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Intercondylar Shelf Angle: A New Method to Determine Race from the Distal Femur

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ABSTRACT: This study documents racial variation in the intercondylar shelf angle. The intercondylar shelf is actually the "roof" of the intercondylar notch, and on a lateral radiograph of the femur this is a distinctive feature called Blumensaat's Line. The angle between Blumensaat's Line and the posterior shaft of the femur can be quickly and easily measured. Variations in this angle are not dependent on the size of the femur, nor is the angle affected by arthritis in the notch or by trauma to the articular surfaces. Even fragmentary femora can be measured. This is a non-invasive technique that can be used in skeletal cases as well as cases where there are intact soft tissues.

KEYWORDS: physical anthropology, forensic anthropology, human anatomy, knee, racial variation, radiography

Modern physical anthropologists have countless methods to analyze and describe human variation. However, only a few of these methods use analysis of the femur to distinguish race [*1–4*] and even fewer use metric analysis of the intercondylar notch [*5*].

Baker et al. [*5*] identified a slight difference in the average height of the intercondylar notch between Whites and Blacks in a skeletal sample. Although racial variation in the intercondylar shelf angle has not been previously described in the literature, differences in the intercondylar shelf angle should correspond to differences in height of the anterior edge of the intercondylar notch. A more acute angle would result in a higher notch, and a more obtuse angle would result in a lower notch. Therefore, the average intercondylar shelf angle in Blacks should be more acute than that of Whites, to account for the average differences in notch height between the races (Fig. 1).

Measurement of the angle between the intercondylar shelf and the posterior shaft of the femur in a sample revealed a relatively consistent and statistically significant difference between American Whites and Blacks.

Materials and Methods

Anatomy

The intercondylar notch is the central fovea in the distal metaphysis of the femur. It is bounded on the lateral side by the lateral femoral condyle and on the medial side by the medial femoral condyle. Anteriorly it extends to the border of the articular cartilage, and posteriorly it extends to the intercondylar line, which separates it from the popliteal surface [*6,7*].

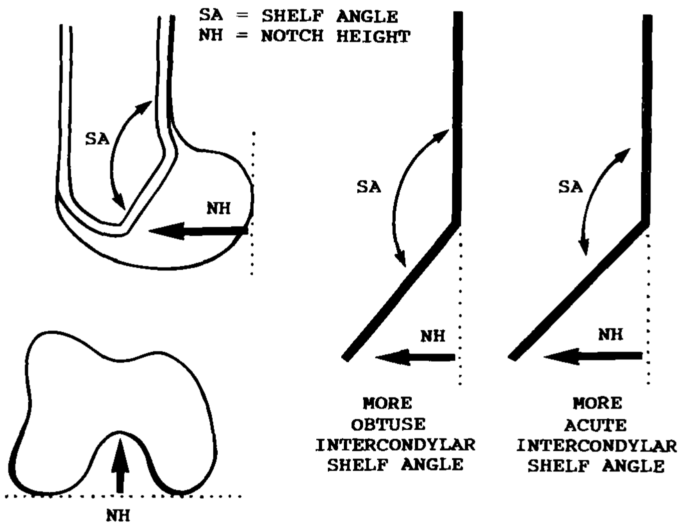

FIG. 1—*Variation in the height of the intercondylar notch reflects variation in the angle of the intercondylar shelf.*

The intercondylar shelf is a line of dense cortical bone that forms the "roof" of the intercondylar notch. It is best seen in a sagittal section of the femur. This area of dense bone can also be seen in a lateral radiograph of the knee, and it appears as a relatively radiopaque line. This line was first described by Blumensaat in 1938, and in clinical studies, this line has often been used as a reference point for the normal position of the patella [*8,9*]. Blumensaat's line and the posterior cortex of the femur are the two anatomical landmarks used in this study (Fig. 2).

Patient Sample

A list of 85,000 knee patients was obtained from the Hughston Orthopaedic Clinic in Columbus, Georgia, and an additional 2000 from the University of Tennessee Medical Center in Knoxville, Tennessee. The race of each patient was self declared at the time of medical evaluation. From the list in Georgia, a restricted random sample of 200 White and 200 Black patients was generated, and from the list in Tennessee, a restricted random sample of 100 of each race was obtained. Lateral radiographs were retrieved for all 600 patients.

Radiographs from 177 individuals were excluded because of various factors such as the presence of a total joint replacement,

