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Antero-posterior axis of tibia in patient undergoing total knee replacement in Indian population

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ABSTRACT

Introduction: Aim of this CT- based study was to find out a reliable anatomical axis for proper rotational placement of the tibial component during knee replacement surgery in the Indian population.
Material and methods: CT scanning was performed pre-operatively on all the 45 patients (13 men, 32 women, total 68 knees) due to undergo knee replacement for osteo-arthritic knees. The tibial anteroposterior (AP) axis is defined as a line drawn perpendicular to the surgical epicondylar femoral axis and passing through the center of posterior cruciate ligament (PCL) attachment. Angles between various anatomic landmarks and the defined tibial AP axis were identified.
Results: The mean angle between line connecting the medial border of patellar tendon and centre of PCL and the defined tibial AP axis was 0.06 (−5 to 7; SD 2.65) and was closest to defined AP axis of tibia. This axis remained the closest irrespective of the varying femoro-tibial angle and severity of tibial bowing.
Discussion: In our patients, the line connecting the medial border of patellar tendon to the centre of the PCL has been found to be an independent, reliable and reproducible rotational axis for placing the tibial trial and definitivite prosthesis. This is particularly helpful for those surgeons, who prepare the femur earlier than the tibial cut and trial.
Conclusion: This tibial AP axis along with other anatomical landmarks is a reliable and reproducible landmark for implanting the tibial prosthesis in a proper rotational alignment in the Indian population.

1. Introduction

Rotational mal −alignment after total knee replacement surgery (TKR) induces patella-femoral complications, femoral-tibial problems, and early wear.[1–5] When balancing a knee mechanically, the *trans*-epicondylar axis of the femur has emerged as a useful and reliable anatomical and functional reference point for the femur. However, controversy persists regarding the correct anteroposterior axis of the tibial component. The medial one third of the tibial tubercle is widely used as the anterior reference for the rotation. However, there can be marked variation in proximal tibia amongst ethnic groups. Marked tibia vara exists in the Indian population especially those who are the candidates of knee replacement surgery.[6]

This is in common with the other Asian populations.[5,7–9] In these patients such bony landmarks become unreliable and has been found that the tibial component can be placed malrotated if ethnic variations are not taken into consideration.[5] Posterior condylar axis,[10] the mid sulcus line,[11] and other landmarks[12] have been described but are distorted due to arthritic process and therefore difficult to identify during surgery.

The line connecting the center of the posterior cruciate ligament (PCL) to the medial patellar tendon at its insertion[9] and from the center of the posterior cruciate ligament to the anterior border of the proximal third of the tibia[7] have been noted to be reliable rotational landmarks for tibial components place-ments in Japanese and Korean patients respectively. However, these references need further evaluation in context with Indian patients who are undergoing knee replacement surgery.

This study, which is a CT based study, was therefore undertaken, to identify femoro-tibial angles, extent of tibial bowing and a reliable anatomical antero- posterior axis (AP) in Indian patients which would help surgeons Implant the tibial component properly.

2. Materials and methods

This was a single institution prospective study conducted in the Departments of Orthopaedics and Radiodiagnosis, which was

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approved by the Institutional Ethics Committee. 45 patients (68 knees) aged above 40 years with either primary or secondary osteoarthritis who were to undergo Total Knee Arthroplasty were included in the study. The study period extended from November 2014 till October 2015.

A standing radiograph of both the lower limbs (AP view) and CT scan of the lower limb (on the side of affected knee) extending from the adductor tubercle of femur till the level of ankle joint was done as part of the study. Informed consent was taken prior to these investigations. The patient was told about the radiation exposure, which in the CT study was about 1.5–2.0 mGy. This is significantly lesser than the radiation exposure that occurs during a normal diagnostic CT scan of the knee (about 8.0–10.0 mGy). No harmful effects are expected at this low dose. Patients with previous lower limb fractures, flexion contracture >30° or any congenital or pathological malformations of the lower limb were excluded from the study.

The parameters used by the authors in this study to determine the Antero-Posterios axis of the Tibia are the same as that used in a similar study conducted by Kim CW et al.[7]

The socio-demographic data of all patients was tabulated. This included age, sex, height, weight, and body mass index (BMI). History-taking and clinical examination were completed.

Subsequently, standing AP radiograph of the lower limb was acquired. In the AP radiograph, femoro-tibial angle was measured based on the anatomical axis of femur and tibia (Fig. 1). Patients were divided into three groups based on the value of this angle. The varus group had femoro-tibial angle less than 0°, the angle was 0–6° in the neutral group and more than 6° in the valgus group.

Tibial bowing was also determined (Fig. 2). For this purpose, the tibia was divided into four equal parts and an angle was calculated between the axis of proximal one–quarter and distal one-quarter. The axis of proximal one –quarter is that line which joins the midpoint of the medial and lateral tibial spines and mid-point of intra-medullary canal. The axis of the distal one –quarter is that line which joins the mid point of the talar dome and the mid point of the intra-medullary canal. If the point of intersection of the two axes is oriented medially, it is called medial bowing and the opposite is lateral bowing. Based on this,the patients in the study were divided into two groups. One group showed <3° medial/lateral bowing and the other group showed >3° medial/lateral bowing.

The next step was a CT scan of the lower limb. CT was done in a 16 slice scanner (Somatom Emotion, Siemens, Erlangen,Germany). The patient was placed supine on the CT table with knees in neutral position and arms by the sides or hands over abdomen. A lead apron was used to shield the rest of the body from unwanted radiation exposure. 10 mm axial sections were acquired from the adductor tubercle of femur till the ankle joint. Later coronal reconstruction was done. In axial sections, the line joining the sulcus of medial femoral epicondyle to the lateral femoral

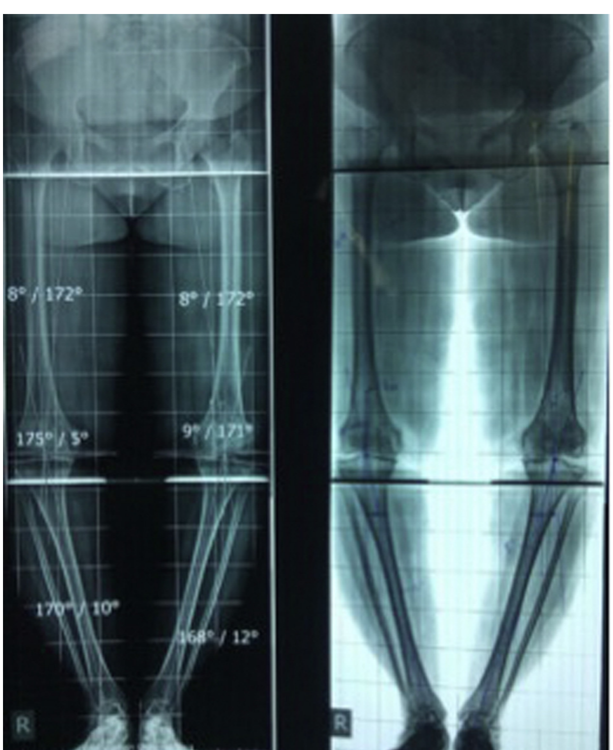

Fig. 1. Standing AP radiograph of the lower limbs to determine femoro-tibial angle.

Fig. 2. The standing AP radiograph of the lower limb is also used to determine tibial bowing.

epicondyle is called the surgical transepicondylar axis (SEA). It is projected onto the axial section at tibial plateau level where posterior cruciate ligament (PCL) is seen at the posterior condylar notch. The antero-posterior (AP) axis of the tibia is defined as a line perpendicular to the SEA, which passes through the center of PCL. The AP axis can now be projected onto other axial sections as required and accordingly angles can be measured in these sections (angles A-F). All these measurements were done manually (Figs. 3–10).

These levels include-

- Angle A- angle between AP axis and line connecting medial one-third of tibial tubercle or patellar tendon to PCL at the level of the patellar tendon-tibial attachment
- Angle B- angle between AP axis and line connecting medial border of patellar tendon to PCL at the same level as angle A
- Angle C, D, E- angle between AP axis and lines connecting most prominent anterior border of tibia to PCL at proximal one-third, mid level and distal one-third of tibia respectively
- Angle F- angle between AP axis and line connecting lateral border of the extensor hallucis tendon to PCL at the level of the ankle joint

Data were summarized as mean + standard deviation (SD) and compared by Mann-Whitney *U* test. A two-tailed p value < 0.05 was considered statistically significant. Analysis was performed on SPSS software (Windows version 7.0).

