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Measurement of Femoral Anteversion by Biplane Radiography and Computed Tomography Imaging: Comparison With an Anatomic Reference

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RATIONALE AND OBJECTIVES. **The ability of biplane radiography and standard computed tomography (CT) imaging techniques to measure accurately the human femoral anteversion was evaluated and compared with an anatomic reference: the osteometric method.**

METHODS. **Femoral anteversion of 10 normal adult cadaveric human femora were determined using a standardized anatomic measurement method (the anatomic reference) and the 2 selected common imaging techniques (biplane radiography and CT).**

RESULTS. **On average, anteversion measurements using biplane radiography were 2½ times greater in magnitude than measurements using the anatomic reference (absolute mean difference, 13.5°; $P = 0.004$). In contrast, the discrepancy between CT and anatomic reference measurements was notably less and not statistically significant (absolute mean difference, 2.8°; $P = 0.351$). In addition, biplane radiography demonstrated greater inter- and intrarater variability than CT imaging for repeated measurements of the same bone specimens.**

CONCLUSIONS. **Compared with the anatomic reference, CT imaging was an accurate and valid technique for measuring the femoral anteversion. In contrast, biplane radiography demonstrated significant inconsistencies in the measurement of this anatomic parameter.**

KEY WORDS. **Femur, anteversion, measurement, radiography, computed tomography.**

OPTIMIZING FEMORAL anteversion has been considered an important requirement for normalization of hip mechanics.[1–8] Consequently, accurate and reproducible measurement of this anatomic parameter has been reported to be critical to the design and proper surgical placement of total hip prostheses.[1–6] Although direct anatomic measurement of this angle has typically been desirable, in many instances this may not be possible during clinical procedures or research experiments using live animal and human subjects and in cadavers in which soft tissues have not been removed.[9–11] Biplane radiography and computed tomography (CT) are 2 common imaging techniques used frequently to measure this anatomic parameter under these circumstances.[11–18] But to date, there has been no experimental clarity in the literature about their accuracy or reliability.[19] Previous investigations have attempted to validate the accuracy and reliability of these techniques by demonstrating statistically significant measurement correlation between each of these methods with 1 of several nonstandardized measurement controls, including intraoperative measurement, physical examination maneuvers, and comparisons with other imaging procedures such as axial tomography and fluoroscopy.[11–13,15,19–23] To the best of our knowledge, no study has compared these techniques with an anatomic reference, a measurement method considered by many to be the most accurate approach for measuring femoral anteversion.[1,2,7,8,24]

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The purpose of the present study was to examine the accuracy and reliability of biplane radiography and CT by comparing these 2 imaging techniques with an anatomic reference containing well-defined morphologic criteria. The present investigation does not purport to establish population means or variances for the magnitude of femoral anteversion in a large population sample. Such data already exist in the scientific literature (see Table 1).[1,2,8,10–51]

Materials and Methods

Design of the Study

Anteversion angles were measured using common radiographic (biplane projections)[14–16] and CT methods used in clinical and research orthopedics.[11,17,18] True anteversion angles were determined using the osteometric method (anatomic reference) previously described by Ruff and others.[8,24,26,29] All measurements were made on 10 normal adult cadaveric human femora (10 males: 6 right, 4 left; all skeletally mature; mean age 47 years, range 20–64 years). In all cases there was no evidence of skeletal pathology noted in the clinical records, on radiography, and by direct inspection of the bones. Equipment used included an osteometric table, a standard hospital X-ray machine, and a "second-generation" CT body scanner.

Anatomic Reference

Anatomic axes and 3-dimensional orientation of each bone were established with the posterior condyles placed flat on an osteometric table.[8,24,26,29] Landmarks used are shown in Figure 1A–C. The anteversion angle (Fig. 1D) was measured with a clear plastic protractor containing half circles, similar to instruments used by other anatomic studies.[8,24,26] The true anteversion angle was defined in a transverse plane. The angle was subtended by the line connecting the centers of the femoral head and neck (head-neck or cervical axis) and the line connecting the centers of the distal condyles, parallel to the posterior-most surfaces (transcondylar axis; Fig. 1D).[8,24]

