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The Inadequacy of Short Knee Radiographs in Evaluating Coronal Alignment After Total Knee Arthroplasty

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A B S T R A C T

Background: Prior studies have associated coronal alignment after total knee arthroplasty (TKA) with implant survivorship. Results have been based on either the femorotibial angle (FTA) on a short knee film or the hip-knee-ankle angle (HKA) on a full-length radiograph. The purpose of this study was to determine if the FTA on short knee radiographs can accurately predict the true HKA alignment after TKA.

Methods: Two orthopedic surgeons measured the FTA, HKA, medial proximal tibial angle, and lateral distal femoral angle in 262 patients who had both short and full-length standing radiographs before and/or after primary TKA. Overall coronal alignment was considered neutral if the FTA was between 2.4° and 7.2° on short knee x-rays or if the HKA was between −3° and 3° on full-length films.

Results: Preoperatively, 13.9% (26/187) of knees had a neutral FTA on short films, but 50% (13/26) of those were in varus or valgus on full-length films. Postoperatively, 51.4% (106/206) of knees had a neutral FTA on short films, but 27.4% (29/106) of those knees were in varus or valgus on full-length films. When comparing alignment classifications (neutral, varus, or valgus) based on the short vs full-length images, 13.9% (26/187) of patients had discordant classifications on preoperative imaging, and 33.0% (68/206) had discordant classifications on postoperative imaging.

Conclusion: A significant proportion of patients were misclassified as varus, valgus, or neutral based on the FTA when compared to the HKA. Short knee x-rays serve as an inaccurate proxy for full-length films when assessing coronal alignment after TKA.

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Because coronal plane malalignment in total knee arthroplasty (TKA) has been shown to cause increased polyethylene contact stresses and potentially contribute to early implant failure [1-6], restoration of the overall mechanical alignment to within 3° of neutral has traditionally been a key objective in TKA. However, recent clinical studies have called into question the presumption that neutral mechanical alignment is associated with increased implant survivorship and improved functional outcomes [7-10], and the optimal range of coronal plane alignment in TKA remains a subject of debate.

Preoperative and postoperative coronal plane alignment is typically reported by using either the femorotibial angle (FTA), a measure of the anatomical axis on short (14 × 17 inch) standing anteroposterior (AP) knee radiographs, or the hip-knee-ankle angle (HKA), a measure of the mechanical axis on full-length (14 × 51 inch) standing AP hip-to-ankle radiographs [7-11]. As surgeons traditionally target a neutral mechanical alignment in TKA (and femoral and tibial component positions perpendicular to their mechanical axes), a standing AP hip-to-ankle radiograph provides a more direct assessment of mechanical alignment and the weight-bearing axis of the lower extremity. Although previous studies have attempted to correlate the FTA to the HKA on short and full-length radiographs of native knees [12-15], no such studies exist for patients after TKA. Consequently, it is not known whether optimal target ranges for coronal plane alignment as measured on short knee radiographs can be extrapolated to patients with full-length radiographs, and vice versa. The purpose of this study was to determine if the FTA as measured on short knee radiographs can accurately predict the true HKA alignment as measured on full-length radiographs both before and after TKA. Our hypothesis is that the value of the FTA in predicting a patient's true HKA alignment will be limited, thus restricting comparisons between prior studies that have drawn conclusions using these 2 measurement methods.

Materials and Methods

After obtaining institutional review board approval, we retrospectively identified 262 patients from our departmental joint registry who received a TKA between January 2010 and June 2014 by 1 of 3 attending surgeons. Inclusion criteria were patients with osteoarthritis or inflammatory arthritis older than 18 years who had both a set of

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weight-bearing short AP knee radiographs and standing full-length AP images that included the pelvis and entire lower limb either before or after TKA. Long image series could be either a classic hip-knee-ankle roentgenogram taken on a long cassette or a 2-dimensional hip-to-ankle image obtained using an EOS X-Ray Imaging Acquisition System (EOS Imaging, Inc, Paris, France). Patients were excluded if they had prior traumatic fractures to the ipsilateral femur, knee, or tibia. In addition, patients with neuromuscular disorders, congenital anomalies, or ambulatory and/or standing difficulties were excluded. Demographic information including age, sex, body mass index (BMI), and the side of the operative extremity was recorded.

All standing short AP knee radiographs were taken on a 14 × 17 inch cassette centered at the knee joint, with the patellae facing forward and the legs in full extension. The standing full-length radiographs were taken in a similar fashion, except on 14 × 51 inch cassettes such that the femoral head and talus were captured on the same image. The EOS X-Ray Imaging Acquisition System was also used to acquire standing hip-to-ankle images. Only the 2-dimensional image obtained using the EOS system was analyzed, as it corresponds to a standing full-length radiograph obtained using conventional radiography [16,17]. Preoperatively, 187 patients had both short and long images, with 3 (1.6%) of 187 having a standing hip-knee-ankle x-ray and the remainder having an EOS image. Postoperatively, 206 patients had a complete pair of radiographs, with 14 (6.8%) of 206 having a standing hip-knee-ankle x-ray and the remainder having an EOS image.

Three measurements for the study were made on the short AP knee radiographs: the femorotibial angle-short (FTA-short), anatomical medial proximal tibial angle (aMPTA), and anatomical lateral distal femoral angle (aLDFA). The FTA-short was the angle subtended by the anatomical femoral axis and the anatomical tibial axis on a short AP knee radiograph, expressed as a deviation from 0°. As a matter of convention for this study, varus was assigned a negative value; and valgus, a positive value. On the short film, the anatomical femoral axis was defined as the line connecting the midpoint of the endosteal cortices of the proximal most portion of the femoral shaft included on the film to the center of the distal femoral shaft 10 cm proximal to the joint line. Likewise, the anatomical tibial axis was determined as the line connecting the midpoint of the endosteal cortices of the tibial shaft 10 cm distal to the tibial plateau and the midpoint of the tibial shaft as far distal as the radiograph would allow. The aMPTA was defined as the medial angle formed between the anatomical tibial axis and the joint line of the proximal tibia. For a native knee, this was the line that connects the highest points of the medial and lateral plateaus. When a TKA was present, the line was set parallel to the inferior aspect of the tibial component's metal tray. The aLDFA was the lateral angle between the anatomical femoral axis and the joint line of the distal femur, determined as the line connecting the distal most aspects of the medial and lateral femoral condyles for both native and replaced knees [18,19] (Fig. 1). These measurement methods replicated those previously described by Ritter et al [9,18], who reported the impact of alignment measured on short knee films on clinical outcomes and survivorship after TKA.

Four measurements made on the full-length radiographs and EOS imaging included the femorotibial angle-long (FTA-long), mechanical lateral distal femoral angle (mLDFA), mechanical medial proximal tibial angle (mMPTA), and HKA. The FTA-long was the angle between the anatomical femoral axis and anatomical tibial axis. On full-length radiographs, the anatomical femoral axis was defined as the line connecting the midpoint of the endosteal cortices of the femoral isthmus to the midpoint of the femur 10 cm proximal to the joint line. Similarly, the anatomical tibial axis was determined as the line connecting the midpoint of the midshaft of the tibia to the midpoint of the tibia 10 cm distal to the joint line [19,20]. The mechanical femoral axis was defined as the line connecting the center of the femoral head, as determined by a best-fit circle, and the midpoint of the widest dimension of the distal femur. The mechanical tibial axis was set as the line connecting the center of the tibial spines to the center of the talus. The mMPTA was determined as the medial angle between the mechanical tibial axis and the joint line of the proximal tibia. For a native knee, this was the line that connects the highest points of the medial and lateral plateaus. When a TKA was present, the line was set parallel to the inferior aspect of the tibial component's metal tray. The mLDFA was defined as the lateral angle between the mechanical femoral axis and the joint line of the distal femur, determined as the line connecting the distal most aspects of the medial and lateral femoral condyles for both native and replaced knees [21]. Finally, the HKA was determined as the angle between the mechanical axes of the femur and tibia [10]. The FTA-long and HKA were both expressed as deviations from 0° (Fig. 1). Two observers independently performed radiographic measurements, and interobserver reliability was calculated.

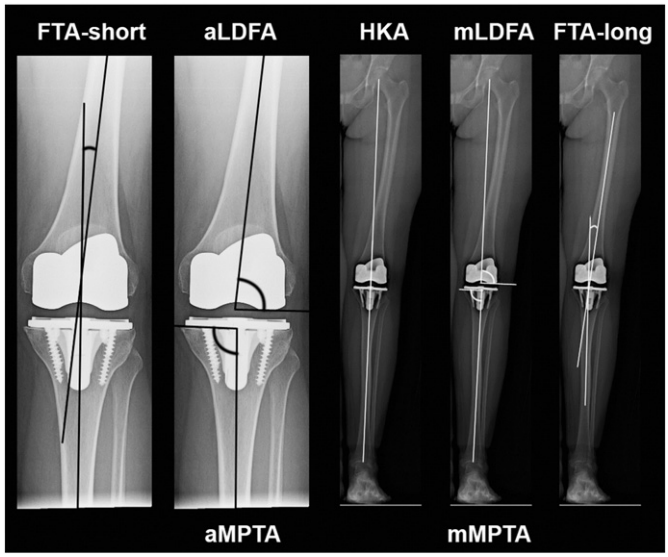

Fig. 1. Postoperative short and full-length radiographs show the measurements of anatomical and mechanical alignment assessed in this study.

When assessing coronal alignment on short films, an FTA-short value less than 2.4° was considered varus, neutral between 2.4° and 7.2°, and valgus greater than 7.2°. For full-length films, an HKA less than −3° was considered varus, neutral between −3° and 3°, and valgus greater than 3°. In addition, when assessing the alignment of the tibial component after TKA, aMPTA value less than 88° was considered varus, neutral between 88° and 92°, and valgus greater than 92°. These values were chosen to maintain consistency with the definitions of varus and valgus established by clinical outcomes and survivorship studies that evaluated coronal alignment on short and full-length radiographs [7-9]. If measurements between the 2 independent observers were discordant based on their assigned classification (neutral, varus, or valgus), the measurement of the first observer was used to classify that radiograph.

Microsoft Excel (Microsoft Corporation, Redmond, WA) was used to perform all data computations. Correlation coefficients were graded using previously described semiquantitative criteria: excellent for $0.9 \le r \le 1$, good for $0.7 \le r \le 0.89$, fair/moderate for $0.5 \le r \le 0.69$, low for $0.25 \le r \le 0.49$, and poor for $r \le 0.24$ [22].

Results

Interobserver correlation coefficients between the 2 independent observers for both the preoperative and postoperative radiographic

Table 1
Interobserver Correlations for Preoperative and Postoperative Measurements.

FTA-short	aMPTA	aLDFA	HKA	mMPTA	mLDFA	FTA-long
Preoperative						
0.98	0.89	0.91	0.99	0.90	0.91	0.99
Postoperative						
0.90	0.86	0.94	0.96	0.90	0.93	0.96