the center of the knee and controls backward movement of the tibia, Medial Collateral Ligament (MCL) that gives stability to the inner knee, Lateral Collateral Ligament (LCL) that gives stability to the outer knee.

Patients present with signs of pain, swelling, loss of full range of motion, discomfort when. outpatient, as with any procedure, the potential risks of ACL reconstruction are bleeding and surgical site infection. Certain risks include: [2] knee pain or rigidity, slow graft healing, Graft failure after returning to sport.

Because ACL is a central knee stabilizer, the aim of surgery is to restore the knee's integrity so that the patient can prevent further damage and return to sports. The final goal of participation in this stressful operation depends on graft collection, surgical procedure and post-operative rehabilitation [4].

Reconstructions of the Anterior Cruciate Ligament (ACLRs) fail at a small but significant rate. The rate of failure after ACLR varies from 0.7% to 10%. The location of the graft, and therefore the positioning of tibial and femoral tubes, is therefore considered critical to the success of reconstructive ACL surgery. Postoperative plain x-rays provide a reliable and valid way to evaluate the placement of anatomical graft. Radiographs can aid in predicting risk factors for potential graft failure and poor outcome.

Such risk factors include incorrect tunnel placement, unnecessary alignment with varus or valgus, and increased extension or hyperextension with potential impingement of the graft. Precise positioning of tibial and femoral tunnels has a great effect on the results after ACLR [5]

Objectives of the study

(a) To assess the post-operative radiological outcome in ACL reconstruction. (b) To determine degree of mal-position in tibial and femoral tunnel placement. (c) To assess the graft impingement post ACL reconstruction.

Material and Method

It is a prospective cohort study conducted between January 2018 and May 2019 at the Department of Orthopedics, Vydehi Institute of Medical Sciences and Research Centre, Whitefield, Bangalore. The study included patients using hamstring graft from either sex of ACL tear undergoing reconstruction of ACL. Sample of 35 patients fulfilling the inclusion criteria were included in the present study after calculating on scientific basic with formula. Historical data collection and pub-med search was done. The sample size was calculated with statistical input from the following reference article: Radiologic assessment of femoral and tibial tunnel placement based on anatomic landmarks in arthroscopic single bundle anterior cruciate ligament reconstruction. Ethical clearance was taken from the institutional ethics review board (IERB) prior to conducting the study.

Inclusion Criteria: (a) Diagnosed to have ACL tear clinically and radiologically with/without associated Menisci injuries, (b) Age group 15-55 years, (c) Both male and female.

Exclusion criteria: (a) ACL injury in individuals associated with osteoarthritis.

(b) ACL avulsion fractures. (b) Observed chondral lesions that could modify the post op rehabilitation protocol. (c) Collateral or/and PCL injuries. (d) Associated tibia plateau fractures. (e) Previously operated knee.

Pre-operative work up: All patients who met the requirements of inclusion and exclusion were screened and included in the study after their agreement and willingness to undertake the requisite investigations and management as part of the study. A common protocol of history taking, clinical examination, routine blood investigations and pre- operative x-ray imaging and MRI (Magnetic Resonance Imaging) were performed as a part of the pre-operative preparation.

Consent for surgery was obtained for all the patients who were included in this study. All consent was obtained prior to surgery. Patients and their attenders were well explained about the advantages and disadvantages of procedure. Risk benefit ratio was explained.

The information is compiled from the hospital database for patients who have undergone ACLR. These patients ' post-operative radiographs were collected. The research included postoperative full-extension antero-posterior and lateral knee x-rays. 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 35 patients who met the inclusion and exclusion criteria are included for measurements. Aperture fixation using titanium screws is used for all the cases included. The position of femoral and tibial tunnels on the postoperative radiographs is assessed by the reader.