Biplane Radiography

In biplane radiography, orientation of the bone was established with the use of anteroposterior and lateral radiographs (Fig. 2). To accomplish this, each cadaveric femur was placed with its posterior condyles flat on the surface of the X-ray table directly above the properly inserted X-ray cassette with its proximal end raised (using modeling clay) to a height corresponding to the longitudinal axis of the femoral diaphysis in the sagittal plane. A laser beam emitted from the X-ray tube was used to determine the longitudinal alignment (or axis) of the bone in the frontal plane. The X-ray machine was set at 60 kV and 8 MA-s. The anteroposterior radiograph was made with the X-ray tube centered over the mid-neck of the femur with the beam aimed perpendicular to the surface of the table and the cassette. Similarly, the lateral radiograph was made with the X-ray tube centered over the mid-neck of the femur but with the specimen rotated 90° laterally. The specimen was supported with modeling clay so that the head of the femur pointed upward. As before, the beam was aimed perpendicular to the surface of the table and the cassette. To correct for potential variation in magnification and resolution, an object of known size and shape (ie, a "phantom") was included in each radiograph. Each film cassette was 28×35 cm and captured an image of the proximal one third of the femur.

For determining the anteversion angle, the anteroposterior and lateral radiographs of each bone were placed on an illuminated view box and covered with a transparent film. With an erasable pen, appropriate axes of orientation (the head-neck or cervical axis and the longitudinal axis of the diaphysis) were determined using the procedures described by Ogata and Goldsand (Fig. 2).[15] The head-neck or cervical axis ran through the middle of the femoral neck and intersected the center of the femoral head. The longitudinal axis of the diaphysis was represented by a straight line connecting the midpoints of the mediolateral breadth of the diaphysis proximal to and distal to the lesser trochanter. According to Ogata and Goldsand,[15] these axes of orientation could simply be drawn "by eye" and should be considered "accurate enough" for most purposes. However, in some cases in which significant bowing of the femoral diaphysis is present, these investigators calculated an "averaged" longitudinal axis of "the shaft [diaphysis]" on the lateral radiograph (ie, in the sagittal plane).[15] An "averaged" longitudinal axis was not needed in the present study. Cervicofemoral angles α and β were determined using these axes and a clear plastic protractor that contained half circles (Fig. 2). These angles were then used to calculate the anteversion angle of the proximal femur by applying the trigonometric equation $\tan AV = \tan \beta / \tan \alpha$, where AV is anteversion.

CT Imaging

The CT scanner used in the present study was a second-generation Picker 1200 SZ model manufactured in 1984. Settings were adjusted to 130 kV, 190 MA-s, and 20 cm field size. To determine the anteversion angle, two 1-mm slices, 1 containing the femoral neck and another near the distal aspects of the epicondyles, were obtained on each bone. With each specimen oriented as described in the preceding section and based on the procedures developed by Hernandez et al,[17] the proximal slice was obtained in a transverse plane at a location containing the head, the neck, and the greater trochanter (Fig. 3A). The distal slice was obtained in a transverse plane at a location just slightly below the upper pole of the patella (if present on the specimen) and near the distal aspects of the epicondyles. Both the proximal and distal slices were parallel to each other; that is, repositioning of the femur with respect to the scanner was not necessary during image acquisition. In the

TABLE 1. English Language Literature Review: Comparison of Human Femoral Anteversion Data in a Historical Context

	Degrees of Anteversion	Year
Anatomic measurement		
Mikulicz[25]	11.6°	1878
Kingsley and Olmsted[26]	8.021° (n = 630); 24.4°, 17.2°*† (n = 30)	1948
Hubbard and Staheli[31]	13.9° (n = 10)	1972
Henriksson[10]	NP* (n = 123)	1980
Ruff and Hayes[8,24]	22.7°‖ (n = 119)	1981, 1983
Moulton and Upadhyay[32]	15.38° (n = 102)	1982
Yoshioka and colleagues[27,28]	7.4° (n = 32)	1987
Lausten et al.[33]	14.0°‡ (n = 30)	1989
Kane et al.[34]	NP	1992
Ruwe et al.[19]	NP§	1992
Miller et al.[22]	16.4° (n = 24)	1993
Kuo et al.[2]	10.0° (n = 33)	1998
CT		
Hubbard and Staheli[31]	42°*#†† (n = 20)	1972
Weiner et al.[18]	NP	1978
Hernandez et al.[17]	NP††	1981
Kushner et al.[35]	NP#	1985
Reikerås et al.[36]	13° (n = 47)	1985
Mahboubi and Horstmann[37]	29.4°* (n = 18)	1986
Berman et al.[38]	30°* (n = 19)	1987
Horstmann and Mahboubi[39]	10.0° to 40.0°*	1987
Murphy et al.[11]	NP (n = 32)	1987
Høiseth et al.[23]	11.4° (n = 33)	1989
Kitaoka et al.[40]	6.3° (n = 18)	1989
Lausten et al.[33]	13.5°‡ (n = 30)	1989
Ruwe et al.[19]	NP	1992
Miller et al.[22]	11.4° (n = 24)	1993
Abel et al.[21]	7.2° (L), 10.3° (R)* (n = 2)	1994
Biplane radiography		
Dunlap et al.[13]	8.7°†† (n = 200); 31.0°, 23.7°*† [n = 430]	1953
Ryder and Crane[41]	NP*††	1953
Magilligan[16]	NP	1956
Shands and Steele[42]	16° to 39°*†† (n = 238)	1958
Reynolds and Herzer[20]	NP††	1959
Hubbard and Staheli[31]	40°*†† (n = 20)	1972
LaGasse and Staheli[43]	NP*	1972
Fabry et al.[44]	24.14°*†† (n = 864)	1973
Ogata and Goldsand[15]	24° (n = 4)	1979
Ruby et al.[45]	32°*†† (n = 28)	1979
Burr et al.[46]	NP**	1982
Herrlin and Ekelund[14]	28° (n = 20)	1983
Proubasta et al.[47]	NP	1984
Philips et al.[48]	48.1°* (n = 29)	1985
Reikerås et al.[36]	10.1°†† (n = 67)	1985
Høiseth et al.[23]	approximately 10°†† (n = 29)	1989
Ruwe et al.[19]	NP	1992
Axial tomography/projection(s)		
Dunn[12]	NP*	1952
Budin and Chandler[49]	NP*	1957
Ruby et al.[45]	NP*	1979
Kane et al.[34]	NP*††	1992
Ultrasonography		
Moulton and Upadhyay[32]	10° to 34° (n = 36)	1982
Philips et al.[48]	42.4°* (n = 29)	1985
Berman et al.[38]	26°* (n = 19)	1987
Upadhyay et al.[50]	20.0° (n = 25)	1987
Lausten et al.[33]	23.4° to 24.0°‡ (n = 30)	1989
Miller et al.[22]	21.1° (n = 24)	1993
Fluoroscopy		
Rogers[51]	NP	1931
LaGasse and Staheli[43]	NP*	1972
Ruby et al.[45]	35°* (n = 28)	1979

Studies are listed by methodology in reverse chronological order. Anteversion angles are reported (where applicable) as means or median values. Techniques reviewed included: anatomic measurement of the bone, CT, biplane radiography, axial tomography/projection(s), ultrasonography, and fluoroscopy. NP, not provided; L, left femur; R, right femur.

* Measurements in children (defined as ≥1 but less than 17 years of age).

† Measurements in infants (defined as less than 1 year of age).

‡ Median value given instead of the mean.

§ Clinical method.

‖ Archeological human sample from Pecos Pueblo, New Mexico. In Ruff's Ph.D. Thesis (1981), mean femoral anteversion angles were reported in the context of sex and side differences. They generally ranged from 17.8° to 24.6°.

\# Axial or transaxial tomography.

** The method includes a cross-table lateral radiogram of the femoral condyles.

†† Positioning apparatus required.

