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Original Article

Can the Visibility of Both Prosthetic Posterior Femoral Condyles on a Postoperative Radiograph Assure that Limb Rotation Is Appropriate to Allow Accurate Measurement of the Anatomic Knee Axis?

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ABSTRACT

Background: To better define radiographic parameters for a true anterior–posterior (AP) knee radiograph after total knee arthroplasty, we cataloged the radiographic appearance of 7 different designs of commercially available femoral components at various points of rotation to correlate the visibility of the prosthetic posterior femoral condyles (PPFCs) with the amount of rotation of the femoral component, and hence, the limb.

Methods: AP radiographs of 7 left-sided, cruciate-retaining femoral trial components were obtained at 5° increments of rotation from 20° internal rotation (IR) to 20° external rotation (ER). Rotational profiles were cataloged based on the visibility of either or both of the PPFCs.

Results: Three categories of femoral component rotation profiles were noted, based on the visibility of the PPFC: overt ER with only the medial PFC visible at greater than 10° ER, overt IR with only the lateral PFC visible at greater than 20° IR, and near-neutral rotation with both medial and lateral PPFCs visible between 5° ER and 15° IR.

Conclusion: An acceptable AP radiograph to measure the anatomic knee axis after total knee arthroplasty is one where both the medial and lateral PPFCs are visible on either side of the trochlear flange.

Total knee arthroplasty (TKA) is a highly effective procedure for relieving pain and disability associated with end-stage osteoarthritis of the knee. Optimal outcomes from modern TKA are predicated on many factors, including patient selection, surgical technique, and postoperative rehabilitation and pain management protocols. One quantifiable measure of a successful TKA is assessing the mechanical axis of the lower limb. Historically, restoration of the anatomic axis within 3°-7° of valgus was deemed optimal for ensuring implant survival [1,2]. Abnormal alignment, especially varus tibiofemoral alignment, can lead to loosening, radiolucent lines, and early TKA failure [3,4]. Some controversy, however, presently exists as to whether restoration of preoperative "kinematic" alignment yields an acceptable anatomic axis [5-7]. Regardless, the tibiofemoral angle (TFA), the angle subtended by the anatomic axis of the femur and the tibia on an anteroposterior (AP) knee radiograph, is routinely used to measure both preoperative deformity and subsequent assessment of postoperative correction of the preoperative deformity.

A "true" or "neutral" AP radiograph of the unreplaced knee has been defined based on several visual criteria, including visualization of both tibial spines [8] and bisection of the fibular head by the lateral edge of the lateral tibial plateau [9,10]. However, there are no strict numerical parameters that help define and standardize AP knee radiographs. Moreover, the few radiographic landmarks available for assessment can be absent or distorted after TKA. Thus, there are limited means to standardize and define a true or neutral AP knee radiograph in patients who have undergone TKA.

Previously published studies have demonstrated the effect of limb rotation on the projection of axes and angles on a 2-dimensional radiograph [3,8]. Lonner et al [11] used a synthetic femur and tibia model implanted with TKA components to demonstrate the statistically significant effect of limb rotation on the TFA after TKA. Radtke et al [12] also used synthetic femur and

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tibia models implanted with TKA components and found a significant effect of limb rotation on the radiographic evaluation of limb alignment after TKA, with increased internal rotation (IR) simulating tibiofemoral valgus alignment and increased external rotation (ER) simulating tibiofemoral varus alignment.

The variability imparted by limb rotation calls into question all publications that report anatomic TKA alignment without controlling for limb rotation. In spite of this, most studies on TKA report postoperative anatomic knee alignment using short films without respect to neutral knee rotation in the AP view. This study was undertaken based on our clinical observation of a quantifiable effect of knee rotation on the TFA on AP knee radiographs in a randomly selected series of 9 knees status after TKA (Fig. 1).

