

# Comparison of fluoroscopic techniques for assessment of femoral rotational alignment

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## Abstract

**Objectives:** Anatomic rotational reduction of diaphyseal femur fractures is essential in restoring limb mechanics. Errors in reproducing anteroposterior (AP) or lateral knee reference radiographs of the contralateral limb could result in inaccuracies during rotational reduction. The objective of this study was to examine whether fluoroscopic rotational variation can be observed with the same degree of precision with AP and lateral distal femur projections.

**Methods:** AP and lateral radiographs were obtained from intact knees of 7 cadaveric specimens using fluoroscopy. The lateral condylar width and coronal femoral width from the AP images and the posterior condylar offset and sagittal femoral width from the lateral images were measured by 3 reviewers. Interclass correlation coefficients (ICCs) among the 3 reviewers were calculated. The mean data from all reviewers were plotted against angle of rotation, and the slope ( $M$ ) and regression of the line were then determined.

**Results:** ICCs were 0.997 (lateral) and 0.994 (AP), demonstrating excellent interobserver agreement. The mean ( $\pm$ SD)  $M$  value for lateral images was  $0.016 \pm 0.001$  and for AP images was  $0.009 \pm 0.001$  ( $P < .0001$ ). The higher lateral  $M$  value represents a more appreciable difference in size of the measured segment for the same rotational change.

**Conclusions:** The observed rotational change was 1.76 times greater on lateral images compared to AP images; thus, the lateral images may be more precise as a reference for rotation. The routine use of lateral knee radiographs to guide intraoperative rotational alignment of the femur may therefore be justified.

**Keywords:** diaphyseal femur fracture, femoral rotation, fluoroscopic technique, knee radiograph

## 1. Introduction

Malrotation is a known complication following fixation of diaphyseal femur fractures. Anatomic rotational reduction of diaphyseal femur fractures is critical to restoring proper lower extremity mechanics.<sup>[1,2]</sup> Failure to achieve correct alignment often leads to unplanned revision surgery. Revision femoral nailing may have increased rates of complications such as infection, nonunion, or nail destabilization due to overlapping drill holes for interlocking screws. Computed tomography (CT) is the gold standard for measuring rotation outside of the operating room; however, it is of limited practicality intraoperatively due to cost, increased radiation exposure, and the need for portable imaging equipment.<sup>[3-6]</sup> Intraoperatively, many techniques have

been described for using fluoroscopy to assess rotational reduction of femoral diaphyseal fractures.<sup>[7-12]</sup>

Traditionally defined knee radiographs include an anteroposterior (AP) view, in which the patella is centered between the medial and lateral femoral condyles, and a lateral view, in which the posterior border of the medial and lateral femoral condyles are superimposed.<sup>[13]</sup> The fluoroscopic assessment of femoral diaphyseal fracture reduction is dependent upon surgeon ability to reproduce reference radiographs obtained from the contralateral limb. Current techniques describe obtaining either a true AP or a true lateral radiograph of the uninjured contralateral knee. The knee image is paired with an AP image of the hip obtained while maintaining the intact extremity in a static position. This process is then completed on the injured side intraoperatively, and the rotational alignment is considered restored if the paired knee and hip lesser trochanter profiles match between the injured and uninjured extremities. While the option is given to reference either an AP or a lateral image of the knee, it is unclear which view is more likely to be reliably reproduced with the operative side.<sup>[5,6]</sup>

The aim of this study was to compare the ability of reviewers to identify rotational change from AP versus lateral knee radiographs using defined measurements on images obtained from cadaveric specimens. Our hypothesis was that change in fluoroscopic rotational variation of the distal femur can be observed with the same degree of precision with either AP or lateral projections.

## 2. Methods

This study utilized 7 intact fresh frozen specimens from hemipelvis to toes. All specimens were radiographically evaluated

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**Figure 1.** Specimen positioning. A Schanz pin in the anterior superior iliac spine is connected to an external fixator frame. The lower leg is secured to blankets with cloth tape after the knee is in maximal extension.

for the absence of prior orthopaedic intervention, fracture, or other anatomically distorting pathologic processes. Specimens were placed on a radiopaque table in the anatomic supine position with the knee in maximal extension. In order to standardize specimen positioning and facilitate unobstructed fluoroscopic images, specimens were secured to the table with a construct consisting of a Schanz pin placed in the anterior superior iliac spine which was then connected to an external fixator frame. The lower leg rested on blankets and was not moved as the fluoroscopy machine rotated around the table (Fig. 1).

All fluoroscopic images were obtained with a C-arm system (GE OEC 9800, Chicago, IL). The fluoroscopic unit was rotated and images were obtained until the medial and lateral posterior condyles were aligned on lateral radiographs. This was defined as the 0° position, or as the true lateral image. From this position, a series of fluoroscopic images were obtained in increments of 2° to a maximum of 10° rotation in both a clockwise and counter clockwise direction (Fig. 2A). The rotational attitude of the image intensifier was determined with a mobile phone securely mounted to the image intensifier and the use of a protractor application (Angle Meter (FREE) Version 4.1). Tolerances on the application were accurate to 0.1°. Images beyond 10° of rotation demon-

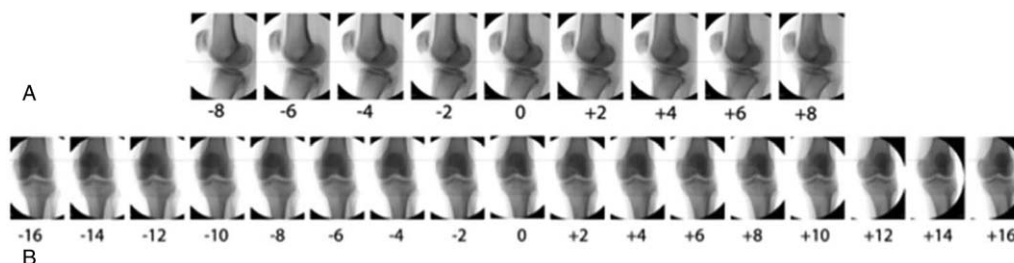
strated such obliquity that they could not be reasonably used as a surrogate for a true lateral radiograph.

The image intensifier was returned to the 0° lateral position, and then rotated 90° to a position defined as 0° AP. A series of clockwise and counterclockwise rotations were performed from this position and images were obtained in 2° increments, to a maximum of 16° of rotation in each direction (Fig. 2B).

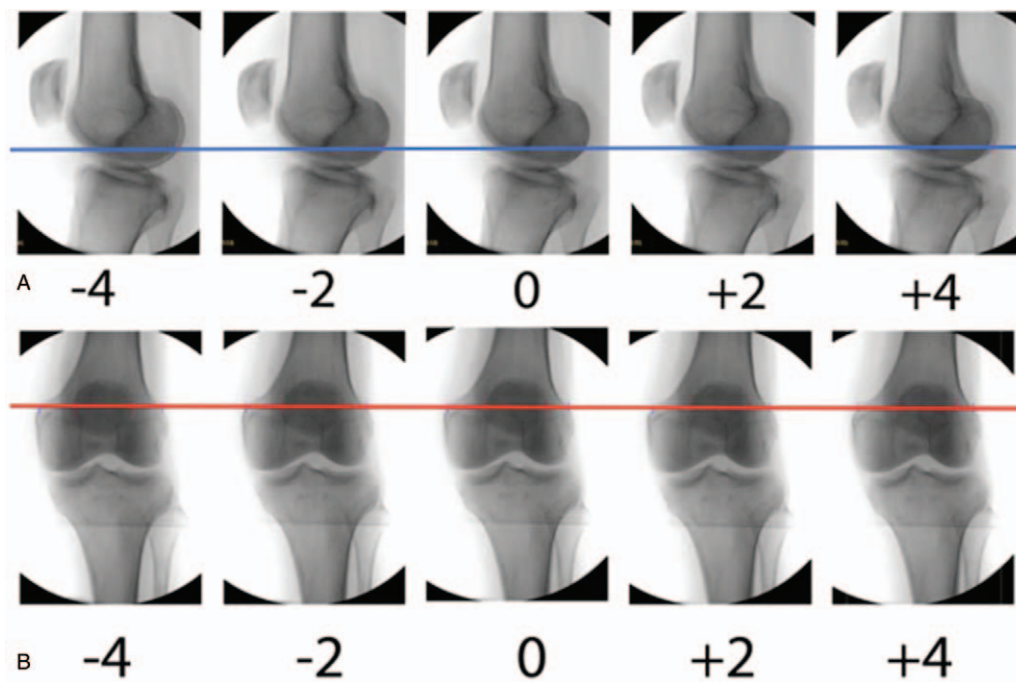
## 2.1. Data analysis

Images were transferred to Photoshop software (Adobe Photoshop CSS Extended Version 2.0 × 64). The lateral and AP fluoroscopic images were compared to ensure the identical magnification and rotational attitude (Fig. 2). Next, a horizontal measurement line was drawn across all images at the same level to ensure uniform measurements in the axial plane. For the lateral images, the measurement line was located where the posterior condyles were completely superimposed on the 0° rotation image (Fig. 3A). On the AP images, the measurement line was drawn at the level of maximal patella width on the 0° rotation image (Fig. 3B). The lateral knee measurements were obtained by measuring the posterior condylars offset (PCO), which was defined as the distance between the posterior border of the medial and lateral condyles and the sagittal width of the femur (SFW), which was defined as the width of the femur from anterior to posterior along the measurement line (Fig. 4). The AP knee measurements were obtained by measuring the lateral condyle width (LCW), which was defined as the width between the lateral femur edge and lateral patella edge along the measurement line, as well as coronal femoral width (CFW), which was defined as the width of the femur along the measurement line (Fig. 5). The unit of measurement was pixels in Photoshop software; measurements were accurate to the nearest 0.01 unit. Three of the coauthors independently obtained these measures for each group of images.

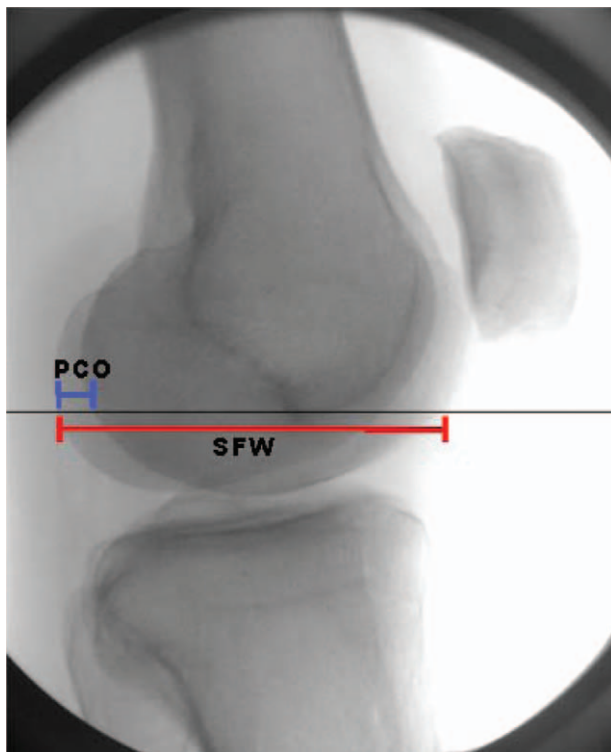
A ratio was created for each image to standardize measurements among all specimens. For the lateral images, the PCO was divided by the SFW (PCO/SFW, Fig. 4). For the AP images, the LCW was divided by the CFW (LCW/CFW, Fig. 5). Interclass correlation coefficients (ICCs) (two-way mixed model, absolute agreement) and 95% CI between the measures of the 3 observers were calculated using Statistical Package for the Social Sciences to examine variability among reviewers.<sup>[14]</sup> The mean and standard deviation of the ratios of the 3 reviewers were then calculated. Scatter plots of the mean ratios of the 3 reviewers versus the degree of C-arm rotation for each specimen were then created (Figs. 6 and 7). Linear regression analysis was performed on these plots and the slope ( $M$ ) and correlation coefficient were recorded.



**Figure 2.** Lateral (A) and AP (B) images aligned to ensure identical magnification and rotational attitude.



**Figure 3.** Magnified images showing the measurement line. (A) Lateral images with a horizontal measurement line drawn at the point where the posterior condyles are completely superimposed on the 0° rotation image. (B) AP images with a horizontal measurement line drawn at the level of maximal patella width on the 0° rotation image.



**Figure 4.** Lateral measurements. PCO, distance between medial and lateral posterior condyle along the measurement line. SFW, width of entire femur along the measurement line.

For the lateral radiographs, the *M* value represents the change in posterior condyle offset in relationship to the lateral distal femur width with each degree of rotation. For the AP radiographs, the *M* value represents the change in the condylar width in relationship to the width of the distal femur with each degree of rotation.

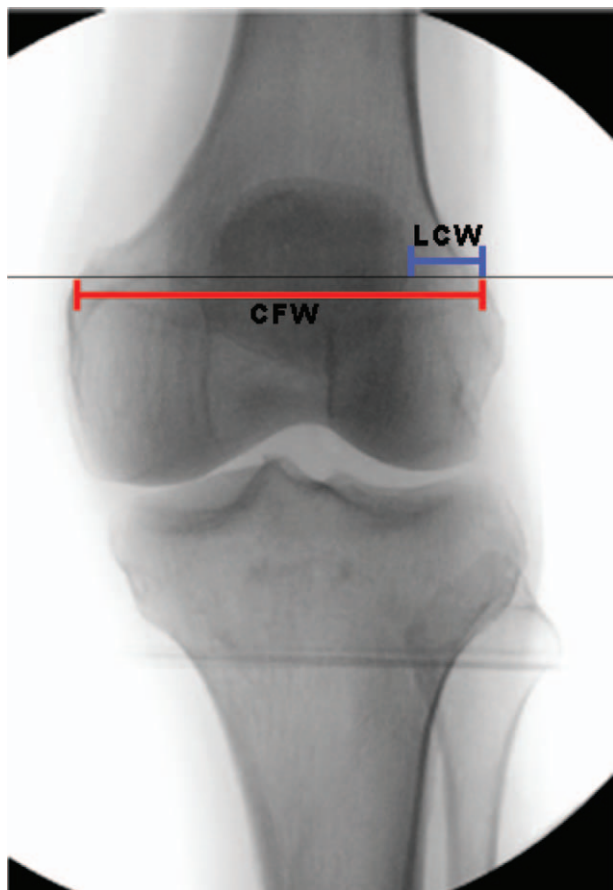
A paired t-test comparing the 2 *M* values (lateral and AP) for each limb was performed using Minitab software (Minitab 17, State College, PA). The level of significance was set at 0.05 and a confidence interval (CI) of 95%.

### 3. Results

The average age of our cadaveric specimens was 75 years (range, 47–87 years). Specimens were from 4 females and 3 males, and included 4 right and 3 left limbs.

The plots of the mean lateral and AP ratios of the 3 reviewers versus the degree of C-arm rotation for each specimen are shown in Figure 6 (lateral data) and Figure 7 (AP data). The *M* values determined from these plots are reported in Table 1. The mean *M* value for the lateral images was 0.016 (SD 0.001) and for the AP images was 0.009 (SD 0.001) ( $P < .0001$ ). A higher *M* value represents a more appreciable difference in the size of the measured segment for the same rotational change; thus, the measurement from the lateral images represents a greater amount of change observed during rotation than that observed during rotation of AP images.

The mean ICC for lateral images was 0.997 (range 95% CI 0.990–0.999) (Table 2) and for AP images was 0.994 (range 95% CI 0.983–0.998) (Table 3). This demonstrates excellent interobserver reliability.<sup>[14]</sup>



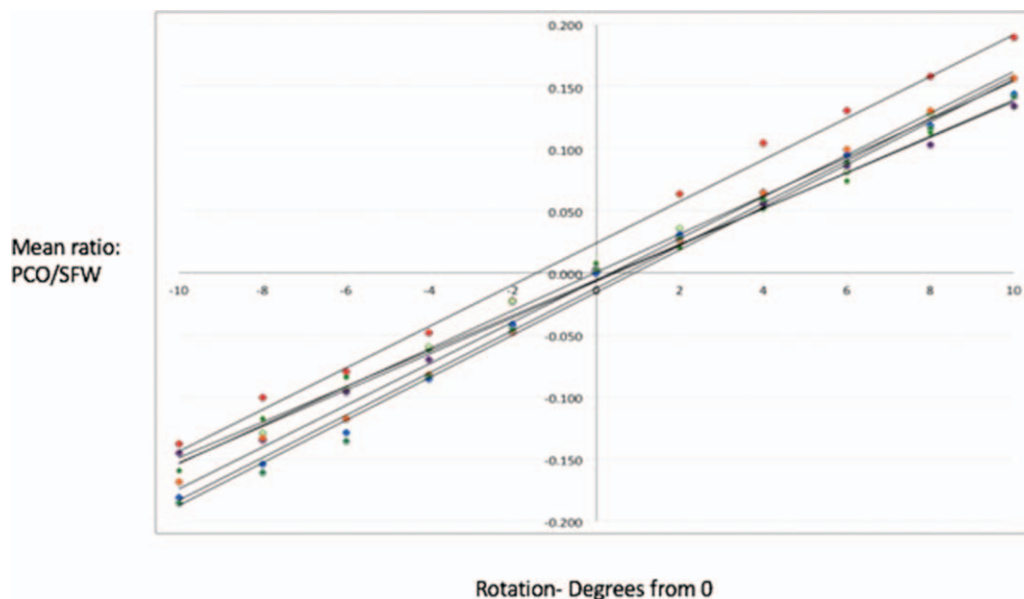
**Figure 5.** AP measurements. LCW, the width between the lateral femur edge and lateral patella edge along the measurement line. CFW, the width of the entire femur along the measurement line.

#### 4. Discussion

Malrotation is a common complication of intramedullary nailing for diaphyseal femur fractures. It is difficult to detect clinically, and likely underappreciated.<sup>[1]</sup> Femoral anteversion is highly variable among individuals, and malrotation may lead to gait disturbances; functional complaints with activities such as running, sports, and stairs; and early-onset arthritis.<sup>[2]</sup> Many techniques have been described for radiographic intraoperative assessment of femoral rotation. In his review, Hak<sup>[8]</sup> reported that the most accurate fluoroscopic method for assessing rotation was the lesser trochanter profile. Deshmukh et al,<sup>[15]</sup> described this method involving comparing the lesser trochanter profile on the injured and uninjured leg with the C-arm rotated exactly 90° relative to a true lateral x-ray of the knee or at the same degree of rotation relative to an AP image of the knee. This author's preferred technique is the Deshmukh method using lateral knee radiographs as we feel these can be more precisely reproduced on the injured and uninjured legs.

It is often stated that femoral rotation should be measured using orthogonal views of the femur, including hip and knee. However, Ajuwon et al<sup>[13]</sup> found that lateral radiographs were not always orthogonal to patella-centered AP radiographs. During surgical fixation of femoral shaft fractures, a combination of lateral and AP radiographs is typically obtained intraoperatively to assess rotation as well as confirm placement of hardware. Even with specific criteria for what determines a true AP and true lateral image, these are subject to individual perspective, and there will likely be differences from one viewer to the next. It is important to know the variation that typically exists within and between lateral and AP radiographs of the knee.

The current literature does not describe how accurately surgeons can identify rotational variation in AP or lateral images of the knee. We therefore sought to quantify the ability of reviewers to identify rotational change in radiographs. Our results suggest the observed change is greater on lateral images compared to AP images. The mean *M* value for lateral images,



**Figure 6.** Plot of the mean lateral ratio (PCO/SFW) measured by 3 reviewers versus the angle of rotation for each of the 7 specimens.

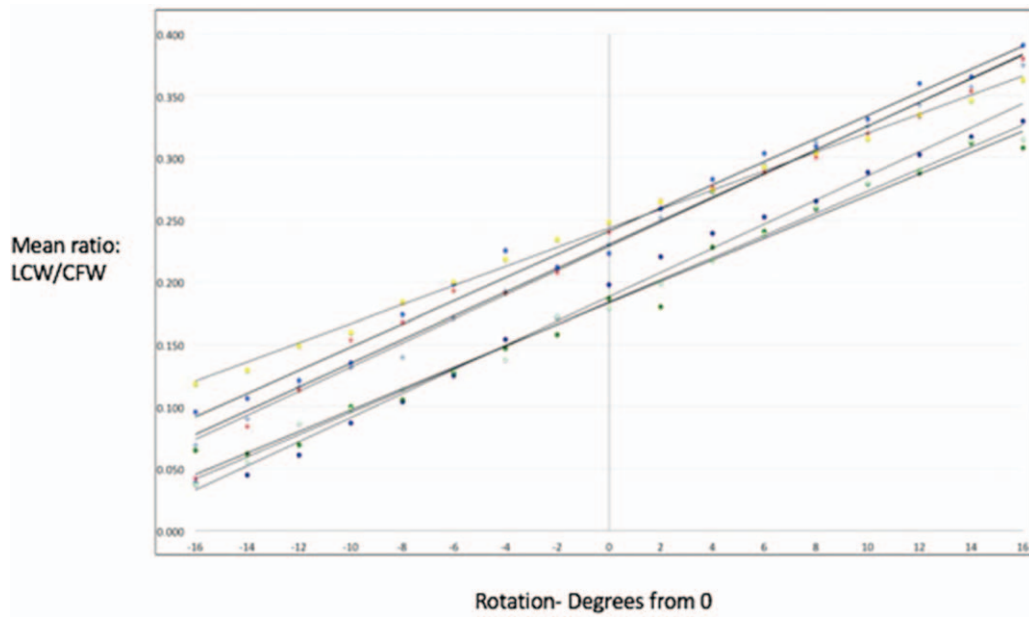


Figure 7. Plot of the mean AP ratio (LCW/CFW) measured by 3 reviewers versus the angle of rotation for each of the 7 specimens.

**Table 1**

**M values measured from the AP images (PCO/SFW) and the lateral images (LCW/CFW).**

Paired T-test	Mean	Standard deviation	Standard error mean	Minimum	Maximum
PCO/SFW	0.0160	0.0012	0.0005	10.0143	0.0172
LCW/CFW	0.0091	0.0007	0.0003	0.0077	0.0097
Difference	0.0017	0.0017	0.0006		

95% CI for mean difference: (0.005, 0.008).

T-test of mean difference = 0 (versus ≠ 0): T-value = 10.88 P-value = .000.

M = slope calculated from linear regression analysis of Figs 6 and 7.

representing change in posterior condylar offset, was nearly 1.76× that of the M value for AP images, which represents change in the LCW in relationship to the width of the distal femur. This leads us to conclude that there is a more obvious change when looking at lateral radiographs compared to AP radiographs. Using the lesser trochanter profile technique for rotational reduction of femur fractures, lateral radiographs could provide a more precise comparison of the injured and uninjured legs.

This study was limited due to the small number of cadaveric specimens analyzed. When obtaining images, rotational variation was estimated to the nearest 0.1° allowing up to 5% error. While we had very high interobserver reliability, we were limited in having only 3 reviewers to make measurements. However, the ICC values for the data from the 3 reviewers were excellent. Knee measurements were not correlated with hip measurements because using the lesser trochanter profile technique, the hip image is always obtained

**Table 2**

**Interclass correlation coefficient for lateral Images.**

Lateral	ICC single measures	95% CI lower	95% CI upper
1	0.991	0.976	0.997
2	0.998	0.995	0.999
3	0.994	0.983	0.999
4	0.999	0.997	1.000
5	0.997	0.988	0.999
6	0.999	0.996	1.000
7	0.998	0.995	0.999
Average	0.997	0.990	0.999
Min-max	0.008	0.021	0.003

**Table 3**

**Interclass correlation coefficient for anteroposterior Images.**

AP	ICC single measures	95% CI lower	95% CI upper
1	0.996	0.992	0.999
2	0.986	0.952	0.995
3	0.993	0.984	0.997
4	0.997	0.992	0.999
5	0.999	0.997	1.000
6	0.993	0.979	0.997
7	0.993	0.984	0.997
Average	0.994	0.983	0.998
Min-max	0.013	0.045	0.005

as an AP image. This is a limitation to our study as we cannot comment on the relationship of knee measurements with hip measurements.

In conclusion, there appears to be a greater observed difference in landmarks with lateral compared to AP images of the knee. The results from this study can be used to help improve assessment of rotation for patients being treated for diaphyseal femur fractures. Clinical validation is needed, thus future investigations should focus on assessment of the lesser trochanter hip profile combined with AP and lateral knee radiographs to determine if rotational accuracy can be improved.

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