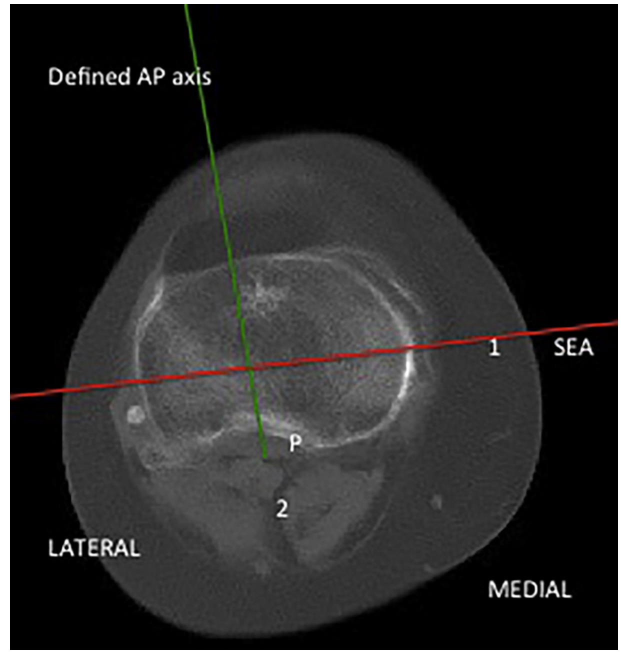

Fig. 4. Axial CT image in which line 2 (denoted in Green color) is the defined AP axis. It is perpendicular to line 1 and passes through the center of the posterior cruciate ligament (PCL).

3. Results

Table 1 shows the mean values of the various angles between the defined tibial AP axis and the lines connecting the center of the PCL attachment to the most prominent anterior border at the proximal one-third, middle third, distal one-third and the ankle level.

The closest AP axis was analysed with respect to the femoro-tibial angles and the tibial bowing.

The mean femorotibial angle was varus (<0°) in 48 knees (mean 10.68, −29 to −3),

neutral (0° to 6°) in 20 knees (mean 3.5, 0° to 6°). There was no valgus knee found in our study. Nineteen patients had tibial bowing with in a range of 0–3°, while 49 had bowing exceeding 3°.

At the level of patellar tendon attachment to the centre of PCL, the mean values between the defined Anteroposterior axis of the tibia and the lines from the medial border of the patellar tendon and medial one-third of the tibial tuberosity were 0.06°(SD 2.85°, −5° to 8°) and 3.26°(SD 2.53°, −2° to 10°) respectively.

In the varus group, the closest mean angle to the defined AP tibial axis was the angle B, which was −0.50°(SD2.63, −5 to 7). Angle C 0.65° (SD 4.01, −6 to10), was the second most closest value; while in the neutral group the, the closest mean angle to the defined AP tibial axis was the angle D, which was −1.10(SD7.22, −16 to 17)

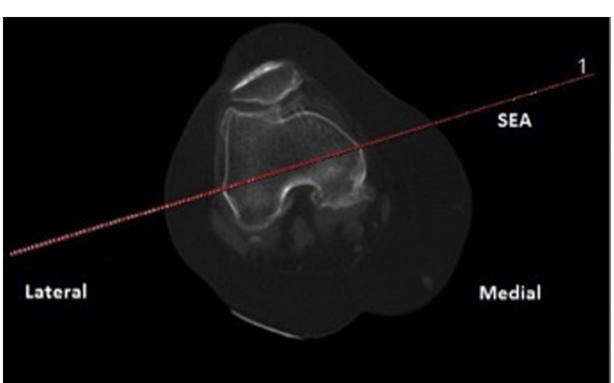

Fig. 3. Axial CT image in which line 1 (denoted in Red color) connects the sulcus of the medial femoral epicondyle to the lateral epicondyle. This is called the 'Surgical Epicondylar Axis' (SEA).