Among them, we noted discrepancies between the actual and apparent TFA that ranged from 2.2° to 7.7° depending on whether only one or both PPFCs were visible on the AP radiograph. To quantify the effect of this simple radiographic finding and verify its usefulness as a measure of acceptability of limb rotation, we documented the radiographic appearance of femoral components from 7 commercially available TKA systems at various degrees of rotation.

Materials and Methods

Our original observations were made in a series of PFC Sigma (DePuy Synthes, Warsaw, IN) TKAs. To more precisely determine the effect of limb rotation on the radiographic appearance of this and other available prosthetic designs, we obtained AP radiographs of 7 left-sided, cruciate-retaining femoral trial components of comparable size from 3 major manufacturers to account for variations in design geometry. The components were as follows: DePuy Sigma (DePuy Synthes), Depuy Attune (DePuy Synthes), Zimmer NexGen (Zimmer Biomet, Warsaw, IN), Zimmer Persona (Zimmer Biomet), Smith & Nephew Legion (Smith & Nephew, London, UK), Smith & Nephew Genesis (Smith & Nephew), and Stryker Triathlon (Stryker; Kalamazoo, MI). The components were of comparable size in both the AP and medial-lateral dimensions according to manufacturer specifications (Table 1).

The femoral components were individually affixed in neutral flexion/extension and upright to a goniometer and placed at a fixed distance and perpendicular to a radiographic beam. AP radiographs of the femoral components were taken at 9 points of rotation relative to the radiographic beam: neutral, 5° IR and ER, 10° IR and ER, 15° of IR and ER, and 20° of IR and ER (Fig. 2). All radiographs were obtained in one sitting to standardize image quality and appearance of the femoral components.

Radiographs of the femoral components were then examined for general patterns in the appearance of the PPFC in relation to the central, trochlear flange of the femoral component that remained uniform across all 7 components.

Table 1
Dimensions of Femoral Components

Femoral Component	Manufacturer Size	A/P Dimension (mm)	M/L Dimension (mm)
Stryker Triathlon	4	62	68
Zimmer Persona	6	59.6	67.8
Zimmer NexGen	E	61.5	68
S&N Genesis II	4	59	66
S&N Legion	4	59	66
DePuy Attune	5	60	66.5
DePuy Sigma	3	61	66

A/P, anterior–posterior; M/L, medial–lateral; S&N, Smith & Nephew.

Fig. 1. (A) Routine postoperative AP knee radiograph with overt rotation of 90-year-old male status after left TKA with TFA measuring 2.5° varus. (B) The same patient after repositioning of the limb to eliminate overt rotation. TFA measured 2.3° valgus. AP, anterior–posterior; TFA, tibiofemoral angle; TKA, total knee arthroplasty.

Results

Three Categories of Femoral Component Rotation Profiles

Visual examination of our radiographs (Fig. 2) demonstrated 3 broad categories of femoral component rotation profiles, based on the appearance of the PPFC relative to the central trochlear flange, that were uniform regardless of the component manufacturer: overt ER, overt IR, and near-neutral rotation. Overt ER, observed uniformly across all 7 components beginning at 10° ER, was characterized by the entire medial PPFC being visible and the absence of the lateral PPFC. Overt IR, seen uniformly across all 7 components at 20° IR was characterized by the entire lateral PPFC being visible. Near-neutral rotation, seen uniformly across all 7 components from 15° IR to neutral rotation, was characterized by borders of both PPFCs partially visible on either side of the central trochlear flange. The only nonuniform variation of the PPFC among the femoral components was seen at 5° ER. The medial PPFC was absent in all components except the 2 Smith and Nephew models, where the upper border of the medial PPFC could be seen.

Discussion

This study was prompted by our clinical observation that “overt malrotation” of the limb, as determined by the appearance of a single PPFC on an AP knee radiograph, can alter the TFA by as much as 7.7°. In this study, we characterized the radiographic rotational profiles of 7 femoral components from 3 major orthopedic device manufacturers.