# Implications of Reference Axes Used for Rotational Alignment of the Femoral Component in Primary and Revision Knee Arthroplasty

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**Abstract:** A careful review of the literature revealed that no data had been reported on the angular difference or similarity between the posterior condylar axis used by many surgeons for primary total knee arthroplasty and the transepicondylar axis, which has been considered a useful anatomical landmark for femoral component placement in revision total knee arthroplasty. The purpose of this study was to determine whether measurable differences exist between the posterior condylar axis and the transepicondylar axis of the human femur. Nineteen pairs of human donor femora were measured. This study demonstrated that when the posterior condylar axis was taken as 0° of rotation, the transepicondylar axis was found to be approximately 5° externally rotated for both right and left femora, a significant difference ($P < .05$). However, there was no statistically significant difference in the angle measured between the posterior condylar axis and the transepicondylar axis when comparisons were made between matched right and left femora ($P > .05$). It is suggested that this information can be applied to improving the techniques currently used in the placement of both primary and revision femoral knee components. **Key words:** knee arthroplasty, revision, component, rotation.

Following the advent of total joint arthroplasties in the mid 1970s, there began an era of discussion directed at understanding mechanisms of failure in various types of arthroplasties. With regards to total knee arthroplasty (TKA), only a few publications have thoroughly outlined mechanisms of failure and methods for improving the clinical success of the technique.[2,5,6,20] A comprehensive article published on the subject of primary TKA failure by Moreland,[20] has emphasized that "... prosthetic alignment is the most important factor influencing postoperative loosening and instability." This view has been extensively supported in the literature.[2,3,5,6,12,13,16,27] Lotke and Ecker,[17] using radiographic criteria, have also documented a statistically significant correlation between a good clinical result and a well-positioned prosthesis with initial arthroplasties.

Primary TKA is currently enjoying improved long-term clinical success as biomechanical studies and basic science principles are applied to improve the technique.[4,11,24] However, comparable advances in the realm of revision knee arthroplasty have not been appreciated.[8] Obstacles such as infection, soft tissue contractures, and poor bone stock make revision TKA a challenge. Perhaps the most difficult technical aspect of revision arthroplasty deals with the inherently distorted tibial and femoral anatomy used to

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align revision components. A technical consideration that has come to our attention deals with the rotational alignment of the femoral component in revision TKA. Hungerford and Krackow[12] support using an axis through the posterior femoral condyles in primary TKA to rotationally align the femoral component but have also suggested that an axis through the epicondyles, which they noted to be "externally rotated about 10°," may be used as a secondary reference. Laskin and Rieger[16] concur, recommending a posterior femoral condylar axis to rotationally align the femoral component in primary TKA with a proviso that the transepicondylar axis be used as a rotatory reference if the condyles are eroded. Indeed, the condition of the femoral condyles at revision TKA can be interpreted as analogous to a clinical situation in which both femoral condyles are eroded. Unfortunately, there have been no studies published that report the angular difference or similarity between the posterior condylar axis used by many surgeons for primary TKA and the transepicondylar axis, which may be useful as a guide for femoral component placement in revision TKA.

The purpose of this study was to use retrieved, paired human donor femora to establish the average degree of rotation between the posterior condylar axis and the transepicondylar axis in order to understand whether any significant difference or similarity exists between these two reference axes. Our hypothesis was that the posterior condylar axis and transepicondylar axis would be dissimilar, giving measurably different degrees of rotation to the femoral component.

## Materials and Methods

Nineteen pairs of human donor femora were used in this study. Five pairs were obtained from females and 14 pairs from males. Ages ranged from 17 to 89 (average age, 43 ± 19 years). Specimens were cleaned of soft tissue, and accessioned and stored in 70% ethanol prior to making measurements.

A modification of an established technique designed by Ruff[25] was used to align each femur according to three coordinate axes (x, y, and z) (Fig. 1). This system was used to position each specimen in a three-dimensional space along its biomechanical axis (z axis) with the condyles flat on a leveled measuring table, reproducing the position of the femur as it would be aligned in a femoral cutting-jig during joint arthroplasty. Measurements necessary for determining the angular differences between the posterior condylar and transepicondylar axes could then be established.

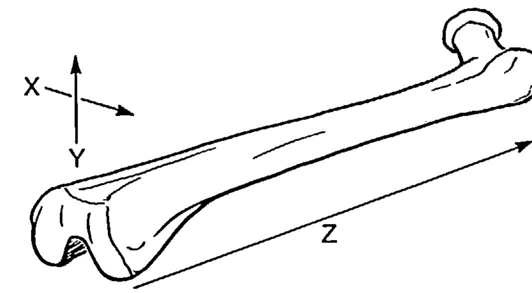


**Fig. 1.** Representative diagram demonstrating the three spatial reference axes used to orient the femur for reproducible measurement taking.

The heights of the lateral and medial epicondyles, landmarks that coincide with the attachment of the joint-stabilizing collateral ligaments, were then measured to the nearest tenth of a millimeter. This was accomplished by taking the distance from the eminence of each landmark to the measuring table. Each measurement was repeated 3 times in separate trials and verified by an independent observer, with the average of the three measurements taken as the value used for each calculation. The difference between the mean medial epicondylar and mean lateral epicondylar height defined the length of the opposite side of a right triangle (Fig. 2) The distance between the two epicondyles from apex to apex—the transepicondylar width (TEW)—which was also averaged 3 times, provided the hypotenuse of the same right triangle (Fig. 2). Using a simple trigonometric relationship of arcsin θ, the angle θ between the posterior condylar axis and transepicondylar axis was calculated.

## Statistical Analysis

Means and standard deviations were calculated for each measurement taken, including heights, widths, and angles. Paired *t*-test analyses were used to deter-

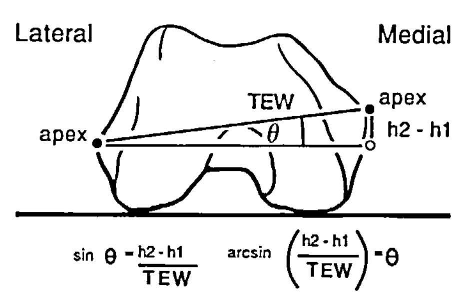


**Fig. 2.** $h_2$ and $h_1$ lateral and medial epicondylar heights, respectively, provided the length of the opposite side of a right triangle; the distance from apex to apex of each epicondyle, the transepicondylar width (TEW), provided the hypotenuse for calculation of the angle θ.

mine if a significant difference existed between the medial and lateral epicondylar heights and also between calculated angles found in paired femora.

## Results

When both men and women were taken as a group, paired *t*-test analyses demonstrated that the mean medial epicondylar heights at 31.4 ± 3.1 mm were vertically higher and significantly different ($P < .05$) when compared to lateral epicondylar heights at 24.7 ± 3.1 mm. This anatomical difference in epicondylar height was used to calculate the angle of rotation between the posterior condylar axis and the transepicondylar axis. For the group, the mean and SD for transepicondylar width measured 84.7 ± 5.2 mm. In all cases, values obtained for men were larger than for women, with medial epicondylar heights being 7% greater, lateral epicondylar heights being 15% greater, and transepicondylar widths averaging 11% wider.

For angles calculated between the posterior condylar axis and the transepicondylar axis, the mean and SD for right femora was 4.9° ± 2.1° of external rotation, while that for the matched left femora was 4.9° ± 2.3° of external rotation. Paired *t*-test analyses revealed that there was no statistical difference ($P > .05$) in the amount of rotation calculated when right and left femur pairs were compared. The sample size for the female group was too small to compare any statistical difference between men and women adequately, but the values obtained in this study gave some suggestion that angular measurements in women (6.4° ± 2.2°) may be larger than in men (4.4° ± 2.0°).

Figure 3 illustrates the individual angles calculated

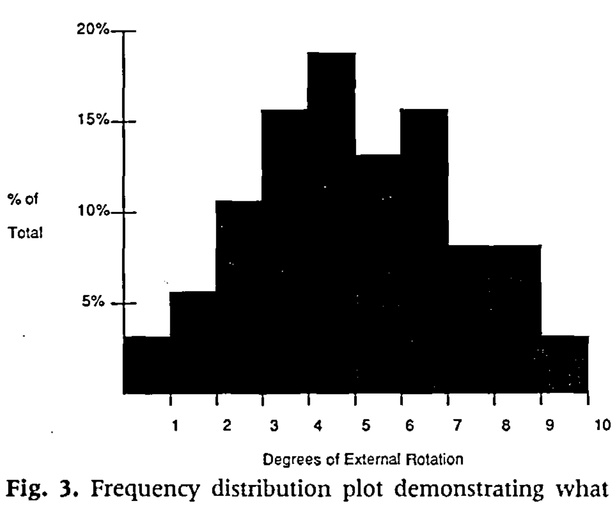


**Fig. 3.** Frequency distribution plot demonstrating what proportion of the sample fell into a particular degree of external rotation.

for the each member of the study group plotted on a frequency distribution histogram against percent of total number. A near normal distribution for the angular measurements was calculated for the study group, with two thirds of the population sampled falling between a range of 3°–7° of external rotation between the posterior condylar and transepicondylar axes.

## Discussion

The objective of this study was to investigate the angular difference between the posterior condylar axis, commonly used to rotationally align the femoral component in primary TKA and the transepicondylar axis, which may be used in primary and revision TKA. Using a population of normal femora, our data demonstrated that the transepicondylar axis was anywhere from 0.1° to 9.7° externally rotated compared to the posterior condylar axis, with an average external rotation of nearly 5°. This is in contrast to the 10° value mentioned by previous authors.[12] The significance of these findings is important in light of the biomechanical relevance of the axes examined and the degree of precision required by the surgeon performing primary and revision TKA.

Many orthopaedic surgeons performing primary TKA advocate using the posterior condylar axis to align cutting-jigs for resection of the distal femur. Reference has been made in both orthopaedic and biomechanical literature by Walmsley[28] and others[12,15,18,19,22,23,26] that the posterior condylar axis defines the neutral axis of rotation for the femur about the knee. This would make the posterior condylar axis a useful guide for determining planes of resection in at least primary TKA. However, biomechanical studies[14,21] directed at understanding kinematics of normal knee motion have revealed a different axis of rotation. Instant center of motion analysis describes the uniplanar motion of the tibiofemoral joint. By using successive roentgenograms at 10° increments of flexion, Nordin and Frankel[21] described the instant center of motion in a normal knee joint as having an everchanging axis centered primarily through the femoral epicondyles. This concept of the polycentric nature of normal knee motion and its relationship to the design of the knee prosthesis has been independently reported in the orthopaedic literature by Gunston,[10] Yoshioka et al.,[29] and Elias et al.[7]

The biomechanical relevance of the angular difference in the posterior condylar and transepicondylar axes is also indirectly supported by Insall et al.[13] Their group advocates resecting unequal amounts of bone off the lateral and medial femoral condyles in primary TKA in order to produce a varus tilt to the transverse axis of the knee. Their method resects larger amounts of bone off the posterior surface of the medial condyle of the femur and balances this with resection of uneven amounts of bone off the proximal tibia. This creates a situation analogous to one in which the transepicondylar axis is used as a reference for resection, placing the femoral component in relative external rotation. Their logic for this method of resection is supported by two principles: first, it places the transverse axis of the knee perpendicular to the mechanical axis of the lower extremity, and second, it positions the femoral component so that capture of the patella in the patellofemoral groove is facilitated, therefore preventing patellar subluxation and dislocation. Interestingly, patellofemoral problems have been cited in the literature as one of the major causes for failure of both primary and revision TKA.[1,9,20]

Whether the posterior condylar axis or the transepicondylar axis provides proper orientation of the femoral component in rotation is debatable. Data from this study suggest that further biomechanical analyses of how geometric contours of present-day femoral components interact with different axes to alter or preserve normal knee motion are required.

Ideally, most surgeons are attempting to duplicate the same precision in revision TKA as that expected in primary TKA. In view of the results of this study and the foregoing discussion, it is clear that a surgeon must be aware of three obstacles in preparing to rotationally align the femoral component in TKA. First, they must be aware of the techniques prescribed for the particular prosthesis they have chosen to use in revision and they must adhere to the design of instrumentation used for that particular prosthesis. Second, they must understand that, with the exception of the epicondyles and their related collateral ligaments, all other useful landmarks to rotationally align the femoral component have been eliminated and that the epicondyles, if used, will not be easily identifiable landmarks because of obscuring soft tissues. Last, they should be aware that, although the posterior condylar and transepicondylar axes exhibit approximately a 5° difference, the right and left femora were not different in the angle measured between the axes. This angular similarity between right and left femoral pairs may be useful. If a large angle is found on the contralateral unresected distal femur through information gathered from radiographic evaluations, it would dictate the need for more precise placement of the femoral component and also provide a guide for the amount of rotation needed. Future clinical and cadaveric investigations would be helpful in determining if this is possible.

## Summary

The hypothesis presented in this study has been supported: the posterior condylar axis and the transepicondylar axis are dissimilar axes, giving measurably different degrees of external rotation over a relatively large range of normal knees. This information may be useful in improving both the techniques of revision and primary TKA, and the design of components used for TKA.

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