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Original Article

Clinical outcome and computer tomography based tunnel placement evaluation following arthroscopic anteromedial portal anterior cruciate ligament reconstruction in non-athletic population

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Abstract: Background: The morphology of distal femur and proximal tibia varies between different ethnicities, and it can affect the tunnel dimensions and positions while doing ACL reconstruction which may affect the clinical outcome. There is limited data on the clinical outcome and CT based tunnel placement evaluation in femur and tibia of Indian nonathletic population. Methods: Thirty non-athletic patients with mean age of 25.50±6.9 years and ACL rupture who underwent single bundle hamstring autograft arthroscopic ACL reconstruction by anteromedial portal were included in the study. Their preoperative IKDC Score, Lysholm-Tegner score, Tegner activity level were calculated and knee stability was assessed clinically using anterior drawer test, Lachman test and pivot shift test. The CT scan of the operated knee was done once the complete extension of the knee was achieved. Using the multimodality workstation available at the department of radio-diagnosis the tunnel parameters of femoral and tibial tunnel was calculated. After 6 months the patients were reassessed for clinical and radiological outcome. The postoperative outcome was compared with preoperative outcome. Results: There was a significant difference in preoperative and postoperative score, the difference in IKDC score was 15.08 points, improvement of 14.65 points was seen in Lysholm-Tegner score and there was marked improvement in Tegner activity level. Tests for knee stability were normal in >90% of patients postoperatively. The CT evaluation showed that the femoral tunnels were positioned at 28.45%±3.69% (20.16%-38.35%) along the deep-shallow axis and 25.81%±3.819% (20.69%-37.35%), the mean tunnel obliquity compared to the femoral shaft axis were 47.34°±5.427° (37.68°-58.16°) in the coronal plane and 47.93°±7.023° (35.11°-63.95°), the mean tunnel length was 3.38 cm±0.331 cm (2.79 cm-4.18 cm). The tibial tunnel were positioned at 45.63%±5.832% (32.23%-58.23%) along the anterior-posterior axis and 47.70%±2.26% (42.40%-51.96%) along the medio-lateral axis. The tibial tunnel length was found to be 3.89 cm±0.519 cm (3.05 cm-5.06 cm). Conclusion: This study helps to ascertain that the ACL reconstruction via anteromedial portal technique using femoral offset zig followed by postoperative home-based rehabilitation technique gives favorable clinical outcomes in Indian non-athletic patients. All patients had improvement in stability of knee after the surgery. The position of femoral tunnels was anatomical but in comparison to Caucasian patients its placement was deeper and higher. Hence, we conclude that the anteromedial portal technique of ACL reconstruction provides favorable clinical outcome and adequate anatomical tunnel placement in Indian non athletic patients.

Keywords: Anterior cruciate ligament, morphology, anatomy, reconstruction, clinical outcome, CT scan, MRI, radiological outcome

Introduction

Anterior cruciate ligament (ACL) is frequently injured structure in the knee, with 40% of injuries attributed to non-contact mechanisms [1, 2]. ACL reconstruction is one of commonly performed procedures in orthopedic sports medicine [3].

Symptoms of ACL injury include hearing a sudden popping sound, swelling, instability of the knee and moderate to severe pain. The Lachman test, pivot shift test and the anterior drawer test are used in the clinical examination of suspected ACL injury. Magnetic resonance imaging (MRI) can diagnose cruciate ligament injuries with high accuracy [1-3].

The ACL does not heal when torn and surgical reconstruction is the standard treatment [4, 5]. Such reconstruction aims at restoring the kinematics and stability of the injured knee, to prevent future meniscal injuries, cartilage damage and degenerative changes [6, 7]. Good-to-excellent results in greater than 90% of patients at 10-year follow-up have been demonstrated [8].

Transtibial, anteromedial portal, accessory anteromedial portal are techniques used for single bundle arthroscopic ACL repair [6-8]. Most of the studies on arthroscopic anteromedial ACL reconstruction have been done in western countries on the Caucasian subset of population and high performing athletes who require early start of activities and return to high-performance activities [7, 8]. There is limited literature available on the arthroscopic ACL reconstruction on non-athletic Indian subset of population.

Most of the literature available for arthroscopic ACL reconstruction is on high performing athletes in contrast to our setting which mostly comprises patients with moderate to low activity levels. It has been shown that the morphometry of distal femur varies between different ethnicities [9, 10]. Differences in the morphometry of knee may have certain effects on tunnel dimensions and positions while doing ACL reconstruction which in turn may affect the clinical outcome [11-13].