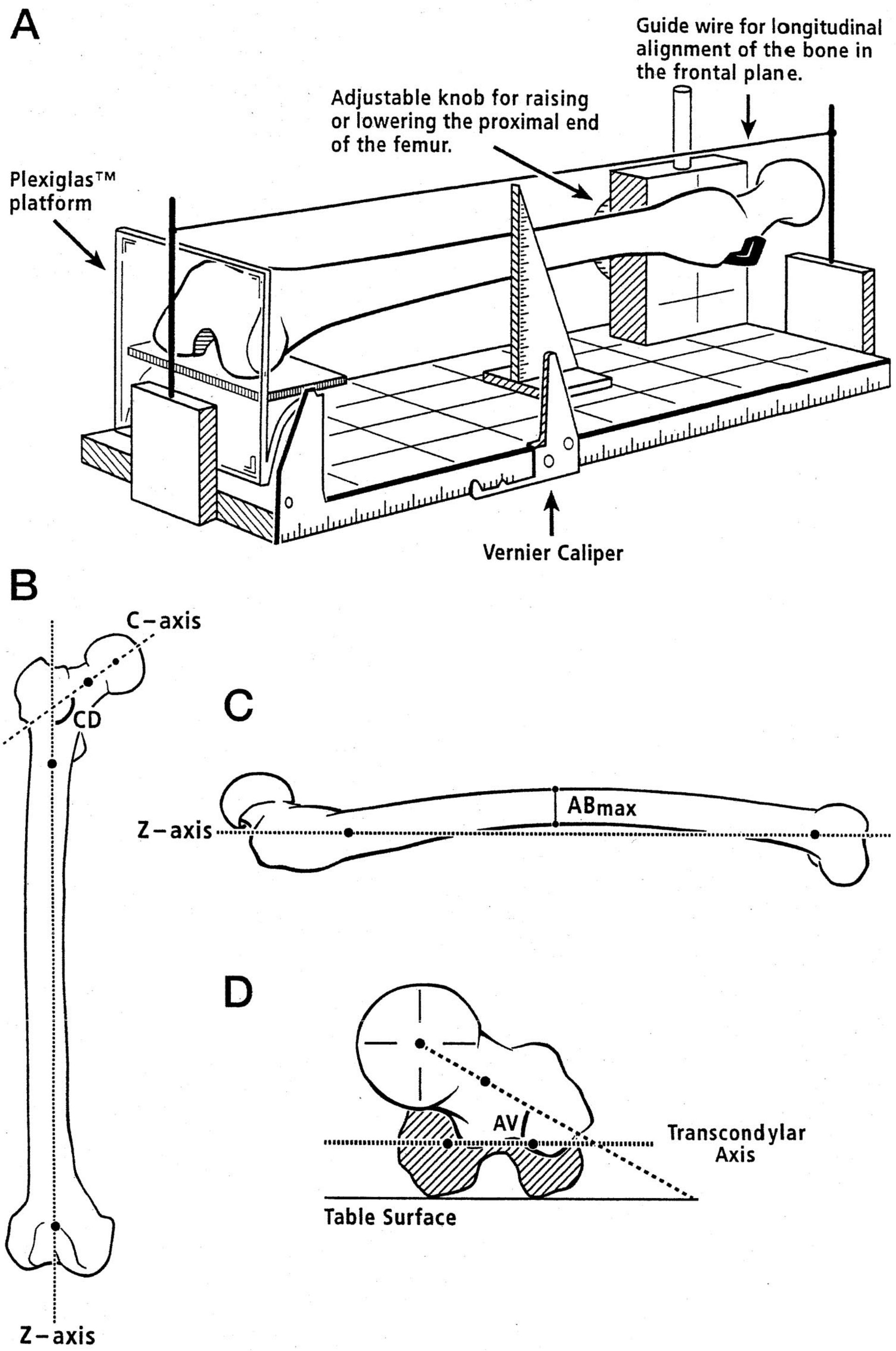

FIGURE 1. (A) Anatomic axes and 3-dimensional orientation of each femur were established with the posterior condyles placed flat on an osteometric table as described by Ruff and others.[8,24,26,29] (B, C) Representations of the longitudinal axis of the femoral diaphysis (Z-axis) in both frontal and sagittal planes. (D) Femoral anteversion (AV) angle in a transverse plane as seen by the observer during measurement. Ab_{max}, maximum anterior bow of the femur; CD, cervicodiaphyseal angle; C-axis, cervical axis of the femoral neck.

present human sample, no additional slices were needed to determine the anteversion angle. However, in some instances, such as in the presence of femoral neck-shaft valgus, superimposing 2 proximal slices to create a summation image may be required to improve measurement accuracy.[11] This summation image usually comprised (1) a slice at the