VINFORMAX version 2.4.2 (IPACS VINCARE) was the method used. We examined 40 IPACS patients with postoperative radiographs. The research included postoperative full extension antero-posterior and lateral knee radiographs. Excluded from the sample were radiographs with poor quality (improper penetration), extreme lateral obliquity (more than 5 mm lack of femoral condyle overlap), or improperly shaped. Postoperative radiographs of 40 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 assessed by the reader.

Post operative x-ray parameters measured were as follows [5]:

Antero-posterior 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 antero-posterior 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]

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].

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]

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 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].

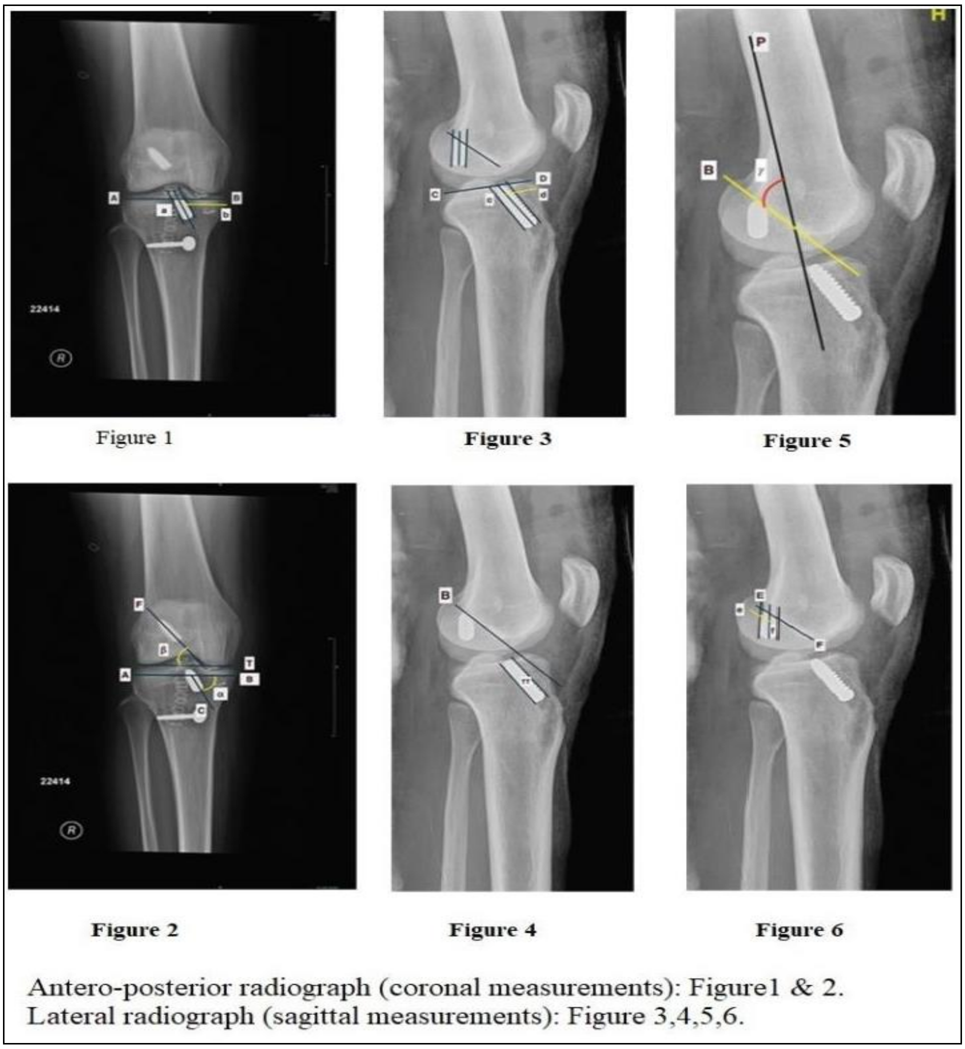

Fig 1: Antero-posterior radiograph (coronal measurements): Figure 1 & 2 Lateral radiograph (sagittal measurements): Figure 3, 4, 5, 6.

Statistics: All the patient data was entered in Microsoft Excel programmed analyzed by SPSS version 19. All the qualitative data are depicted as frequencies and percentage & all the quantitative data are depicted as Mean +/- SD and median with inter-quartile range.

Results

This research included 40 patients undergoing reconstruction of ACL with hamstring tendon graft Aperture fastening using titanium screws. Male preponderance was noted in our study, with 92% of males and 8% of females in the total population of the sample.

Most patients had a third decade of life, with the youngest patient being 18 years of age and the oldest being 54 years of age with a mean age of 32. The nature of the injury in our series was mainly Sports injury, which accounts for 28 patients (70%) and the rest were RTA, Work injury and slip and fall, respectively, which accounts for 12 (30%).

Table 1: Showing the demographic details of the patients included in present study.

		Frequency	Percentage
Gender	Male	37	92
	Female	3	8
Age in years	<20	4	10
	21-30	20	50
	31-40	7	17.5
	41-50	6	15
	51-60	3	7.5
Mode of Injury	RTA	12	30
	Sports	28	70
Side of injury	Right	22	55
	Left	18	45

Table 2: Table showing the various test and frequency of distribution

		Frequency	Percentage
Anterior drawer test	Positive	36	90
	Negative	4	10
Lachman's test	Positive	34	85
	Negative	6	15
Posterior Drawer's	Positive	0	0
	Negative	40	100
Mc Murrey's test	Positive	5	12.5
	Negative	35	87.5

Table 3: Showing various radiological views and distribution among the patients.

		Frequency	Percentage
Tibial tunnel sagittal view	21-30	3	7.5
	31-40	11	27.5
	41-50	17	42.5
	51-100	9	22.5
Femoral Tunnel sagittal view	0-25	0	0
	26-50	40	100
	51-75	0	0
Graft Impingment	<1	27	67.5
	1-25	9	22.5
	26-50	2	5
	51-75	1	2.5
	76-100	1	2.5
Tibial tunnel Coronal view	35-40	25	62.5
	41-45	13	32.5
	46-50	2	5
Angle of Tibial Tunnel	≤60	26	65
	60-65	4	10
	66-70	7	17.5
	≥70	3	7.5
Obliquity of Femoral Tunnel	≤35	3	7.5
	36-40	21	52.5
	41-45	14	35
	46-100	2	5
Femoral Roof angle	≤30	2	5
	31-35	2	5
	36-40	20	50
	≥40	16	40

Table 4: Distribution of radiological parameters in the study

Parameter	Mean ± SD	Category	N (%)
Position of tibial tunnel on sagittal radiograph from anterior edge of tibia(%), n=40	44.98 ± 8.77	21-30	3
		31-40	11
		41-50	17
		51-100	9
Position of the femoral tunnel on sagittal radiograph along the Blumensaat's line (%), n=40	36.4 ± 4.79	0-25	0
		26-50	40
		51-75	0
		76-100	0
Impingement of the graft on sagittal radiograph (%), n=40	32.5%	0	67.5
		1-25	22.5
		26-50	5
		51-75	2.5
		76-100	2.5
Angle of the tibial tunnel on coronal radiograph (°), n=40	58.7 ± 8.7	≤60	26
		60-65	4
		66-70	7
		≥70	3
Position of the tibial tunnel on coronal radiograph (%), n=40	39.3 ± 4.2	35-40	25
		41-45	13
		46-50	2
		>50	0
Obliquity of the femoral tunnel on coronal radiograph (°), n=40	39.8 ± 3.26	≤35	3
		36-40	21

		41-45	14
		≥46	2
Femoral roof angle radiograph (°), n=40 on sagittal	MEDIAN 39 with IQR 4	≤30	2
		31-35	2
		36-40	20
		>40	16

SD – Standard Deviation; IQR – Inter-quartile Range

Discussion

The aim of ACLR surgery is to provide the torn ligament with an isometric, anatomic, impingement-free graft. The Multicenter ACL Revision Study [6] showed some degree of technical error as the major cause of failure after ACLR either in isolation or in combination with trauma and/or biological problems 80 percent believed they had femoral tunnel malposition in the patients who felt they had technical problems contributing to their failure. For the effective placement of tibial and femoral tunnels for ACLR, various studies have identified arthroscopic and anatomic landmarks. We placed the femoral tunnel slightly behind the native footprint center so that the tunnel has 1-3 mm of intact posterior wall and about 2 mm higher than the articular cartilage.

The femoral tunnel was positioned below the lateral inter-condylar ridge and slightly lateral to the bifurcate ridge in the absence of native foot print. The tibial tunnel was placed 3-4 mm ahead of the posterior cruciate ligament (PCL) and slightly medial to the lateral meniscus inner edge. Studies have investigated the relationship between arthroscopic anatomic landmarks and postoperative radiological and functional outcomes [7, 8]

Nema SK, Balaji G, Akkilagunta S, Menon J [5] study showed placement of

femoral tunnel at an average of 30 ± 10.7, We placed femoral tunnels at an average of 36.4% ± 4.8% 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 [9]

A strong correlation has been shown between functional results and subsequent placement of femoral tunnels on lateral radiographs [7]. The angle of placement of tibial tunnels in the coronal plane is important in order to prevent postoperative impingement of the cruciate ligament and loss of flexion. In our analysis, the angle of the tibial tunnel in the coronal plane in 90% of patients was < 70 °.

Howell *et al*. reported a coronal plane angle >75° which was associated with loss of flexion and increased laxity. 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 39.3% ± 4.19% lateral to the medial border of the medial tibial plateau.

Anterior impingement of the graft was examined and found to be associated with increased effusions, lack of extension, and increased rates of failure [10, 11]. Studies subsequently suggested tibial tunnel positioning of about 50 percent (36 percent –45 percent) along the length of the anterior tibial plateau in the impingement-free zone of 21–28 mm to prevent impingement [7, 10, 11].

Radiographic findings from the MARS cohort in revision ACLRs found variation in the location of tibial tunnels [6]. 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 44.98% ± 8.77% posterior from the anterior edge of tibia along the tibial plateau. we found placement of the tibial tunnel using anatomic landmarks, radiographic impingement ranging from 1% to 100% was found in 32.5% 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].

A 45 ° postero-anterior weight bearing view (Rosenberg view) of the knee should be used to calculate the graft inclination. We calculated graft tendency indirectly due to patient factors in the study by calculating obliquity of the femoral tunnel on coronal radiograph. In our sample, the average angle of the femoral tunnel on coronal radiographs was 39 °. In this analysis, the femoral tunnel placement was guided by the tibial tunnel through an accessory antero-medial portal rather than the trans-tibial technique. Coronal obliquity of graft is one of the most crucial factors for rotational stability of the knee. A femoral tunnel placed obliquely is much more efficient in resisting rotatory loads if compared with vertical tunnel close to the roof of the inter-condylar notch.(5) The reconstructed ACL can be closer to the native ACL if we position more horizontal femoral tunnel.

The limitations of the study is that the cohort was mostly a non-local population group where radiographic follow-up evaluation could not be done for further evaluation of the impingement of the graft and the possibility of widening or positioning the tunnel. Poor technology or inadequate X-rays can prevent accurate measurement. Although it would have been desirable to compare functional outcomes and laxity measurements with radiological parameters, due to patient restriction we were unable to do so.

Conclusion

In this research, the radiological outcome for patients who underwent ACL reconstruction using hamstring tendon graft is that the placements of the femoral and tibial tunnels are well associated with anatomical landmarks except for graft impingement, which is seen radiologically in 32.5% of patients.

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