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IDENTIFYING THE ROTATIONAL AXES OF DISTAL FEMUR IN SOUTH ANDHRA POPULATION OF INDIA USING IMAGE TOOL SOFTWARE

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ABSTRACT: AIM: To study the normal relationship of the anteroposterior (APA), transepicondylar (TEA) and posterior condylar (PCA) axis of normal cadaveric femoral bones using digital technology and special computer program. **MATERIAL AND METHOD:** The study comprised of 196 dry adult femora from 98 right and 98 left sides irrespective of sex and age belonging to Andhra Pradesh population of India. The bone collections were obtained from the Anatomy department, Narayana medical college, Nellore, India. The femurs were kept in normal anatomical position on OB. The photographs were taken from the distal end of all the femurs placing the camera lens 10cm constantly away from it with a digital camera. Using the reference points, angle between APA-TEA, APA-PCA and TEA-PCA were identified. The statistical significance of difference between the right and left groups was evaluated by using Student paired t-test. Data were presented as mean±SD. P-value less than 0.05 were considered statistically significant. **RESULTS**: The relationship of the angle between the APA-TEA, APA-PCA and TEA-PCA were observed. The angle of AP-TE, AP-PC and TE-PC was 94.84±3.43°, 87.64±1.62° and 6.84±2.71° respectively on right side. On the left side, the angle of AP-TE, AP-PC and TE-PC was 92.36±4.06°, 93.61±2.54° and 3.19±0.99° respectively. **CONCLUSION:** The normal femoral rotational alignment from cadaveric bone study using computer aided software can be helpful to the surgeon in selecting appropriate reference axis in any particular knee surgeries. In this regard the present data can be taken into consideration for the femoral rotational alignment during any intraoperative surgeries of knee and in total knee arthroplasty.
KEYWORDS: Femur, Rotational axes, Imaging software, Total knee arthroplasty, Distal femur.

INTRODUCTION: Accurate rotational alignment of the femoral component is an important surgical factor for successful total knee arthroplasty (TKA).[1,2,3,4] Improper rotation of the femoral implant during TKA may lead to abnormal patellofemoral kinematics, stiffness, abnormal gait patterns, flexion instability, asymmetrical flexion gaps and early failure.[5,6,7]

Various anatomic landmarks have been described for serving as rotational reference points for primary TKA. Three rotational axes referenced in distal femur for the placements of the femoral component during TKA are 1) anteroposterior axis (APA) or Whiteside's line, 2) transepicondylar axis (TEA) and 3) posterior condylar axis (PCA).[8,9,10]

Some degrees of external rotation of the femoral component are known to be crucial to prevent patellofemoral complications such as lateral tracking, subluxation and patellar component failure[11]. There is a controversy in the literature regarding the amount of external rotation and the ideal anatomical axis for optimal rotational alignment of the femoral component. Previous studies suggested that the APA of the distal femur was an easy and reliable landmark for

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rotational alignment of the femoral component, especially in the valgus knee.[12,13,14] However a number of studies have supported the clinical TEA i.e. the line connecting the medial and lateral epicondylar prominences, most consistently recreates a balanced flexion space and normal patello-femoral tracking.[15]

In the literature, most of the studies on these axes were in osteoarthritic knees during the arthroplasty procedures, the results of which might not represent normal relationship due to the deformed bones in those cases. Moreover reference axis from plain X-ray, CT or MRI scan can be inaccurate because most of these will be diseased cases of the knee and the axes measured may not be as accurate as in the normal subjects.[13,16]

Knowing the normal relationship of the above said three axes, it can be helpful to the surgeon in selecting one or more appropriate reference axis to properly rotate the femoral component in any particular knee during the operation.[17,18] In the present study computer software is applied to study the relationship among the APA, PCA and TEA in cadaveric femurs instead of using manual goniometer.

MATERIAL AND METHODS: The study comprised of 196 dry adult femora from 98 right and 98 left sides irrespective of sex and age belonging to Andhra Pradesh population of India. The bone collection was obtained from the Anatomy department, Narayana medical college, Nellore, India.

As criteria of inclusion, none of the femora presented fractures, malformations, damage due to conservation or pathologies that could influence the development of the studied region. Each of the femurs was digitally photographed in standardized position on acrylic osteometric board (OB). The femurs were kept on normal anatomical position, of which the posterior most point of medial and lateral condyles (distally) i.e. posterior condylar axis (PCA), and the greater trochanter (proximally) were rested on OB and the anterior surface of shaft directed upwards. The photographs were taken from the inferior surface of distal end of all the femurs by placing the camera lens 10cm constantly away from it (Fig. 1) with the help of a digital camera (Sony DCR W270, Tokyo, Japan). The stored images were transferred to a PC unit.[19]

All the digital images were processed to locate the six reference points and three lines using Adobe Photoshop 7.0 for Windows and the final images were saved in jpeg format (Fig. 2a). The formatted images were transferred to Image Tool Software (UTHSCSA Image Tool for Windows version 3.0, San Antonio, TX, US) and analyzed (Fig. 2b). With the help of reference points the angle between APA-TEA, APA-PCA and TEA-PCA were identified. The data was fed in computer program SPSS ver.10 for Windows (SPSS Inc., Chicago, IL, USA). The statistical significance of difference between the right and left groups was evaluated by using Student paired t-test. Data were presented as mean±SD. P-value less than 0.05 were considered statistically significant.