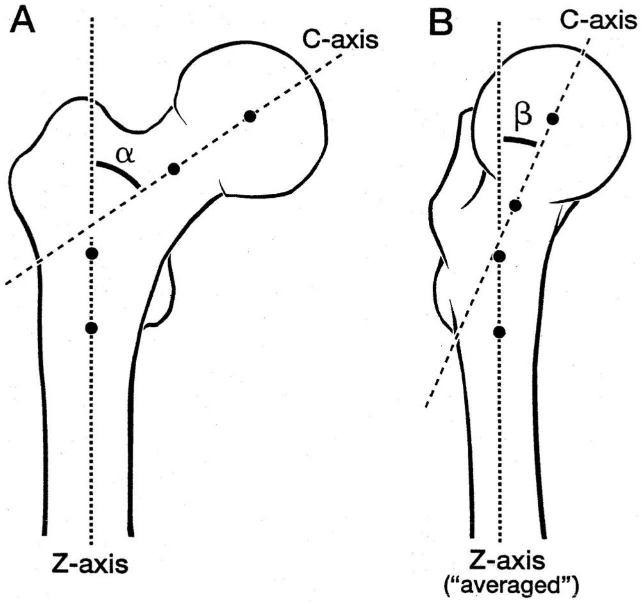

FIGURE 2. Biplane radiographic method based on the work by Ogata and Goldsand.[15] (A, B) Anteroposterior and lateral radiographic images of the bone. Cervicofemoral angles α (A) and β (B) were each defined by the angle subtended by the head-neck axis (cervical or C-axis) and the longitudinal axis of the proximal femoral diaphysis (Z-axis). These angles were used to determine the femoral anteversion (AV) angle by applying the trigonometric equation tan AV = tan β/tan α.[15]

center of the femoral head and (2) a slice at the center of the base of the femoral neck.[11]

An object of known size, shape, and material (ie, a "phantom") was included in each CT slice to account for variations as a result of magnification and spatial resolution.[52] For determining the anteversion angle of the proximal femur, the slices were superimposed over an illuminated view box (Fig. 3) and measured with a clear plastic protractor that contained half circles (Fig. 3C).

Observer Variability

For assessing the impact of interobserver (interrater) and intraobserver (intrarater) variations on the measurement reproducibility (reliability) of each technique, repeated measurements were made on each bone specimen by the principal investigator and 2 research assistants. After several instruction sessions, each individual independently measured the 10 specimens without comparing data. The 2 assistants were blinded to the purpose of the study and had no previous knowledge of the published population values for normal adult human femoral anteversion.

Data Analysis

Statistical analyses were conducted using the STATVIEW system package (Version 5.0) developed by the SAS Institute (Cary, NC). On the basis of the work by Bland and Altman,[53,54] the significance of the differences between each set of measurements from the 2 imaging techniques and the anatomic reference (ie, accuracy) were evaluated using the 1-way analysis of variance (ANOVA) procedure with the Fisher post hoc pair-wise comparison test. When appropriate, 95% confidence limits were reported for these measurement differences.[53,54] Pearson correlation coefficients were also calculated to evaluate the differences between (interrater variation) and within (intrarater variation) observers. Statistical significance was set at $\alpha \leq 0.05$.

Results

Means, medians, standard deviations, standard errors, range, and 95% confidence limits for measurement readings and differences are listed in Tables 2 and 3. On average, the femoral anteversion measurement using biplane radiography was 2½ times greater than the corresponding measure-

