Do Five Tibial Reference Lines Consistently Set the Rotation of the Tibial Component in Kinematically-Aligned TKA?

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INTRODUCTION: Consistently setting the internal-external rotation of the anteroposterior axis of the tibial component within $0 \pm 6^\circ$ of the correct reference line is an important goal in total knee arthroplasty (TKA) because it improves patient satisfaction. After mechanically-aligned TKA, patients have a higher prevalence of anterior knee pain, patellar tilt, patellar subluxation, and patellar component failure when the internal rotation of the tibial component is greater than $5^\circ$ with respect to a tibial reference line perpendicular to a line connecting the lateral epicondyle with the sulcus of the medial epicondyle (transepicondylar axis) [1, 2]. Patients have a higher prevalence of unexplained knee pain when the tibial component is internally rotated greater than $6^\circ$ with respect to a tibial reference line connecting the most anterior point of the tibial tubercle to the geometric center of the tibia [3].

Five tibial reference lines are used because in mechanically-aligned TKA there is no universally accepted sagittal plane for setting the rotation of the anteroposterior axis of the tibial component. In kinematically-aligned TKA, the anteroposterior axis of the tibial component should be set parallel to the sagittal kinematic plane [4-6].

Because 20 - 25% of patients are dissatisfied after mechanically-aligned TKA [7-9], orthopedic surgeons and patients seek better functional outcomes. Kinematically-aligned TKA performed with either generic instruments or patient-specific guides leads to better function and flexion and more normal contact kinematics than mechanically-aligned TKA [6, 10-12]. However whether any of five tibial reference lines used with mechanically-aligned TKA sets the rotation of the anteroposterior axis of the tibial component consistently parallel to the sagittal kinematic plane is unknown.

Accordingly, the present study constructed five tibial reference lines on three-dimensional bone models of the normal lower extremity from Caucasians and determined the consistency of each of the five reference lines by computing the frequency that each line was within $0 \pm 6^\circ$ of the sagittal kinematic plane.

METHODS: Fifty three-dimensional bone models of a normal lower extremity from Caucasians were created from computer tomograms with a maximum slice thickness of 1 mm. Each model showed the entire femur and tibia, and no evidence of arthritis, fracture, internal fixation, or joint replacement. The average age was $50 \pm 15$ years (range, 23 to 81 years), of which 27 were males. The kinematic planes of the knee were registered to each tibia (Figure 1).
**Figure 1.** The composite shows a three-dimensional model of a right lower extremity and the steps for orienting the extremity in the three orthogonal kinematic planes. The bone model was imported into software (A). With the tibia hidden, the medial and lateral femoral condyles were superimposed to project the femur in the sagittal kinematic plane (B). The most posterior points of each femoral condyle and the greater trochanter were made tangent to a plane which projected the femur in the coronal kinematic plane (C). The femoral transformations were applied to the tibia. With the tibia unhidden and the femur hidden, rotation of the tibia perpendicular to the sagittal and coronal kinematic planes projected the proximal tibial in the axial kinematic plane (D). The yellow line projected on the proximal tibia is parallel to the sagittal kinematic plane.
To define the five tibial reference lines, eight landmarks were identified on each tibia (Figure 2). The most anterior point of the tibial tubercle was identified on the projection of the tibia in the coronal kinematic plane by translating the coronal kinematic plane anteriorly until tangent to a single point on the tibial tubercle. A plane was constructed parallel to the axial kinematic plane through the most anterior point and the medial border and medial 1/3rd of the tibial tubercle were identified. The center of the PCL fossa and the center of the medial and lateral tibial condyles were identified on the projection of the proximal surface of the tibia in the axial kinematic plane. The center of each tibial condyle was the center of a circle that best fit at least ten points on the periphery of each condyle [13]. A virtual resection parallel to the axial kinematic plane was performed 10 mm distal from the deepest portion of the medial tibial condyle to simulate the level for placing a 10 mm thick tibial liner and component. The most posterior points on the medial and lateral condyles were identified. Three of the tibial reference lines connected the medial border [14], medial 1/3rd [14, 15], or most anterior point [14] of the tibial tubercle with the center of the PCL fossa. The other two tibial reference lines were perpendicular to either a line connecting the centers of the medial and lateral tibial condyles or a line connecting the most posterior points on the tibial condyles [13].

