Introduction: Today over 19 companies distribute total knee implants (Ranawat, 2002) in the United States. Many of these products have been designed to improve the functionality, wear, longevity, and stability of the total knee implant. Despite improvements in design, however, implant alignment remains a crucial factor and malalignment is a common problem (Archibeck, 2002). It has been demonstrated that malalignment causes increased wear of the implant, decreases longevity of the construct, and alters kinematics of the knee. Most contemporary implants are designed to be aligned to the flexion-extension (FE) axis of the knee. It is this FE axis and the way in which it is defined and identified in the operating room which is producing many of the malalignment problems seen in TKA’s.

Traditionally, the FE axis has been approximated using the trans-epicondylar axis (TEA), a line joining the medial and lateral femoral epicondyles (Churchill, 1998). Recent studies show this approximation to be inadequate due to the low predictability of the TEA (Katz, 2001). Some researchers state that flexion and extension occurs about a fixed axis in the posterior condyles (Churchill, 1998; Hollister, 1993). Further research has shown that the FE axis is centered in the posterior condyle (Elias, 1990; Eckhoff, 2001) and that the posterior femoral condyles are circular in shape (Eckhoff, 2001). This fixed axis is designated the cylindrical axis (CA) (Eckhoff, 2001). The hypothesis of this abstract is that there is a statistically significant difference between the TEA and the CA and the CA can be identified consistently and repeatably.

Methods: 10 fresh frozen cadaver specimens from mid femur to mid tibia were obtained from 5 individuals. These specimens were scanned using Computed Tomography at 1mm slices. The CT scan data were then put into a custom developed volume viewer program. This enabled the isolation of the osseous surface of the femur using a custom segmentation program. Following the segmentation process, the 3D femoral model was put into a cylinder fitting program and fit independently by four investigators.

Two co-axial cylinders were placed in the posterior condyles to achieve the best fit possible to the articular surface corresponding to the flexion range of 15 – 115 degrees. The line connecting the center of each cylinder was taken to be the cylindrical axis (Figure 1). The most prominent points of the lateral and medial femur were taken to be the epicondyle and these positions were marked on the model. A line connecting the two points was taken to be the trans-epicondylar axis (Figure 1).

Individual data points designating the X, Y, and Z coordinate in 3D space were found for each end of both axes where they penetrated the osseous surface. These points were recorded and compared using Microsoft Excel to evaluate reproducibility of the technique. The difference in the angles of the trans-epicondylar axis and the cylindrical axis were calculated using the 3D Dot Product and compared using Excel. Later, four investigators refit cylinders to two of the ten specimens according to the refined protocol. These specimens were analyzed using the same statistical analysis.

Results: The average difference between the trans-epicondylar axis and the cylindrical axis was 4.0º with a standard deviation (SD) of 1.6 in the initial ten specimens. The difference between these two axes was significantly greater than 0 with a p value of .01. These specimens had coordinates in 3D space for both the lateral and medial cylinder centers with less than 2.6mm SD when the four investigators data was compared. When the refitted specimens were analyzed the SD for the cylinder coordinates was 1.6mm. The coordinates for the epicondyles were also recorded and showed a SD of 1.0mm when looking at inter-observer variability for the two refit specimens. The difference between the TEA and the CA using the refined technique is displayed in table 1.

Discussion: The results from ten cadaveric specimens demonstrated there is a difference between the TEA and the CA (Figure 2). An average difference of 4.0 degrees was found between the two axes. The coordinates of the cylinders showed a SD of 2.6mm, which was due to individual investigator subjectivity. Therefore, the protocol and the cylinder fitting program were changed to allow the cylinder fitting process to be more objective. Two specimens were refit according to the refined protocol using the same program and showed a similar difference in orientation of the TEA when compared to the CA. The difference between the two axes was 3.3 degrees with an inter-observer SD of less than 1 degree (Table 1). The variability between investigators for cylinder coordinates dropped from a SD of 2.0mm to 1.6mm. This shows that the technique is very reproducible between investigators and that the CA coordinates are predictable to within 1.6 mm. The epicondylar coordinates showed a SD of 1.0mm which is excellent and smaller than the cylinder’s coordinates; however, our method of locating the epicondyles is far more accurate than the visual and tactile techniques used in the operating room. Further cadaveric testing with the refined cylinder fitting protocol is currently underway to increase sample size and statistical significance. These results show the CA should be considered when trying to approximate the optimal flexion-extension axis of the knee because it is predictable and equidistant from the articular surface through an arc of flexion 15-115 degrees.

References:
Eckhoff, DG; Dwyer, TF; Bach, JM; Spitzer, VM; Reining, KD. (2001). Three dimensional morphological of the distal part of the femur viewed in virtual reality. The Journal of Bone and Joint Surgery, 83-A, 43-50.
Elias, SG; Freeman, MAR, Gokcay, EL. (1990) A correlative study of the anatomy and geometry of the distal femur. Clinical Orthopaedics and Related Research, 260, 98-103.

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Table 1 - Angular difference (degrees) between the epicondylar and cylindrical axes.

<table>
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<th>SPECIMEN</th>
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<th>IV#2</th>
<th>IV#3</th>
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<td>0.6</td>
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</table>

Fig 2 - Femur model showing TEA and CA

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