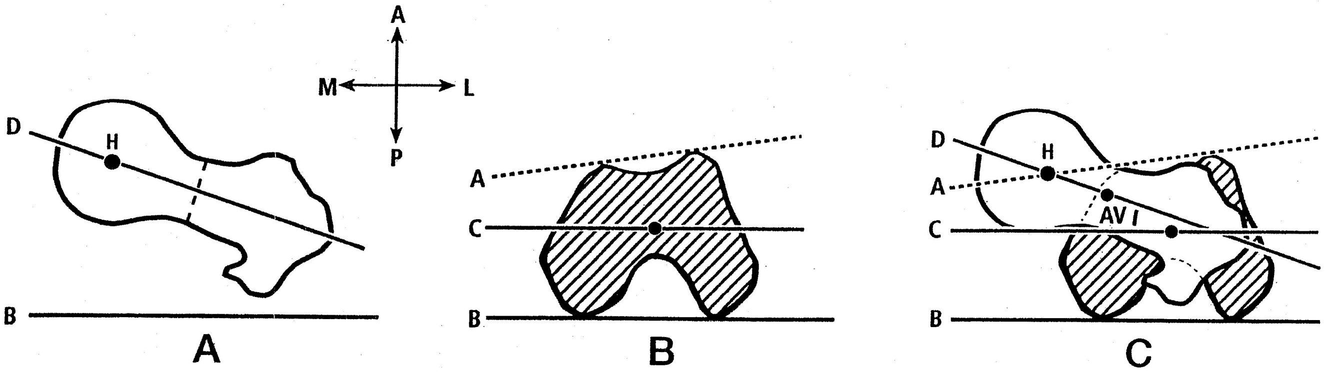

FIGURE 3. Based on the work of Hernandez et al,[17] the proximal CT slice was obtained in a transverse plane at a location that contained the head, the neck, and the greater trochanter (A). The distal CT slice was obtained in a transverse plane at a location just slightly below the upper pole of the patella (if present on the specimen) and near the distal aspects of the epicondyles (B). Femoral anteversion (AV) was defined as the angle subtended by the head-neck axis (line D) and the transcondylar axis (line C), which is parallel to the posterior-most surfaces of the distal condyles[11,17] (line B; C). A, anterior; P, posterior; M, medial; L, lateral; H, center of the femoral head.

TABLE 2. Femoral Anteversion Data

Method	Mean	Median	SD	SE	Max	Min	[95% Confidence Limits]
Reference	9.6°	9.4°	3.3°	1.0°	26.4°	4.3°	[7.3°, 12.0°]
CT	12.4°	13.3°	3.8°	1.2°	17.6°	7.0°	[9.7°, 15.1°]
Biplane radiography	23.1°	20.8°	6.9°	2.2°	34.3°	13.5°	[18.1°, 28.0°]*

Max, maximum value measured; Min, minimum value measured.

* Statistically significant: 1-way analysis of variance, α level set at $P < 0.05$.

ment using the anatomic reference (absolute mean difference, 13.5°; $P = 0.004$). By contrast, the discrepancy in measurements between CT imaging and the anatomic reference was notably less and not statistically significant (absolute mean difference, 2.8°; $P = 0.351$).

Tables 4 and 5 list means, medians, standard deviations, standard errors, range, and Pearson correlation coefficients for repeated measurements on the same bone specimens made by each observer using each of the imaging techniques. On average, biplane radiography demonstrated greater inter- and intrarater variability (lower correlations among measurements) than CT imaging for these repeated measurements (Tables 4 and 5).

Discussion

Biplane radiography and CT imaging has been used frequently to measure human femoral anteversion clinically and during experiments in orthopedic research.[11–18] However, to date, there has been no experimental clarity in the literature about their accuracy or reliability.[9,19] To our knowledge, no investigation has attempted to quantify the ability of these techniques to measure accurately the femoral anteversion by comparing them with an anatomic reference. The present study provides such comparative data.

Numerous techniques exist for measuring femoral anteversion, and most of them are based on different radiographic projections.[12–16] Early methods included fluoroscopy, axial tomography, and biplane radiography[12–16,34,43,45,49,51]. Because of relatively lower cost and easier access, biplane radiography has traditionally been considered a reasonable choice for measuring femoral anteversion when direct anatomic measurement was not possible.[12–16] But with the introduction of newer technology such as CT imaging, magnetic resonance imaging, and ultrasound, many clinicians and researchers have increasingly come to recognize that biplane radiography has important limitations.[9,11,17,18,32,38,48,55] For example, some investigators have reported large discrepancies in results obtained by this method, concluding that errors as a result of variability in patient or specimen positioning and X-ray cassette placement and radiographic interpretation by radiologists or orthopedic surgeons were common.[12–15]

Because of its increasing accessibility, simpler noninvasive application, and gradually declining cost, CT imaging has recently become popular for measuring femoral anteversion in both clinical and research settings.[11,17] Although this technology has been considered precise, its accuracy has not been firmly established.[9,11] Many scientists, for example, have reported that CT imaging consistently underestimates the femoral anteversion when compared with nonstandardized measurement controls such as intraoperative measurement, physical examination maneuvers, and comparisons with other imaging techniques.[11,17–19] In addition, other investigators have suggested that, in both clinical practice and research experiments that required the use of live human subjects,[42,56–60] CT imaging posed a potential radiation hazard to certain patient populations, especially children. Rads per CT slice, for instance, have been estimated to be 5 to 20 times greater than a standard anteroposterior pelvis radiograph.[18] However, this concern may be unwarranted because most modern CT scanners emit relatively lower, more limited doses of ionizing radiation.

Because ultrasound and magnetic resonance imaging do not emit ionizing radiation, they are attractive alternatives to biplane radiography and CT imaging. However, these recent

TABLE 3. Comparative Analysis

Method Comparisons	CT vs. Reference	Biplane Radiography vs. Reference
% Difference	25.8%	99.2%
Mean difference	2.8°	13.5°
SD	2.7°	7.5°
t value	0.978	3.682
P value	0.351 (n.s.)	0.004
[95% Confidence limits]	[2.5°, 8.1°]	[1.2°, 22.2°]

Statistical significance is set at $P < 0.05$; n.s., not statistically significant.

TABLE 4. Inter- and Intrarater Variability

Method	Mean	Median	SD	SE	Max	Min
Reference	9.6°	9.4°	3.3°	1.0°	26.4°	4.3°
CT						
Observer 1	11.4°	10.5°	4.1°	1.3°	16.3°	1.9°
Observer 2	11.7°	11.0°	2.9°	0.9°	15.5°	1.7°
Observer 3	14.2°	13.0°	5.2°	1.6°	31.9°	8.0°
Biplane Radiography						
Observer 1	23.1°	21.6°	7.4°	2.3°	34.6°	10.9°
Observer 2	21.0°	17.8°	6.7°	2.1°	30.5°	10.8°
Observer 3	25.1°	26.5°	8.7°	2.7°	37.8°	11.7°

TABLE 5. Correlation Statistics

Correlation (r)	Biplane Radiography	CT
Intrarater		
Observer 1 A–B	0.756	0.981
Observer 2 A–B	0.642	0.964
Observer 3 A–B	0.702	0.992
Interrater		
Observer 1–2	0.707	0.959
Observer 1–3	0.703	0.938
Observer 2–3	0.665	0.873

innovations require access to technology that may be relatively expensive and may not be readily available to many clinicians and investigators at various academic and community-based institutions.[9,32] Moreover, scientific investigations have yet to demonstrate that these techniques are superior to biplane radiography or CT in accuracy, reliability, image resolution, or cost-effectiveness.[9,32,38,48]

Despite the use of similar methods and homogeneous population samples, previous studies using various imaging techniques have reported inconsistent mean values and/or ranges of normal adult human femoral anteversion (Table 1). These discrepancies, in part, were due to the differences in defining the complex relationships between various anatomic features of the proximal, mid-, and distal regions of the femoral diaphysis. If these anatomic landmarks and accompanying axes of orientation are not properly or consistently selected, then significant errors in accuracy could occur, leading to erroneous findings.

Because of such inconsistencies and/or structural variations, difficulties in identifying the anatomic orientation of the femur were often encountered during biplane radiographic measurements. For example, uncertainties in defining and/or clearly recognizing the geometric relationships of the proximal femur could lead to misalignment of the head-neck axis, as well as the diaphyseal axis of the limb bone in the sagittal plane (Fig. 4).[10,61] This, in turn, could lead to significant changes in the trigonometric parameters that were used to calculate femoral anteversion. Consequently, significant errors in accuracy and in measurement reproducibility (reliability) could occur while using this technique, and was probably the case in the present study.

In contrast, CT imaging avoided many of these problems. Unlike biplane radiography, CT imaging allowed the observer to measure femoral anteversion by viewing the proximal and distal ends of the femur in a transverse plane. Simultaneous visualization of these proximal and distal landmarks negated the confusion that may arise when attempting to define the head-neck and diaphyseal axes in 2-dimensional planes produced by biplane projections. Thus, it was not surprising that the reported difference in mean anteversion magnitudes between CT imaging and the anatomic reference was notably less in the present study (within 2.8°; $P = 0.351$, not statistically significant), and that the inter- and intrarater variability observed during repeated measurements of the same bone specimens were less for this technique than for biplane radiography (Tables 4 and 5).