Axes measured in the distal end of femur were,
1. APA: Anteroposterior axis is the line drawn from the trochlear or patellar groove, anteriorly to the apex or center of the intercondylar notch, posteriorly.[20]
2. TEA: Trans-epicondylar axis is the line joining the most prominent point of the medial and lateral epicondyles of femur.[21]
3. PCA: Posterior condylar axis is the tangent line joining the posterior point of the medial and lateral femoral condyles.[7]

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Angulations calculated between these three axes were AP-TE; AP-PC and TE-PC (Fig.2b)

RESULTS: The relationship of the angle between the APA-TEA, APA-PCA and TEA-PCA were observed. The angle of AP-TE, AP-PC and TE-PC was 94.84±3.43°, 87.64±1.62° and 6.84±2.71° respectively on right side. On the left side, the angle of AP-TE, AP-PC and TE-PC was 92.36±4.06°, 93.61±2.54° and 3.19±0.99° respectively (Table 1).

DISCUSSION: There is no compromise regarding the use of the axes and angles for measuring the rotation of the femoral component. Rotation arrangement of the femoral component in TKA is imperative for the outcome of the surgery. Malrotation of the femoral component on the femur may lead to patellofemoral dislocation or subluxation, to wear or loosening of the patellar component.[22] The correlation of AP-TE; AP-PC and TE-PC axes and angles noted in the literature vary as they are found to have different methodology in each study.

Accomplishing optimal femoral component rotational alignment in TKA is crucial in establishing a balanced knee reconstruction and ensuring adequate patello-femoral tracking. Unbalanced knees can lead to instability, patellofemoral problems, persistent pain, stiffness, and generally poorer outcomes including early failure.[23] Although the desired positions and guiding landmarks for placement of the femoral and tibial components in the coronal and sagittal planes have been well described, rotational positioning of the components can still be problematic.[24,25,26] Performing a TKA requires the accurate execution of key bone cuts in the correct orientation to the appropriate axes. There is huge potential for cumulative errors to occur, which may have significant and dramatic effects on function and longevity.[16]

A number of studies are found in relation to the anatomy and functional axes of the normal femur.[13,27,28,29] These include the use of the TEA, APA and PCA. Various intraoperative techniques have been described to achieve the optimal femoral component rotation. The axis of the posterior femoral condyles has normally been used as the reference for neutral rotation of the femur.[30] This was thought to be a reasonable landmark because the goal of TKA is to re-establish alignment of the anatomic femoral condyles.[11,31] However, recent biomechanical analyses using instant centers of motion analysis have suggested that the TEA parallels the primary center of rotation of the knee joint but not the posterior condylar axis.[23] The fixed axis that closely approximate the epicondylar axis reported is the TEA has currently attracted attention as an ideal rotational reference that provides functional kinematics (31 Doro LC). Furthermore, several authors also reported that the TEA most consistently recreates a balanced flexion gap.[3]

In a study on 100 arthritic knees in TKA reported by 32 Poilvache et al, the AP-TE, AP-PC and TE-PC angle was 90.33±2.44, 86.92±2.71 and 3.60±2.02 degrees, respectively. Matsuda et al[3] findings of the femoral measurements showed the AP-PC and TE-PC angles of 83.70±2.44, 6.03±3.60 degrees in normal knees and 83.43±2.54 and 6.00±2.35 degrees in varus knees, in which AP-TE angle was not reported. Arima et al[12] studied AP-PC and TE-PC angles in normal femurs by visual measurement were 86.2±2.0 and 4.4±2.9 degrees and by radiographic measurement were 86.9±1.7and 5.7±1.7 degrees respectively, with radiographic measurement less than the visual measurement.

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In the present study relationship of the angle between the AP-TE, AP-PC and TE-PC was 94.84±3.43°, 87.64±1.62° and 6.84±2.71° respectively on right side. On the left side, the angle of AP-TE, AP-PC and TE-PC was 92.36±4.06°, 93.61±2.54° and 3.19±0.99° respectively. These observations were almost coinciding with the other findings and is found to significant ($p < 0.0001$). The comparison of angles of all the femurs observed between AP-TE and AP-PC was 93.60±3.95 and 90.62±3.67 respectively with the mean difference 2.98±5.18 was also found to be significant (Table 2). However this study is only restricted to the normal femurs but not to the arthritic and other deformed femoral axes which may differ from the present study.

Using image tool software technique, the relations between AP, TE and PC axes in normal dry femora observed in the present study may provide a minimal error of these measurements, as these measurements are mostly done on the surgical table at the time of TKA procedures. The clinical TEA is found to be more significant than the other axis in this study as well with the other studies. As this TEA has the perpendicularity to the mechanical axis of femur and tibia with knee fixed at 90°,[33,34] makes it a sound landmark for rotational alignment of femurs in TKA.

Even though the epicondyles have been considered as the reliable anatomic landmarks, it is difficult to impound its peak exactly during the surgery.[12] Since the aim of TKA is to achieve a normal rotational alignment of the femur, a multi reference axes should be used rather depending upon any single rotational axis of the distal femur.[35] Though there are many controversial debates regarding the rotational measurements, the normal cadaveric bone study in particularly the computer aided image software methods can be relied upon than the visual calculated measurements. In this context, the normal anatomical knowledge of rotational axes of distal femur namely AP, PC and TE and its association in the cadaveric dry bones must be studied and verified. The data presented in this study therefore may be taken into deliberation in the analysis of the rotational axes during TKA.

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Variables	Right side Mean±SD (In degrees) n=98	Left side Mean±SD (In degrees) n=98	t-value	p-value
AP-TE	94.84±3.43	92.36±4.07	4.62	< 0.0001*
AP-PC	87.64±1.62	93.61±2.54	19.61	< 0.0001*
TE-PC	6.84±2.71	3.19±0.99	19.61	< 0.0001*
Table 1: Comparison between right and left femurs for AP-TE, AP-TC and TE-PC				

Independent sample T-Test was applied. * represents extreme significant.

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FEMUR		Mean±SD (In degrees) n=196	Paired Difference Mean±SD (In degrees)	t-value	p-value
Pair 1	AP-TE	93.60±3.95	2.98±5.18	8.048	< 0.0001*
	AP-PC	90.62±3.67			
Pair 2	AP-TE	93.60±3.95	88.58±3.19	389.130	< 0.0001*
	TE-PC	5.01±2.74			
Pair 3	AP-PC	90.63±3.67	85.61±5.54	216.192	< 0.0001*
	TE-PC	5.02±2.74			
Table 2: Comparison of both side of femurs for AP-TE, AP-TC and TE-PC					

Paired sample T-Test was applied. * represents extreme significant.

Figure 1: The orientation of femur and camera on the osteometric board. A-optical axis; B-anatomical axis; C-camera lens.
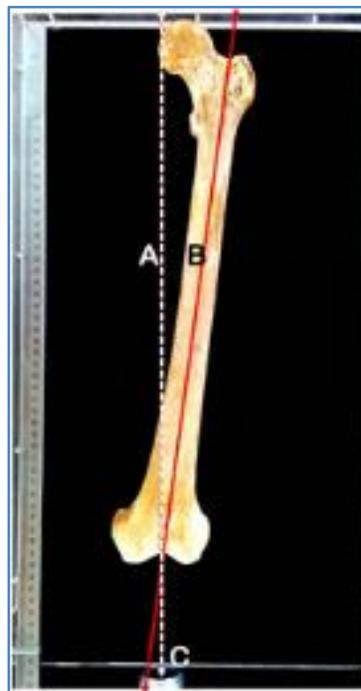
Figure 1

Figure 2a: Schematic diagram of distal femur showing the rotational axes and its angles. APA–anteroposterior axis; TEA–transepicondylar axis; PCA–posterior condylar axis; AP-TE–angle between APA and TEA; AP-PC–angle between APA and PCA; TEA-PCA–angle between TEA and PCA; TEA'–parallel line to TEA; 1-6–reference points (Red dots). **2b:** Screenshot image of distal femur and its axes for measurement of angles using image tool software in Windows.
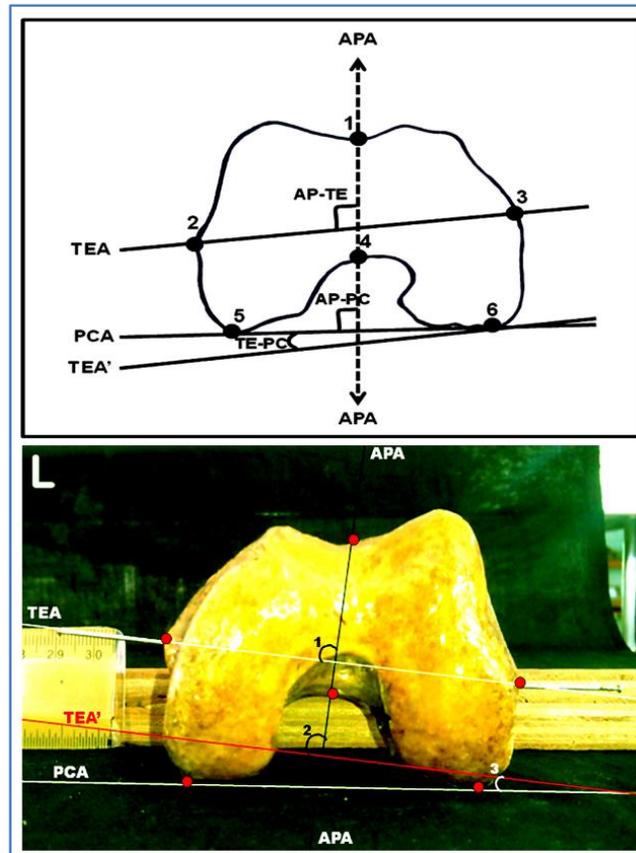
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Figure 2a & 2b

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