The Relationship of Joint Line and Flexion/Extension Axes of the Knee to the Mechanical Axis in the Coronal Plane

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INTRODUCTION:
Classical and Anatomic Alignment rely on various axes for component orientation in TKA. Studies indicated that the knee has a single flexion/extension axis but debated the location of this axis in the femur[1-2]. The relationship of the flexion/extension axis in the coronal plane to the mechanical axis has received little attention. The purpose of this study was to investigate the relationship of the various axes and references with respect to the mechanical axis in the coronal plane utilizing 3D virtual models of human subjects, along with their relationship or variation to a neutral distal resection.

METHODS:
Subjects were prospectively scanned into a Virtual Bone Database (Stryker Orthopaedics, Mahwah, NJ), which is a collection of body CT scans from subjects collected globally. Only CT scans that met the following qualifications were accepted: ≤ 1 mm voxels and had slice thickness that was equal to the spacing between the slices (≤ 1.0mm), Gantry/detector tilt must 0°, gathered in a non-reconstructive mode and raw DICOM files. All CT scans displayed cropped bones were excluded. An unique tool with the ability to take automated measurements of quantities such as distances, angles or circle diameters on a large number of pre-segmented bone samples was then used to was then used to perform calculations represented in this study.[3]

Demographic information (ethnic origin, gender, age, height, weight) for each subject was recorded. For the analysis, a frontal plane was created on the 3D knee model through the 2 most posterior points of the medial/lateral condyles and the most posterior point of the trochanter. Then a transverse plane was created perpendicular to the frontal plane and bisecting the 2 most distal points on the medial/lateral condyles. Finally, a sagittal plane was created that was perpendicular to the frontal and transversal planes.

The following axes were identified: Mechanical Axis of the Femur (MAF) (line between the center of the femoral head and the center of the knee sulcus); Transepicondylar Axis (line between the medial/lateral epicondyle); Posterior Cylindrical Axis (PC) (line between the centers of the Medial/Lateral Condylar Circle – best fit circles to three points identified on surface). The surface chosen to create the circles was an unique tool with the ability to take automated measurements of quantities such as distances, angles or circle diameters on a large number of pre-segmented bone samples was then used to was then used to perform calculations represented in this study.[3]

Measurements made were the Angle of MAF and the Joint-Line (Femoral Joint Angle), Angle of the MAF and the Transepicondylar Axis (Femoral TE Angle), and Angle of the MAF and the Posterior Cylindrical Axis (Femoral PC angle). Angles measuring 90° were neutral or perpendicular to the MAF. Angles measured <90° were varus and >90° were valgus.

RESULTS:
CT Scans of the Left Knees (n=263), Right Knees (n=256), and combined left/right knee (n=519) were collected for this study.

The mean Femoral Joint Angle for the left knee was 86.2°±2.1° (Range:81.1-92.2) and right knee was 86.0°±2.0° (Range: 80.2°-91.5°). The combined (left/right) mean femoral joint angle was 86.1°±2.0° (Range:80.2°-92.2°). The mean Femoral TE angle for the left knee was 88.8°±2.5° (Range:82.2°-98.4°) and mean angle for the right knee was 88.9°±2.4° (Range:81.7°-96.43°). The combined (left and right) mean angle was 88.8°±2.5° (Range:81.7°-98.4°). The mean Femoral PC angle for the left knee was 87.9°±2.1° (Range:81.8°-93.4°) and the mean angle for the right knee was 87.8°±2.2° (Range:82.6°-94°). The combined (left/right) mean angle was 87.9°±2.2° (Range:81.8°-94.0°). The average deviations from a neutral resection were 3.8°, 1.2° and 2.1° for the Femoral Joint Angle, Femoral TE Angle, and Femoral PC angle respectively. The mean Femoral Joint angle had the lowest variability, while the mean Femoral TE angle showed the largest.

DISCUSSION:
On average, the transepicondylar axis and the posterior cylindrical axis were approximately perpendicular to the mechanical axis in the coronal plane, although distances to the insertion of the collateral ligaments (epicondyles) were not equal to the distal and posterior surfaces throughout the knee range of motion. Although surgeons do not normally attempt to align components in the coronal plane specifically to either axis, this data suggests that the average value is within the accepted ±3° range reported in similar studies for overall positioning. This study does not evaluate the intraoperative variability shown when surgeons chose landmarks. All landmarks were selected based on mathematical analysis of planes and the anatomy thus reducing observer variability. The Femoral PC values are closer to the values of the femoral joint line when compared to the Femoral TE. The Femoral PC may be a more reproducible landmark as it may be determined by either preoperative imaging or intraoperatively from instrumentation that references the distal and posterior surfaces.

SIGNIFICANCE:
The use of the posterior cylindrical axis may have substantial implications for optimizing flexion, midflexion, and extension balance in TKA, especially with single radius knee designs. The use of this axis may allow for more biomechanically symmetric gaps throughout the range of motion of the knee.

REFERENCES: