An Anatomic Study on Whether the Patella is Centered in an Ideal Anteroposterior Radiograph of the Knee

Ademola A. Ajuwon, MD · Ronak Desai, MD · Kathleen Farhang, BS · Colin E. Lasko · Raymond W. Liu, MD

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Abstract *Background:* Currently, an anteroposterior radiograph of the knee is judged based on a centered position of the patella between the femoral condyles. We are not aware of any anatomic literature supporting this recommendation. *Questions/Purposes:* Orthogonal images are required for accurate assessment of knee deformity. Although an image with the patella centered at the distal femur is generally accepted as a true anteroposterior (AP) radiograph of the knee, there is minimal anatomic data to support that this view is orthogonal to a true lateral view of the knee where the condyles are overlapped. We designed an anatomical study to test the relationship between these two radiographic views. *Methods:* We studied 428 well-preserved cadaveric skeletons ranging from 40 to 79 years of age at death. Centering of the patella was calculated based on distal femoral and patellar widths. Multiple regression analysis was then performed to determine the relationship between patellar centering and age, gender, ethnicity, mechanical lateral distal femoral angle (mLDFA), medial proximal tibial angle (MPTA), femoral anteversion, and contralateral centering.

Results: Average patellar centering was 0.13 ± 0.04 , indicating that the average patella was laterally positioned in the distal femur. Only mLDFA and contralateral centering showed statistically significant independent correlations with patellar centering with modest standardized beta coefficients of 0.10 and 0.23, respectively. *Conclusions:* In the average specimen, the patella is laterally deviated by 13% of the condylar width. Clinicians should be aware that a lateral view with the femoral condyles overlapped is not always orthogonal to a patella-centered AP view when planning and implementing deformity correction.

Keywords knee radiographs · knee anatomy · knee deformity analysis · knee alignment

Introduction

Orthogonal images are generally desired for accurate assessment of any deformity. The knee joint is most commonly assessed with anteroposterior (AP) and lateral views [7]. Traditionally, a proper AP radiograph of the knee centers the patella between the femoral condyles in the distal femur, while a proper lateral radiograph superimposes the two femoral condyles over one another [9]. It is generally assumed that a proper lateral view is orthogonal to a proper AP radiograph [9].

Orthogonal imaging has practical implications, as deformity surgeons rely on these images to determine malalignment for preoperative planning [1, 6]. Classic deformity correction planning and technique are predicated on accurate orthogonal images preoperatively and intraoperatively [9]. The importance of proper knee alignment has been demonstrated in other fields including reconstruction, where accurate prosthetic implant position significantly influences rates of revision of total knee arthroplasty [2].

In the operating room, we have noticed that after obtaining a proper lateral radiograph, with the femoral condyles overlapped, a 90° rotation of the intraoperative fluoroscopy unit does not always produce an AP radiograph with the patella centering. Oftentimes, this results in an AP

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A. A. Ajuwon, MD · K. Farhang, BS
School of Medicine, Case Western Reserve University,
Cleveland, OH, USA

R. Desai, MD
Case Western Reserve University, Cleveland, OH, USA

C. E. Lasko
School of Biomedical Engineering,
Case Western Reserve University, Cleveland, OH, USA

R. W. Liu, MD (✉)
Orthopaedic Surgery, Rainbow Babies and Children's Hospital at
Case Western Reserve University, 11100 Euclid Avenue, RBC 6081,
Cleveland, OH 44106, USA
e-mail: raymond.liu@uhhospitals.org

radiograph with the patella laterally positioned. The converse is also true, and if one begins the procedure with an AP view with the patella centered and the fluoroscopy unit is then rotated 90° for a lateral view, the condyles are often-times not superimposed. This complicates accurate determination of deformity correction.

It is commonly recommended that a standing AP view from the hips to ankles be performed with the patella forward [9] and widely noted that the patella is often too laterally positioned despite this request (Fig. 1). Despite the importance of knowing whether a centered patella represents a true AP radiograph, we are not aware of any literature that addresses the normal location of the patella and whether it lies exactly between the femoral condyles in an average human knee.

We designed a study to determine whether a centered patella on the AP view truly represents an orthogonal view to a standard lateral view, where the condyles are overlapped. The aims of this study were to determine typical variance in patellar centering and to determine whether this variation can be

correlated with age, gender, ethnicity, knee alignment, femoral version, or contralateral patellar centering.

Methods

Subjects

We studied 856 paired femora from 428 human cadaveric specimens from the Hamann-Todd Osteological Collection at the Cleveland Museum of Natural History. This collection contains approximately 3,000 well-preserved skeletons. Specimens between the ages of 40 and 79 at the time of death were randomly selected for the study. Exclusion criteria included any obvious articular trauma, obvious metabolic or rheumatologic disease, evidence of infection affecting the joint surfaces, or incomplete skeletons.

In order to perform the patellar centering measurements, the femurs were placed in an anatomic position such that the posterior aspect of the femoral condyles and the most posterior aspect of the proximal femur, excluding the femoral head, lay flat on the table (Fig. 2a). If the femur was retroverted, the proximal and distal femurs were equally elevated on lifts such that the femoral head did not touch the table surface (Fig. 2b). Using this approach, femoral anteversion was left undisturbed throughout the study. The patella was then placed on the femur in the patellar groove. Despite a lack of soft tissue structures holding the patella in place, the patella sat well within the trochlear groove in almost all specimens. Although we recognize that the patella may not rest perfectly in the groove with the knee in an extended position, the goal of this study was to focus on the bony anatomy of the patellofemoral joint. Upon finding the optimal location for each patella within the groove, an anterior-posterior image was obtained. ImageJ software (National Institutes of Health, Bethesda, MD, USA) was used to measure the intercondylar width, the maximal width of the patella, and the distance from the lateral patellar edge to the femoral lateral condylar edge (Fig. 3). All measurements were made oriented to a line parallel to the distal aspects of the femoral condyles. Patellar centering represents how

Fig. 1. It is common for radiology technicians to image patients with the patella lateral, despite standard instructions to centralize the patella. This has led us to question whether the anatomic position of the patella is laterally deviated in some patients. **a** Seventeen-year-old male with bilateral genu valgum, worse on the left, with shortening of the right femur. **b** Eighteen-year-old male, previously treated for left Blount disease, now with genu valgum and shortening of the femur and tibia.

Fig. 2. Typical anatomic placement of the femur and patella. **a** The femur rests with the posterior aspect of the femoral condyles and the posterior aspect of the greater trochanter touching the table. The patella fits within the trochlear groove. **b** In cases with retroversion of the femoral head, the femoral condyles and greater trochanter are elevated on equal platforms to avoid rotational malpositioning secondary to the femoral head.

Fig. 3. Measurements of the distal femur and patella. The width of the femoral condyles, the width of the patella, and the distance from the lateral edge of the patella to the lateral edge of the lateral femoral condyle were measured as illustrated. The specimen was oriented with the distal femoral condyles perpendicular to the vertical lines defining each of these measurements.

lateral the center is located on the distal femur, with a centering of 0 representing a perfectly centered patella and a positive values representing lateral deviation of the patella in proportion to total condylar width:

Patellar centering

$$= \frac{(\text{Femoral width} \times 0.5) - (\text{DPLE}) - (\text{Patellar width} \times 0.5)}{\text{Femoral width}}$$

where DPLE is the distance from the lateral patellar edge to the lateral condylar edge of the femur.

Angular Measurements

To quantify deformity of the distal femur and proximal tibia, we used the mechanical lateral distal femoral angle (mLDFA) and medial proximal tibial angle (MPTA), as described by Paley et al. [10]. The femur from each specimen was positioned with the femur resting on the posterior aspect of the femoral condyles and the most posterior aspect of the proximal femur, excluding the femoral head. As noted above, in retroverted femora, the posterior aspect of the greater trochanter and femoral condyles was elevated to bring the femoral head away from the table. The tibia was then rotated such that the medial and lateral plateaus qualitatively matched with the medial and lateral femoral condyles. The appropriate matching position between the femoral condyles and tibial plateaus is fairly obvious in most cases. An anterior-posterior image was obtained. ImageJ software was used to measure mLDFA as the lateral angle between a line from the center of the hip to the center of the femoral condyles and a line along the distal aspects of the femoral condyles and MPTA as the medial angle between a line along the tibial plateaus and a line from the center of the tibial spines to the center of the tibial plafond (Fig. 4).

Fig. 4. To measure mLDFA and MPTA, the femur was placed resting on the posterior aspect of the greater trochanter and the posterior femoral condyles. The tibial plateaus were then matched rotationally to the femoral condyles to approximate anatomic position, and then the tibia was then shifted distal to allow visualization of the tibial spines. mLDFA was measured as the lateral angle between a line from the center of the femoral head to the intercondylar notch, and a line along the femoral condyles distally. MPTA was measured as the medial angle between a line along the tibial plateau and a line from the center of the tibial spines to the center of the plafond.

Femoral Version

Specimens were positioned with the femur resting on the posterior aspect of the femoral condyles distally and the posterior aspect of the greater trochanter proximally. We utilized the same measures for a retroverted femoral head as noted above. The specimens were then photographed in axial plane. Version was measured as the angle between the bicondylar plane and the neck axis [5].

Interobserver Reliability

Twenty knees were selected randomly and two of the authors independently placed, photographed, and measured each specimen for patella centering.

Statistics

All statistics were performed using SPSS version 21 (Internal Business Machines Corporation, Armonk, NY, USA). Interobserver reliability for patellar centering was evaluated with intraclass correlation coefficient using a two-way random model and single measures reported. Comparisons between age, gender, race, MPTA, mL DFA, femoral version, and contralateral patellar centering (independent parameters) versus patellar centering (dependent parameter) were evaluated with multiple regression analysis.

Results

Mean age for the 428 skeletons was 56 ± 10 years. There were 55 females and 373 males. There were 129 African-Americans, 299 Caucasians, and one skeleton with unspecified race. Mean mL DFA was $88^\circ \pm 2^\circ$, mean MPTA was $87^\circ \pm 2^\circ$, and mean version was $11^\circ \pm 12^\circ$.

Mean patellar centering, expressed as the lateral position of the patella in proportion to total condylar width, was 0.13 ± 0.04 . The intraclass correlation coefficient for patellar centering was 0.81, demonstrating high interobserver reliability.

Multiple regression analysis was performed to compare patellar centering with age, gender, race, MPTA, mL DFA, femoral version, and contralateral patellar centering and showed that only a minimal portion of centering variance could be determined by these variables ($R^2=0.066$). Further analysis did not demonstrate independent correlation between patellar centering and age, gender, ethnicity, MPTA, or version ($P>0.05$ for all). In contrast, there was an independent correlation between patellar centering and mL DFA and contralateral patellar centering. The standardized beta coefficient for mL DFA was 0.10 ($P=0.005$), while the standardized beta coefficient for contralateral patellar centering was 0.24 ($P<0.0005$) (Table 1).

Discussion

Intraoperatively, we have noticed that in many patients, a radiograph taken orthogonally to a patella-centered AP view did not show proper lateral view alignment. We have also

been frequently frustrated by the inability of our radiology technicians to obtain a patella-centered view in many patients. As a result, we began to question whether a patella centered between the femoral condyles truly represents an AP view. To determine the typical position and variance in patellar centering, we examined 856 paired specimens between the ages of 40 and 79 at time of death. The mean patellar centering, expressed as the lateral position of the patella in proportion to total condylar width, was 0.13 ± 0.04 . Based on our data, it is rare to obtain a femur where the patella is perfectly centered in the trochlear groove, which our data demonstrates that the average knee has a noticeable lateral deviation of the patella (Fig. 5) a patellar-centered view for the AP, then this AP view would be significantly non-orthogonal to the lateral view (Fig. 6) and may lead to unanticipated error in positional placement of orthopaedic implants. To our knowledge, this is the first study to assess patellar centering with respect to distal femoral width.

This study was limited by an uneven demographic distribution with more males than females and more Caucasians than African-Americans. This was based upon a random selection of skeletons from a collection that has more males and more Caucasians. The subjective placement of the patella was an important limitation to the study. Though there is inevitable subjectivity in the placement of the patella within the patellar groove, there was reliable fit of the patella within the trochlear groove, and an optimal location was usually found with ease. Interobserver reliability measurements also showed high correlation between measurements made by two of the authors, who independently positioned, photographed, and then measured 20 specimens. The lack of soft tissues in our study was an important limitation that merits special discussion. In typical standing views, there may be some deviation of the patella secondary to the influence of soft tissues. We were unable to represent any of these effects in a cadaveric study and are unable to anticipate whether they would pull the patella medial or lateral. Chondral differences between the medial and lateral condyle also could impact the position of the distal femur and affect patellar centering. The purpose of this first study was to establish the bony architecture of patellofemoral joint, and future studies to establish the