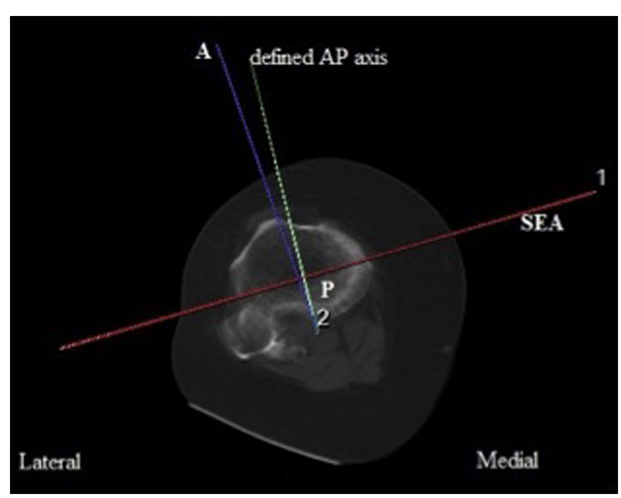

Fig. 5. Axial CT image at the level of the patellar tendon attachment, in which angle A is the angle between the AP axis and the line connecting the medial 1/3rd of the patellar tendon to the PCL.

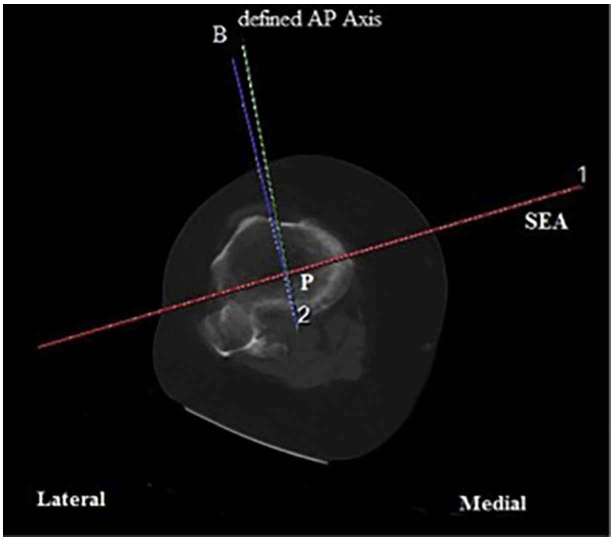

Fig. 6. Axial CT image at the same level as Fig. 5, in which angle B is the angle between the AP axis and the line connecting the medial border of patellar tendon to PCL.

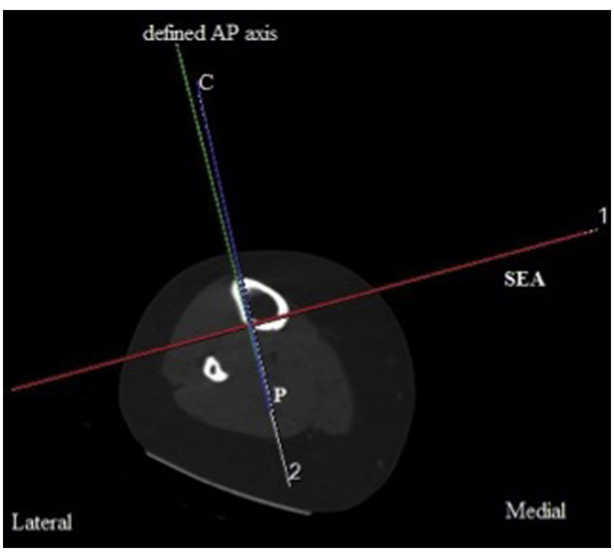

Fig. 7. Axial CT image at the level of the proximal third of tibia in which angle C is the angle between the AP axis and the line connecting the most prominent point on the anterior border of tibia to PCL.

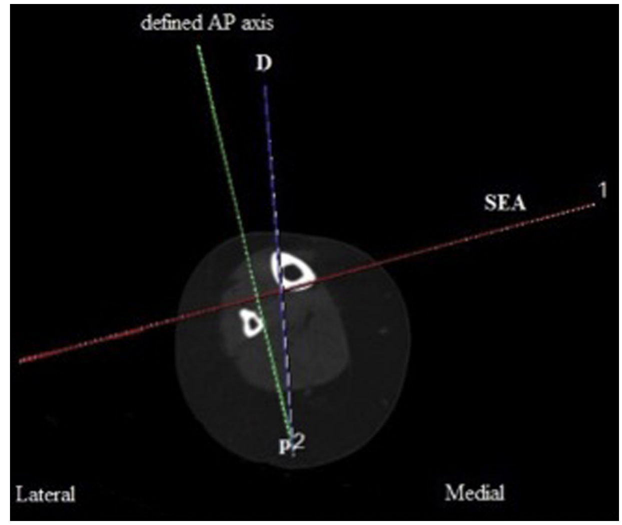

Fig. 8. Axial CT image at mid-tibial level in which angle D is the angle between the AP axis and the line connecting the most prominent point on the anterior border of tibia to PCL.

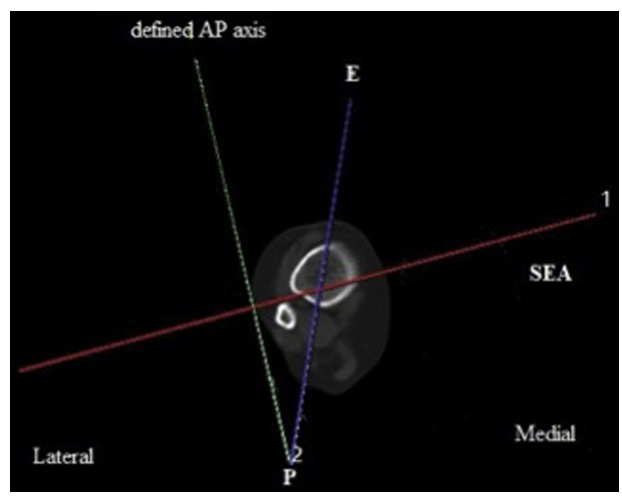

Fig. 9. Axial CT image at the level of distal third of tibia in which angle E is the angle between the AP axis and the line connecting the most prominent point in the anterior border of tibia to PCL.

Table 1
Distribution of AP axis of tibia according to femoro-tibial angle of patients undergoing TKR (n = 68).

AP axis of tibia (degree)	Total (Mean ± SD Range) n 68	Varus(<0°) (n = 48) Mean, SD, Range	Neutral(0 to 6°) (n = 20) Mean, SD, Range	U value	p value
A	3.26 ± 2.53 (−2 to 10)	2.87 ± 2.67 (−2 to 10)	4.20 ± 1.91 (1 to 10)	303.00	0.017
B	0.06 ±2.85 (−5 to 8)	−0.50 ± 2.63 (−5 to 7)	1.40 ± 2.96 (−3 to 8)	303.50	0.018
C	1.12 ± 4.31 (−6 to 10)	0.65 ± 4.01 (−6 to10)	2.25 ± 4.90 (−5 to 10)	395.00	0.253
D	−3.94 ± 6.82 (−18 to 17)	−5.13 ±6.34 (-18 to 17)	−1.10 ± 7.22 (−16 to 17)	312.00	0.024
E	−16.49 ± 9.56 (−41 to 16)	−18.08 ± 10.57 (-41 to 16)	−12.65 ± 4.88 (−22to 16)	302.50	0.017
F	−16.49 ± 9.56 (−45 to 33)	−15.67 ± 12.30 (−45 to −2)	−11.25 ± 6.84 (−23 to 33)	328.50	0.041

Table 2
Distribution of AP axis of tibia according to tibial bowing angle of patients undergoing TKR (n = 68).

AP axis of tibia (degree)	Lateral tibial bowing angle (≤3°) (n = 19)	Lateraltibial bowing angle (>3°) (n = 49)	U value	p value
A	3.37 ± 1.98	3.22 ± 2.73	459.50	0.935
B	0.26 ± 3.02	−0.02 ± 2.81	449.50	0.827
C	1.05 ± 4.20	1.14 ± 4.40	459.50	0.935
D	−1.11 ± 7.94	−5.04 ± 6.07	344.50	0.098
E	−12.32 ± 8.39	−18.10 ± 9.57	346.50	0.104
F	−9.74 ± 12.03	−16.16 ± 10.31	330.50	0.065

Table 2 compares A to F between two groups of the tibial bowing. No statistical difference was noted between any angles. This signifies that extent of tibial bowing did not change the closest angles to the mean Tibial AP axis.