Therefore, the present study aims to assess the clinical and radiological outcomes in the patients who had undergone anteromedial portal ACL reconstruction in our non-athletic population.

Material and methods

Patient enrollment criteria

This prospective observational study was done in a tertiary care centre after obtaining institutional ethical clearance (IEC-HR/2018/36/95). Thirty patients (26 males and 4 females) with a mean age of 25.50±6.9 years were included in the current study after obtaining their informed consent.

The patients not actively involved in sports and had first time single ACL rupture with or without meniscal tear while performing there daily routine activities (non-athletic patients), who had knee instability following injury, underwent single bundle hamstring autograft arthroscopic ACL reconstruction by anteromedial portal were included in the study. Patients with hip and ankle pathologies which may impair functional outcome, patients not willing to participate in study, pregnant and lactating mothers where CT scan was not possible, reinjury of operated knee and patients with multi-ligamentous injury were excluded from the study.

Complete clinical history was taken, and examination was performed and once a provisional diagnosis was made MRI of the knee was advised and the diagnosis of ACL injury was radiologically confirmed. They were offered home based physiotherapy in the form of isometric quadriceps and hamstring exercises till the knee flexion of 120° was achieved.

Their preoperative knee scores were calculated with the help of questionnaires. Knee stability was assessed and documented using the Lachmann test, anterior drawer test and pivot shift test, the findings were recorded in a predesigned proforma.

Surgical technique: Arthroscopic ACL reconstruction was done by the standard technique using anteromedial and anterolateral portals using femoral offset zig. All patients were given standard antibiotics, analgesics and long knee brace in the immediate post-operative period as per institutional protocol. Patients were taught and encouraged to do isometric quadriceps and hamstring exercises in the immediate post-op period. The first dressing was done on post operative day two and patients were taught closed chain exercises. They were discharged after explaining home-based rehabilitation protocol. They regained full knee range of motion in 2-4 weeks and achieved preoperative activity level after 6 months.

All patients were supervised two to three times a week up to 2 weeks, followed by once a week till 6 weeks and then once in a month to ensure that the correct quality of performance and level of difficulty has been achieved.

Diagnostic analysis: Non-contrast CT scan of the operated knee was done after the complete knee extension was achieved. The scan was done on Siemens 64 slice Multi-detector CT

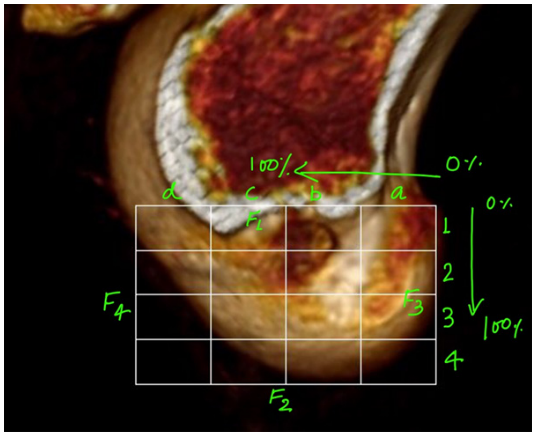

Figure 1. Three dimensional computed tomography of the lateral femoral condyle.

scanner (Somatom Definition AS: M/S Siemens® Health Care; Erlangen, Germany). Axial sections of 4 mm thickness were obtained with the patient in supine position and knee kept in extension, using the spiral mode with no gantry tilt. A standardized protocol was used for CT-kV 120, mAs 100, rotation time 1 s, slice thickness 4 mm, collimation 64 × 0.6 mm and pitch of 0.80 and FOV of 250 mm. Thinner (0.6 mm) sections were reconstructed in bone algorithms as MPR's (Multi Planar Reformations) from the source and viewed in all-coronal, sagittal and desired oblique planes. The reconstruction was done to obtain the desired post-processed views with appropriate degree of rotation in three-dimensional mode by 3D VRT (Volume Rendering Technique).

To identify and assess the femur tunnel position Quadrant method was used (**Figure 1**) [14].

The position of the tunnel was noted in small rectangles, these rectangles were assigned number according to row and column in which the tunnel falls. The femoral tunnel inclination was measured by measuring the coronal and sagittal angle as depicted in **Figure 2** [16].

To measure the femoral tunnel length, the plane in which the entire length of the femoral tunnel showed maximum width was selected using the inbuilt tools present in the multimodality workstation available (**Figure 3**) [17].

The tibial tunnel position was measured by Anatomic coordinate axis method [15]. The anterior-posterior axis position was calculated as the percentage of the distance from the anterior border of the tibial plateau to the aperture tibial center. In contrast, the medial-lateral axis position was calculated as the percentage from the medial border of the tibial plateau to the tibial aperture center (**Figure 4**).

Similar to the Quadrant method used for the femoral tunnel assessment, a rectangle is drawn on the 3D CT cut of the tibial plateau. This rectangle is divided into 16 equal parts by drawing equidistant lines on the rectangle and these were marked "1-4" in the anterior to posterior direction and "a-d" in medial to lateral direction. The tibial tunnel aperture was then labeled in the quadrant where it lies (**Figure 4**).

The clinical score of the patients who have completed six months of follow up was recorded. Stability of knee was assessed using Lachmann test, anterior drawer test and pivot shift test.

Anterior Drawer test was performed on the patients with patient lying on the examination table in supine position, hip flexed in 45 degree and knee flexed in 90 degree and lower leg in neutral position. While examining the patient's foot was stabilized with examiner's thigh and both hands of examiner were placed behind proximal tibia with thumbs on the tibial plateau. Anterior directed force was applied to the proximal tibia and amount of tibial translation was judged. The amount of translation the result was graded according to IKDC 2000. Anterior drawer test was rated normal (0 mm-2 mm) nearly normal (3 mm-5 mm), abnormal (6 mm-10 mm) and severe abnormal (>10 mm) based on the amount of anterior tibial translation on the injured side compared to the uninjured contralateral knee.

Lachman test was performed with patients lying supine and the involved lower limb on the side of the examiner. The examiner then held the femur of the patient with one hand to stablize it with knee in 20-30 degree of flexion. The other hand of the examiner was applied to the posterior aspect of the proximal tibia. An anteriorly directed force was then applied by the examiner to displace the tibia, the amount of anterior translation and the end point was noted by the examiner. Increased tibial translation with a soft end point constituted a positive test indicating disruption of ACL. As described in IKDC 2000 it was graded as normal (-1 mm

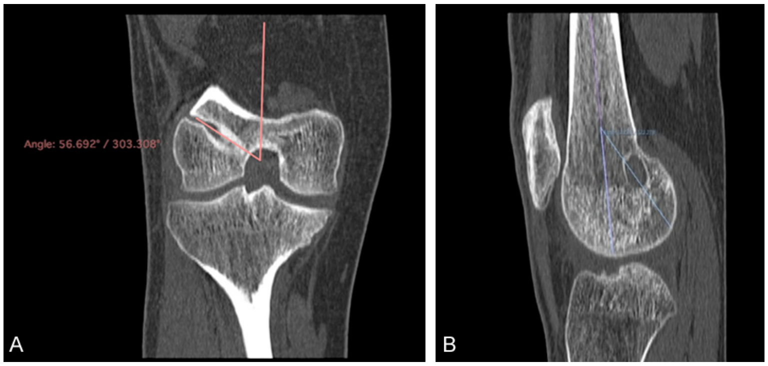

Figure 2. Coronal and sagittal femoral tunnel angle. A. A line parallel to the axis of femoral tunnel and a line bisecting the femoral shaft were used to calculate the coronal inclination of the femoral tunnel in computed tomography scan. B. The sagittal inclination of femoral tunnel was calculated relative to the line bissecting the femoral shaft in the lateral views of computer tomography scan.

to 2 mm), nearly normal (3 mm-5 mm) abnormal (6 mm-10 mm) and severe abnormal (>10 mm): based on the amount of greater tibial translation on the injured side as compared to uninjured contralateral side.

Pivot shift test was performed with patients lying supine. The extended leg was picked up at ankle with examiner's ipsilateral hand internally rotates the knee and flexes the knee from full extension while giving a valgus stress with contralateral hand on the lateral side of proximal tibia. A sudden reduction of the anteriorly subluxated lateral tibial plateau caused by iliotibial tract indicates positive test. According to IKDC2000 it is graded as equal, glide (+), clunk (++) and gross (+++).