Table 1 Multiple regression results

Model	Standardized beta	P value	Unstandardized beta	
			Lower bound	Upper bound
Centering		.657	-.166	.105
Age	-0.022	.519	.000	.000
Sex	-0.014	.684	-.010	.006
Ethnicity	-0.009	.796	-.007	.005
mL DFA	.10	.006	.001	.003
MPTA	-.013	.691	-.001	.001
Contralateral Centering	.24	<0.0005	.168	.299

mL DFA mechanical lateral distal femoral angle, *MPTA* medial proximal tibial angle

Fig. 5. **a–c** A specimen with average centering ratio of 0.123. **a** The AP image demonstrates that this specimen is laterally deviated in the standard anatomic position. **b** The specimens can be rotated to center the patella by elevating the lateral femoral condyle. **c** This axial view demonstrates that if one attempted to obtain a lateral radiograph orthogonal to a patella-centered AP view, the femoral condyles would not appropriately overlap. **d–f** A specimen with a high centering ratio of 0.247. **d** Note the significant lateral deviation of the patella in the AP view. **e** Significant elevation is necessary to rotate this specimen into a patellar-centered AP view. **f** An orthogonal lateral in this case would be significantly out of the plane of a true lateral.

influences of the soft tissues and chondral surfaces will be important.

We utilized the condylar axis to represent a true lateral view. Other methods can be used to determine rotation from a lateral view in lieu of the alignment of the posterior aspect of the femoral condyles. These include the transepicondylar axis and Whiteside's line, both of which have been studied for use in total knee arthroplasty [4, 8, 11]. Use of these axes requires direct visualization of the bones within the joint space, and as a result, their use is most applicable to total joint surgeons. In addition, the epicondylar axis is generally more applicable in the arthritic knee, where asymmetric wear on the posterior condyles may render the posterior condylar axis unreliable [5]. We believe that the use of the posterior condylar axis is more applicable to surgeons addressing limb deformity, who in general are attempting to prevent future arthritis and thus more often treating patients without severe arthritic changes.

A true lateral of the knee is clinically judged by overlap of the femoral condyles distally and posteriorly [9].

However, the true lateral axis of the knee actually occurs with the knee externally rotated by approximately 3° [3]. We chose to define a lateral view using the commonly used radiographic criteria because it is more clinically feasible and widely used. One may argue that the amount of lateral deviation in our “true” anteroposterior radiographs may simply represent the lack of 3° of internal rotation of the specimen relative to the posterior condylar axis. However, based on a simple mathematical model approximating the femoral epicondyles and anterior aspect of the patella as the three essential points of a semicircle, 3° of compensatory internal rotation of our specimens would only alter patellar centering by 0.026, which would still leave our specimens significantly laterally deviated (see [Appendix](#)).

The implementation of any clinical rule in orthopedics should be based on solid clinical or anatomic data. To our knowledge, there is no such data to support the currently held assertion that an AP radiograph with the patella centered between the femoral condyles represents an orthogonal image to a lateral radiograph with the femoral condyles overlapped.

Fig. 6. Three specimens with varying patella positions. **a** Patellar centering ratio of 0.057, one standard deviation below the mean yet still with a laterally positioned patella. **b** Patellar centering ratio of 0.129, at the mean. **c** Patellar centering ratio 0.205, one standard deviation above the mean.

Our data suggests that the bony anatomy of the distal femur does not place the trochlear groove into such a position and calls into question what appears to have been an arbitrary definition of a true AP radiograph of the knee. Further radiographic and clinical studies will be necessary to establish more ideal criteria for an ideal AP knee image.

In conclusion, due to the significant amount of lateral positioning seen in this cadaveric study, we do not believe that a patella centered between the condyles at the distal femur is an ideal subjective measure for a true AP view in the general population. Further investigation is necessary to determine whether an image orthogonal to the flexion axis of the knee may better approximate a true AP radiograph, as opposed to a patella-centered view.

Disclosures

Conflict of Interest: Ademola A. Ajuwon, MD, Ronak Desai, MD and Kathleen Farhang, BS have declared that they have no conflict of interest. Colin E. Lasko reports other from ArthroCare Corp and Zimmer Inc., outside the work. Raymond W. Liu, MD reports other from Orthopediatrics LLC, outside the work.

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Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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