4. Discussion

We found that the line connecting the medial border of patellar tendon to the centre of the PCL was closest but externally rotated by 0.06° to the true AP axis of the tibia and therefore can be reliably used as a landmark to rotational align the tibial component. The more common landmark, that is the line joining the medial one-third patellar tendon to the centre of PCL was externally rotated by 3.2°. The line joining the anterior tibial border at the proximal one third to the centre of the PCL was external rotated by 1.1° and was the second closest axis resembling the true AP axis of the tibia. This would mean that, in extension, if the femur in implanted in the axis to the surgical epicondylar axis, the tibial component can be placed along the line drawn from the centre of the PCL attachment to the medial border of the patellar tendon. This has been found to be an independent, reliable and reproducible axis, which matches with the finding of Akagi.[9] This is particularly helpful for those surgeons, who prepare the femur earlier than the tibial cut and trial. The relationship of rotational alignment of components and patellar tracking are well described.[4,10,13–16] Excessive external rotation of the tibial component may cause tibia to rotate internally, and abnormal patellar tracking.[15] Internal rotation placement of the tibial component, on the other hand can lead to patellar subluxation.[4,14,16]

In our study sample, according to the femoro-tibial angle, only neutral and varus groups were delineated, as there was no valgus knee. Angle B (angle between the defined AP axis and the line connecting the medial border of the patellar tendon to the PCL) was the closest to the defined tibial AP axis in all groups. The value of angle B was also closest to the tibial AP axis within a mean ± SD of −0.50 ± 2.63 when there was varus alignment (<0°). It was externally rotated by a mean ± SD of 1.40 ± 2.96 in group with neutral alignment (0–6°).

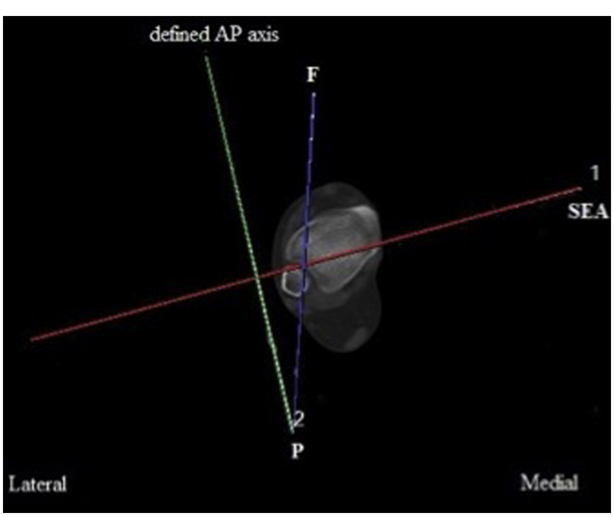

Fig. 10. Axial CT image at the level of the ankle joint in which angle F is the angle between the AP axis and the line connecting the lateral border of extensor hallucis tendon to PCL.

To measure the extent of tibial bowing in Indian patients, We followed the Kim CW study.[7] The tibial diaphysis was therefore divided into four equal parts to have a better representation of the deformity. The data obtained was itself was divided into two groups; Deformity less than 3 ° was considered mild, while more than 3 ° of deformity was considered more severe. The results suggest that line drawn from the medial border of the patella to the centre of the PCL was closest to the true AP tibial axis in both the groups. It therefore means that in Indian patients Line B can safely be used reliably as the rotational tibial axis irrespective of the degree of tibial bowing deformity.

The advantage of using PCL attachment as one of the landmarks is that unlike other landmarks, which are difficult to identify, the attachment of PCL is easily identified on CT scans and per-operatively as it is present in most of the arthritic knees.[17]

There are few limitations of the study. The number of patients is small, however since all these patients underwent knee replacement, we feel it is a uniform representation of advanced arthritic knees in Indian population. Other limitation is the presence of inter-observer variability. Also, possibilities of error in the judgment and variability in measurement could have occurred due to presence of flexion contracture in some of these patients and, presence of some natural longitudinal rotation between femur and tibia even in those patients who could have extended their knee completely.

Due to the limitations, and variability of the individual anatomy, absolute landmarks for rotational components for tibia are difficult to ascertain. However, in our patients, the anteroposterior line connecting the centre of PCL attachment to the medial border of the patellar tendon is a reliable, reproducible axis and can be used along with other landmarks of the patients as observed during and before surgery, to implant the tibial component in correct antero-posterior axis.

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