These findings, however, are not particularly surprising. Clinical experience and data from the orthopedic literature suggest that biplane radiographs in patients are often difficult to standardize.[9,15,16,19,62] Perpendicular views are almost never accurately possible and frequently prone to variability. The measured values in patients are probably even less accurate clinically than in the present controlled cadaveric study. These findings suggest that biplane radiography is probably only valuable for a rough estimation of the femoral anteversion (potential variation in measurement ±13.5°).

Because live human subjects were not included in the present study, the collected data should be interpreted with caution. Extrapolation of these data to the clinical setting should be carried out sensibly, recognizing that in the clinical environment confounding factors such as patient posi-

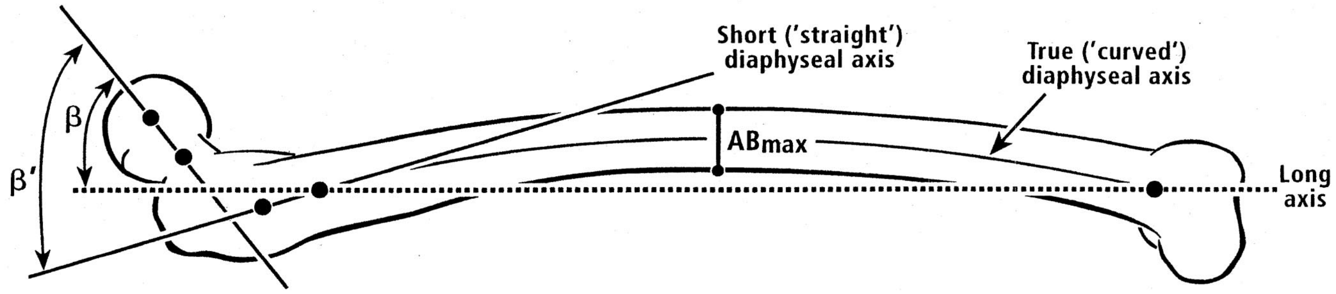

FIGURE 4. The difference between the long axis (eg, as used in most anatomic measurements of the femur) and the short axis (eg, as used in biplane radiography) of the femoral diaphysis in the sagittal plane may commonly contribute to an exaggerated mean measured magnitude of the femoral anteversion angle. For example, the maximum anterior bow of the human femur (located at approximately 55% of the bone length) may produce a significant deviation in the anatomic alignment of the short axis in the sagittal plane.[14–16] This, in turn, could significantly alter the angle β (see also Fig. 2B) and exaggerate the true mean anteversion angle during biplane radiographic measurements. Angle β' represents an increase in the cervicofemoral angle β that could contribute to this apparent exaggeration.

tioning, variability in technician skills, and radiographic interpretation by clinicians could and may lead to significant errors in measurement.[9,62] The present study also lacked inclusion of pediatric femora. Because many hip conditions that require clinical and research knowledge of the femoral anteversion occur in children, a sample including pediatric femora may have lent more predictive power to the present findings.[56] Finally, the present study did not examine the accuracy or reliability of other radiographic methods. The Dunn projection, for example, has been considered by some to be a more standardized view of the anteversion angle than biplane radiographs and may offer measurement possibilities similar to CT imaging.[12] However, to date, this projection has not been used widely by clinicians at various institutions. Reasons for this are not known, but patient positioning may be an important factor. Positioning of a patient in a supine position with the hips and knees flexed at 90 degrees and legs held by an assistant may represent a more cumbersome procedure than the protocol typically used in biplane radiography. In addition, the requirement that the X-ray tube be centered over the upper border of the symphysis pubis raises concerns regarding proper shielding of reproductive organs in younger patients during this procedure. Moreover, many radiology technicians at these institutions may have limited or no knowledge of this radiographic projection for measuring femoral anteversion. Nevertheless, the clinical possibilities of using the Dunn projection or other similar methods deserve further investigation, requiring experimental verification for accuracy and reliability.

Data from the present study suggest that CT imaging was the more accurate and valid technique for measuring the femoral anteversion. In contrast, biplane radiography had significant inconsistencies. The data suggest that marked differences and variability in selecting proper anatomic landmarks accounted for some of the discrepancies found between this latter method and the anatomic reference. Consequently, if anatomic measurement of the femur is not feasible, then CT determination of the femoral anteversion should be considered the imaging technique of choice for both clinical and research purposes.

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