**Figure 2.** A composite of a right tibia shows the eight landmarks for constructing five tibial reference lines. The medial border, medial 1/3rd, and most anterior point were identified on the tibial tubercle (green arc) with the tibia projected in the coronal kinematic plane (A). The center of the PCL fossa and the center of the medial and lateral tibial condyles were identified on the tibia projected in the axial kinematic plane (B). The center of each condyle was the center of a circle that best-fit points drawn on the periphery of each condyle. Removal of the proximal 10 mm of the tibia simulated the resection level of the tibial component. The most posterior point on the medial tibial condyle and lateral tibial condyle were identified (C).

The angle each tibial reference line formed with a line parallel to the sagittal kinematic plane on the tibia quantified the rotational difference. A positive value indicated external rotation of the tibial reference line (Figure 3). The intraclass correlation coefficient (ICC) determined the interobserver variability, and was computed with use of a two-factor analysis of variance with mixed effects with the first factor, observer, being a fixed effect with three levels (observer 1, observer 2, and observer 3), and the second factor, three-dimensional bone model of the tibia, being the random factor with ten levels (model 1 to model 10).
Reference line connecting medial border of tibial tubercle with center of PCL fossa

19°  -6°

Reference line connecting medial 1/3rd of tibial tubercle with center of PCL fossa

24°  0°

Reference line connecting most anterior point of tibial tubercle with center of PCL fossa

24°  6°

Reference line perpendicular to line connecting the center of each tibial condyle

17°  -5°

Reference line perpendicular to line connecting the most posterior point on each tibial condyle
RESULTS: The tibial reference line connecting the medial border, medial 1/3rd, and most anterior point of the tibial tubercle with the center of the posterior cruciate ligament fossa was within 0 ± 6° of the sagittal kinematic plane in 54%, 6%, and 2% of tibias respectively. The tibial reference line perpendicular to a line connecting the centers of the medial and lateral tibial condyles and to a line connecting the most posterior points on the tibial condyles was within 0 ± 6° of the sagittal kinematic plane in 36% and 66% of tibias respectively.

The ICC values ranged from 0.80 to 1.00, which indicate the positioning of the tibial reference lines and computations of malrotation are reproducible.

DISCUSSION: In mechanically-aligned TKA, aligning the rotation of the tibial component within 0 ± 6° of a reference line is important for maintaining both tibiofemoral and patellofemoral kinematics, reducing pain, and improving function [1-3, 6, 16]. Five tibial reference lines are used in mechanically-aligned TKA because there is no universally accepted sagittal plane for setting the rotation of the anteroposterior axis of the tibial component [13]. The present study determined whether any of these five tibial reference lines should be used in kinematically-aligned TKA by computing the frequency that each line is within 0 ± 6° of the sagittal kinematic plane. This study found that none of these five tibial reference lines consistently set the rotation of the anteroposterior axis of the tibial component parallel to the sagittal kinematic plane.

Studies of function and contact kinematics after kinematically-aligned TKA justify the importance of setting the anteroposterior axis of the tibial component and femoral component parallel to the sagittal kinematic plane [6, 10-12]. Restoring the patient’s natural alignment are the principles of kinematically-aligned TKA [4, 17]. A TKA positioned in a natural limb alignment feels more normal, has better function, and has at least equal, if not better, survivorship at 3 and 6 years than mechanically-aligned TKA [6, 10-12].

CLINICAL SIGNIFICANCE: None of the five tibial reference lines should be used to align the anteroposterior axis of the tibial component parallel to the sagittal kinematic plane when performing kinematically-aligned TKA.

REFERENCES: