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What are the bias, imprecision, and limits of agreement for finding the flexion–extension plane of the knee with five tibial reference lines?

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ABSTRACT

Background: Internal–external (I–E) malrotation of the tibial component is associated with poor function after total knee arthroplasty (TKA). Kinematically aligned (KA) TKA uses a functionally defined flexion–extension (F–E) tibial reference line, which is parallel to the F–E plane of the extended knee, to set I–E rotation of the tibial component.
Methods: Sixty-two, three-dimensional bone models of normal knees were analyzed. We computed the bias (mean), imprecision (±standard deviation), and limits of agreement (mean ± 2 standard deviations) of the angle between five anatomically defined tibial reference lines used in mechanically aligned (MA) TKA and the F–E tibial reference line (+external).
Results: The following are the bias, imprecision, and limits of agreement of the angle between the F–E tibial reference line and 1) the tibial reference lines connecting the medial border (−2° ± 6°, −14° to 10°), medial 1/3 (6° ± 6°, −6° to 18°), and the most anterior point of the tibial tubercle (9° ± 4°, −1° to 17°) with the center of the posterior cruciate ligament, and 2) the tibial reference lines perpendicular to the posterior condylar axis of the tibia (−3° ± 4°, −11° to 5°), and a line connecting the centers of the tibial condyles (1° ± 4°, −7° to 9°).
Clinical relevance: Based on these in vitro findings, it might be prudent to reconsider setting the I–E rotation of the tibial component to tibial reference lines that have bias, imprecision, and limits of agreement that fall outside the −7° to 10° range associated with high function after KA TKA.

1. Introduction

Mechanically aligned total knee arthroplasty (MA TKA) is one of the most successful operations for restoring patient function, however 15% to 25% patients report dissatisfaction and 10% require revision surgery by 10 years [1–4]. One cause is internal and external (I–E) malrotation of femoral and tibial components, which is associated with poor function after MA TKA [5,6].

In MA TKA the surgeon uses one of five anatomically defined tibial reference lines for setting the I–E rotation of the tibial component which include: 1) the line connecting the medial border of the tibial tubercle with the center of the posterior cruciate ligament (PCL) fossa, 2) the line connecting the medial 1/3 of the tibial tubercle with the center of the PCL fossa, 3) the line connecting the most anterior point of the tibial tubercle with the center of the PCL fossa, 4) the line perpendicular to the posterior condylar axis of the tibia, and 5) the line perpendicular to the line connecting the centers of the medial and lateral tibial condyles (Cobb's method) [7,8] (Figure 1).

An inaccurate selection of the orientation of the tibial reference line has been proposed as an etiology for patient dissatisfaction and aseptic failure [9]. The accuracy of the selection of the orientation of a tibial reference line for setting the I–E rotation of the tibial component can be quantified by the bias and imprecision. A measurement, such as the angle between a tibial reference line and a target reference line, is biased when both the mean and the standard deviation (SD) respectively of the measurements of this angle in a sample of subjects are different from zero. Hence, an accurate tibial reference line is one that forms an angle with the target reference line in a sample of subjects with a mean and a SD that is not different from zero.

Kinematically aligned (KA) TKA is a new method that has gained interest because two studies showed that patients with a reported better pain relief, better function, better flexion, and a "more normal feeling knee" than patients with a MA TKA [10,11]. In KA TKA the target reference line for setting the I–E rotation of the anterior-posterior (A-P) axis of the tibial component is the flexion–extension (F–E) tibial reference line. The F–E tibial reference line is a functionally defined rather than anatomically defined tibial reference line because it is oriented parallel to the F–E plane of the extended knee rather than to lines connecting anatomic landmarks on the tibia. The F–E tibial reference line is aligned perpendicular to the transverse axis in the femur about which the tibia flexes and extends, and is drawn perpendicular to lines tangent to the distal and posterior

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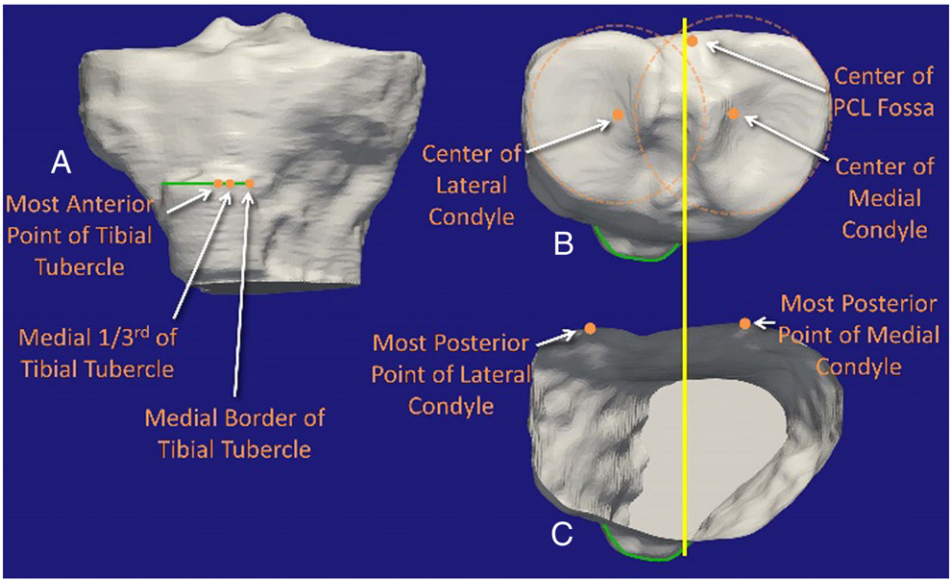

Figure 1. A composite of three views of a right tibia shows the eight tibial landmarks for constructing the five tibial reference lines. (A) The most anterior point, medial border, and medial 1/3 of the tibial tubercle (green arc), were identified on the projection of the tibia in the coronal plane. (B) The center of the PCL fossa and the center of the medial and lateral tibial condyles were identified on the projection of the proximal tibia in the tibial resection plane. (C) The most posterior points on the medial and lateral condyles were identified on the resected tibia. The F–E tibial reference line (yellow) on the proximal surface of the tibia is parallel to the F–E plane.

joint lines of the femur at 0° and 90° of flexion (Figure 2) [12–17]. One study reported that setting the angle of I–E rotation of the A–P axis of the tibial component with the F–E plane of the knee with a limit of agreement of −7° to 10° (i.e. mean ± 2 SDs) is acceptable because these patients reported high satisfaction and function as measured by the Oxford Knee Score (mean 42 of 48 (best)) [18].

Because an inaccurate selection of the orientation of the target reference line has been proposed as an etiology for patient dissatisfaction

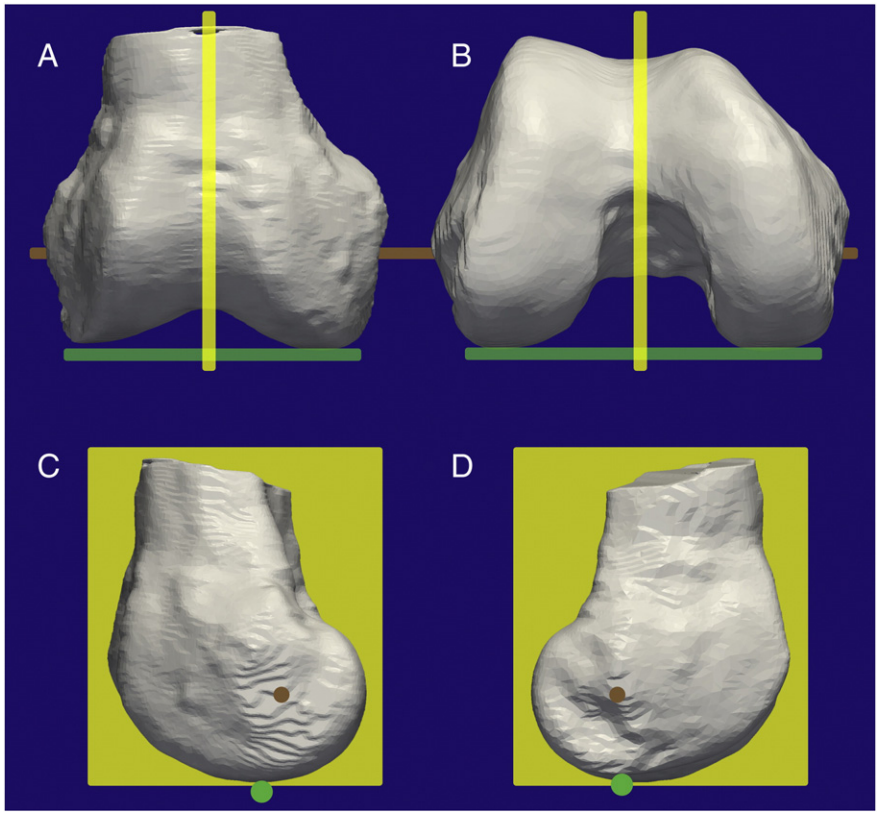

Figure 2. The composite shows a three-dimensional model of a right femur in an (A) anterior, (B) distal, (C) medial, and (D) lateral view. The F–E plane (yellow) is perpendicular to the transverse axis in the femur about which the tibia flexes and extends (brown) and approximately perpendicular to lines tangent to the distal and posterior joint lines of the femur at 0° and 90° of flexion (green).