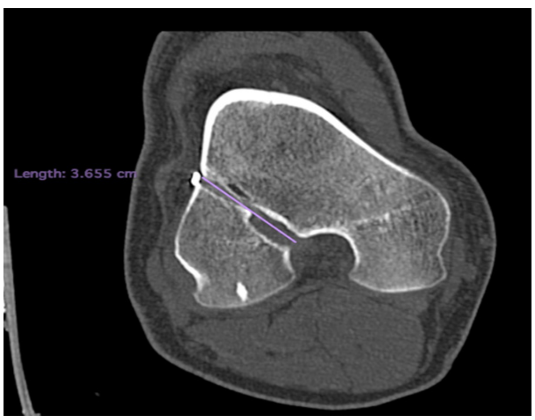

Figure 3. Femoral tunnel length.

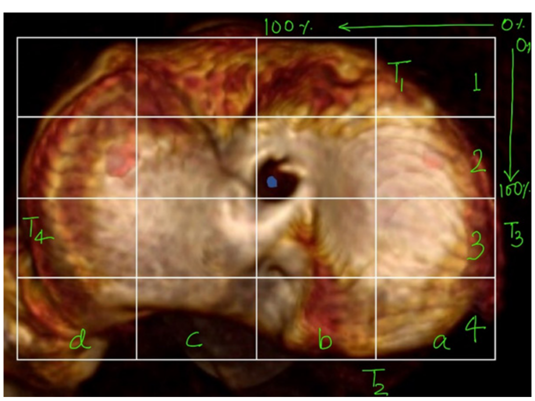

Figure 4. Top view of the proximal tibia. The locations were measured from the anterior border (medial to lateral) and medial border (anterior to posterior) and rectangle in which the center of the aperture lies was named as per the nomenclature given.

The clinical outcome was assessed using Lysholm score, International knee documentation committee (IKDC) score and Tegner activity level, the findings were recorded in a predesigned performa.

Statistical analysis

The collected data was transformed into variables, coded and entered in Microsoft Excel. Data was analyzed and statistically evaluated using SPSS-PC-19 version. Quantitative data was expressed in mean (and standard deviation) or median with an interquartile range and difference between pre and post-operative values were tested by paired t test or Wilcoxon sign rank test while qualitative data were expressed in percentages. Statistical differences between the proportions calculated pre and post-operatively were tested by McNemar Test. '*P*' value less than 0.05 was considered statistically significant.

Results

Clinical outcomes

The clinical evaluation of the knee stability before and after surgery was done by Lachman's

Table 1. Lachman grading in the patients (pre and post-surgery)

Lachman grade	Preop		Postop		*P*-value
	No. of patients	%	No. of patients	%	
Normal	0	0.0	28	93.3	<0.001
Nearly Normal	19	63.3	2	6.7	
Abnormal	10	33.3	0	0.0	
Severely Abnormal	1	3.3	0	0.0	

Table 2. Anterior drawers test in the patients (pre- and post-surgery)

Anterior drawers (grade)	Preop		Postop		*P*-value
	No. of patients	%	No. of patients	%	
Normal	0	0.0	28	93.3	<0.001
Nearly Normal	17	56.7	2	6.7	
Abnormal	12	40.0	0	0.0	
Severely abnormal	1	3.3	0	0.0	

Table 3. Pivot shift test in the patients (pre and post-surgery)

Pivot shift	Preop		Postop		*P*-value
	No. of patients	%	No. of patients	%	
Equal	0	0.0	29	96.7	<0.001
Glide	4	13.3	1	3.3	
Clunk	24	80.0	0	0.0	
Gross	2	6.7	0	0.0	

test, anterior drawer test and pivot shift test. The improvement in the knee stability after 6 months of surgery was found to be statistically significant as depicted in **Tables 1-3**.

Preoperatively the mean (and standard deviation) IKDC score among patients was 67.60±8.67 (49.4-82.0), the interquartile range and median were 61.22-75.0 and 70.0 respectively. Postoperatively, the mean (and standard deviation) IKDC score improved to 82.68±10.22 (63.2-96.6). The interquartile range and median were 74.65-90.50 and 85.65 respectively. *P* value was found to be <0.001, which was statistically significant.

Preoperatively the mean (and standard deviation) Lyhsolm-Tegner score in the patients was 71.37±8.22 (51-86). The interquartile range and median were 66.75-77.5 and 70.75-95 respectively.

Table 4. Lysholm-Tegner score grading pre and post operatively

	Preoperative	Postoperative
Excellent score	0	7
Good score	0	11
Fair score	18	9
Poor score	12	3

Table 5. Tegner activity level pre and post-operative

	Tegner scale preop	Tegner scale postop
Mean	1.60±0.62	3.27±1.38
Median	2	3
IQR	1-2	2-4.25
Minimum	1	1
Maximum	3	6
P value with preop		<0.001

IQR: Interquartile Range.

Postoperatively the mean (and standard deviation) Lysholm-Tegner score improved to 86.02±9.29 (66-98). The interquartile range and median were 79.75-95 and 87 respectively. The *P* value was <0.001, which was statistically significant.

There was a marked improvement in the clinical outcome of the patients at six month post-operative, this was better depicted by Lysholm-Tegner score (**Table 4**). The Tegner activity level also improved markedly which was found to be statistically significant, P<0.001 (**Table 5**).

Radiological outcomes

The femoral and tibial tunnel parameters on CT scan were assessed according to the described methodology, the measurements were recorded and statistical analysis was done, the measurements are depicted in **Tables 6** and **7**.

The mean positions of femoral and tibial tunnel aperture in antero-posterior axis and medio-lateral axis is depicted in **Table 8**. The femur tunnel was found to be more consistent in quadrant 1b and 2b and the tibial tunnel was more commonly present at quadrant 2b.

Table 6. Femoral tunnel parameters on CT scan in study subjects

	Distance (deep-shallow) (%)	Distance (high-low) (%)	Coronal angle	Sagittal angle	Length
Mean	28.45	25.81	47.34	47.93	3.38
SD	3.69	3.819	5.427	7.023	.331
Median	27.79	24.88	46.70	47.90	3.425
IQR	26.4-30.69	23.42-27.7	43.35-50.61	42.29-51.40	3.14-3.54
Minimum	20.16	20.96	37.68	35.11	2.79
Maximum	38.35	37.35	58.16	63.95	4.18

IQR: Interquartile Range.

Table 7. Tibial tunnel parameters on CT scan in study subjects

	Distance (ant-post)	Distance (med-lat)	Length
Mean	45.63	47.70	3.89
SD	5.832	2.260	.519
Median	46.02	48.02	3.82
IQR	42.63-49.04	45.81-49.21	3.66-4.14
Minimum	32.23	42.04	3.05
Maximum	58.23	51.96	5.06

Table 8. Position of femoral and tibial tunnel on CT in study subjects

	Femoral tunnel position	Tibial tunnel position
1a	1	-
1b	15	-
2a	1	-
2b	13	22
2c	-	3
3b	-	5

Discussion

All patients participating in current study were non athletic, they had complaints of instability and giving away episodes in their day to day activities and therefore were considered for surgery.

The current study showed that all the patients participating in the study had improved clinical outcome as assessed by IKDC and Lysholm score and improved activity level as assessed by the Tegner activity scale compared to the preoperative level. All patients had improvement in the knee stability and more than 95% patients had a stable knee postoperatively as assessed by anterior drawer test, Lachman test and pivot shift test.

Irrgang et al. [20] conducted a study to assess the change in IKDC score postoperatively, the patients included in the study were whites, graduates from schools and colleges, out of which most of them were athletes, some were professional athletes. The change in pre and post-operative IKDC score of 11.5 was found to be the significant score of improvement.

In the current study the difference in the postoperative and preoperative mean IKDC score was 15.08 points which shows that overall there is clinically significant improvement in the outcome postoperatively. However, five patients had change in the IKDC score less than 11.5 points, all these patients had poor preoperative IKDC score. In our study all of the patients were Asians and none of the patients were professional athletes.

Youm et al. [22] evaluated 40 patients to compare the clinical outcome and femoral tunnel positions in the patients undergoing arthroscopic single bundle ACL reconstruction. Clinical outcome was assessed with IKDC score, Lysholm knee score and mean Tegner activity level. It was also found that out of 20 patients who underwent anteromedial portal ACL reconstruction, 18 patients (90%) had negative Lachman test and 19 (95%) patients had negative pivot shift test postoperatively. In the current study, 28/30 (93.3%) had normal and 2/30 (6.7%) had nearly normal Lachman grade, 29/30 (96.7%) had negative pivot shift test and only 1 patient had glide while doing pivot shift test postoperatively.

Compared to the femoral tunnel parameters obtained in our study, in the study by Youm et al. [22], the femoral tunnels are lower and deeper in the position and more oblique in the coronal plane. The different operative method used, in a population of different race with lesser number of cases in the study could be the

Table 9. Coordinates of ideal position of ACL insertion on grid of bernard and hertel [23] reported in literature

Study	Depth			Height			Study design	Type of Study
	AMB	PLB	Mean	AMB	PLB	Mean		
Colombet et al. [24]	26.4	32.3	29.35	25.3	47.6	36.45	Descriptive laboratory study	Cadaveric study
Zantop et al. [25]	18.5	29.3	23.9	22.3	53.6	37.95	Descriptive laboratory study	Cadaveric study
Tsukada et al. [26]	25.9	34.8	30.35	17.8	42.1	29.95	Descriptive laboratory study	Cadaveric study
Yamamoto et al. [27]	25	29	27	16	42	29	Descriptive laboratory study	Cadaveric study
Bernard and Hertel [23]			24.8			28.5	Descriptive laboratory study	Cadaveric study
Forsythe et al. [28]	21.7	35.1	28.4	33.2	55.3	44.25	Descriptive laboratory study	Cadaveric study
Tempere et al. [29]			29.2			25.2		Patient study
Iriuchishima et al. [30]			24.1±3.9			33.5±7.7		Patient study
Our study			28.45			25.81	Prospective case study	Patient study
Mean across studies			27.3			34.35		

Note: Data represent percentage by depth (deep to shallow) and lateral wall height (high to low) measured on the grid. AMB: Anteromedial Bundle; PLB: Posterolateral Bundle.

reason for this difference in the femoral tunnel position and obliquity.

The mean value across studies (**Table 9**) for femoral tunnel in term of depth (parallel to Blumensaat line) and height (perpendicular to Blumensaat line) are 27.3% and 34.35%. The value for the same parameters in our study was 28.45% and 25.81% respectively. Comparing the given mean of the table data, it is observed that the placement of femoral tunnels in our patients is deeper and higher in the location. However, it should be noted that most of the studies mentioned in the table are cadaveric study models and all are descriptive laboratory study. The study design used in these studies are different and simple mean calculation doesn't give the femoral anatomic location of the ACL. This could be the reason for the difference in the outcome of our study.

Strength and limitations

The strength of our study is that outcome of ACL reconstruction has been studied in mostly non athletic, Indian patients who have low demands. There is paucity of data in literature with regard to clinical outcome and adequate femur and tibial tunnel position post ACL reconstruction in Indian non athletic patients, this study provides baseline data with respect to that. These values can be used intra-operatively if fluoroscopy-assisted surgery is to be done.

Thus, with established mean ranges of these tunnel positions, in two planes over the femur and tibial side, the ACL graft placement can be evaluated for anatomic or non-anatomic location. This study attempts to clear the controversy over the use of technique in anatomic tunnel placement.

This study is limited by the smaller sample size and shorter follow up. Although it is a 3-D CT based study, the measurements are done on 2-D screen. Also, the digital software which was used for measurements has its own limitations. Small errors in estimating the landmark positions for the measurements as determined by this study and the actual anatomic arthroscopic view may exist. However, given the current quality of 3-D CT images, this margin of error would be limited and would not impact clinical utility of the study.

The anatomic landmarks taken for measurement purpose have anatomic variations. The Blumensaat line is not actually a straight line, as one might believe on the basis of lateral radiographs; in reality, it is an S-shaped curve. Also, the angular orientation of the Blumensaat line is variable, and its location relative to the intercondylar axis can be more posterior, central, or more anterior on the femoral condyle. Because of this great anatomic variation, evaluating the outcome by means of percentages relative to fixed chosen references (such as the length and height of the femoral condyle and length and width of tibial plateau) might introduce a measurement bias and could explain some of the variance.

Conclusion

This study helps to ascertain that the ACL reconstruction via anteromedial portal technique using femoral offset zig followed by post-operative home-based rehabilitation technique gives favorable clinical outcomes in Indian non-athletic patients [18, 19]. All patients had improvement in stability of knee after the surgery. The position of femoral tunnels was anatomical in most of the patients. Hence we conclude that the anteromedial portal technique of ACL reconstruction provides favorable clinical outcome and adequate anatomical tunnel placement in Indian non athletic patients.

Disclosure of conflict of interest

None.

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