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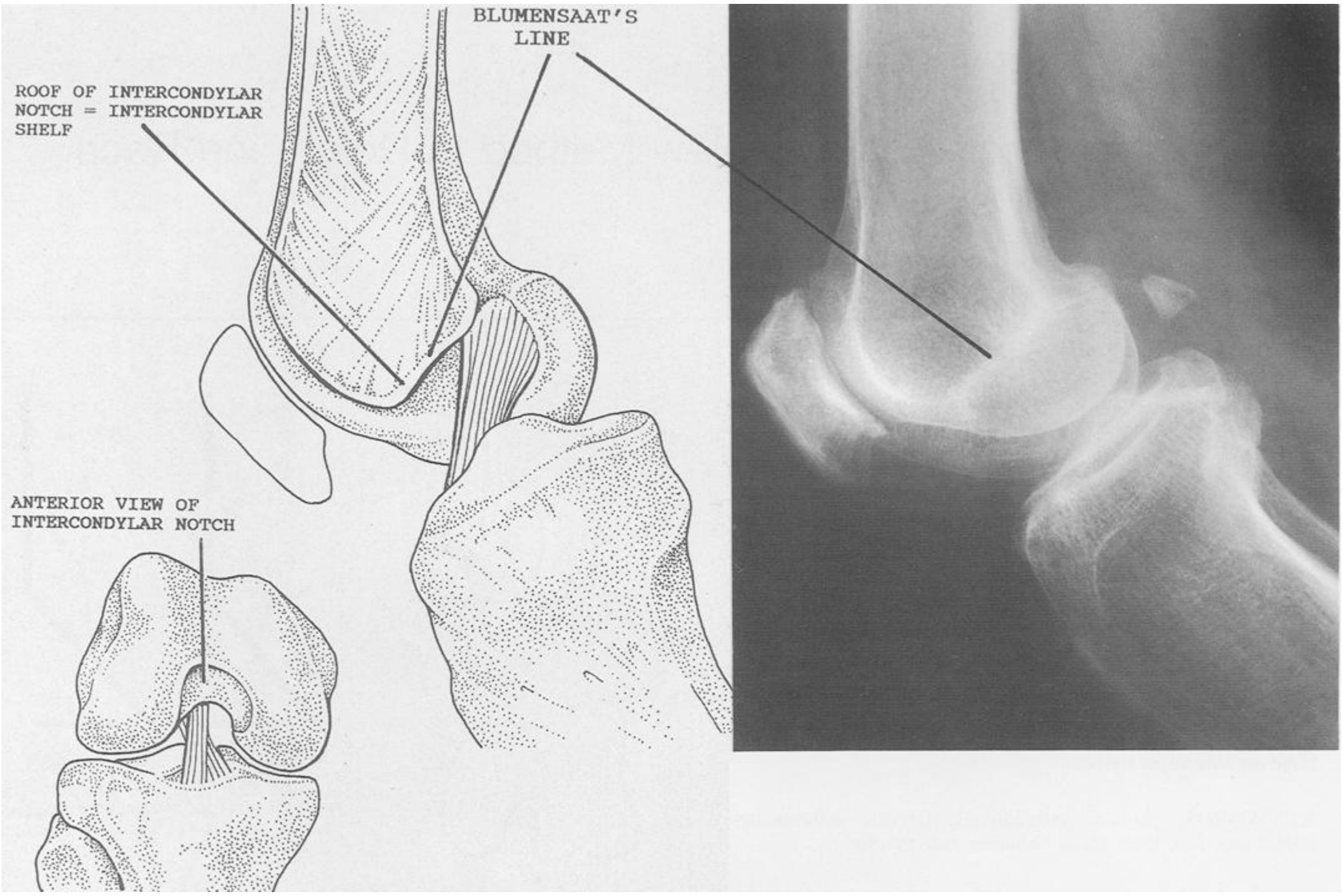

FIG. 2—*Lateral radiograph and sagittal section show the anatomy of the intercondylar shelf in relation to the intercondylar notch.*

malalignment of the distal femur due to trauma, and/or poor visualization of Blumensaat's line due to exposure error. The final sample consisted of 423 individuals. All of these individuals had requested medical evaluation for a variety of complaints relative to the knee. In the sample from Tennessee, 73% of the patients were victims of trauma, primarily motor vehicle accidents. In the sample from Georgia, almost all of the patients had X-rays of the asymptomatic knee included with their initial knee exam.

For the test of the intercondylar shelf angle, only one knee from each individual was analyzed. In cases where the asymptomatic knee was documented in the patient's chart, that knee was selected for analysis of the intercondylar notch angle. In the remaining cases the right knee was used if it was present, otherwise the left knee was used. The sample included 240 Whites and 183 Blacks, 235 males and 188 females.

Each radiograph was placed on a light box, and positioned as if the anterior knee was facing to the left. This was to avoid any possible measuring bias from the positioning of the instruments. A metal ruler was aligned with one edge against the distal one-third of the femur parallel to the posterior cortex of the bone, and a line was drawn with a grease pencil along the opposite edge of the ruler. The ruler was then placed so that one edge went through Blumensaat's line in a "best-fit" alignment. A second line was then drawn along the edge of the ruler through Blumensaat's line. A goniometer was placed over the intersection of these two lines, and the interior angle was measured (Fig. 3).

The intercondylar shelf angle was recorded and was written along with the patient's I.D. number and date of birth on a master log. The presence or absence of a fabella and anterior cruciate tear was also noted and recorded. At the completion of each measurement session, the patient's race and sex were added to the master log. The race and sex of the individual was intentionally omitted from the record until after the angle was recorded, in order to avoid any unintentional bias in marking the radiographs or in measuring the angle. The information was then analyzed to find the amount of variation in a sample population. A repeatability study was also conducted.

Skeletal Sample

In order to test the hypothetical method of determining race from the intercondylar shelf angle, the same method of measurement was applied to a skeletal sample. A total of 67 individuals was randomly selected from the William Bass donated skeletal collection, and one femur was taken from each case. Only the identification number was entered on the master log, and all of the femora were taken en masse to the Student Health Center where they were X-rayed.

Positioning of each femur was critical because it was necessary to get a lateral view that closely approximated the true lateral seen in the patient radiographs. Patients are routinely radiographed after their knee has been precisely positioned in reference to anatomical landmarks on the ankle, hip and knee. In order to obtain a similar alignment, I used a 14 × 17 inch sheet of foam rubber "egg crate" material that was approximately 6 inches thick. A femur could be placed across the sheet and it would fit in between the ridges and

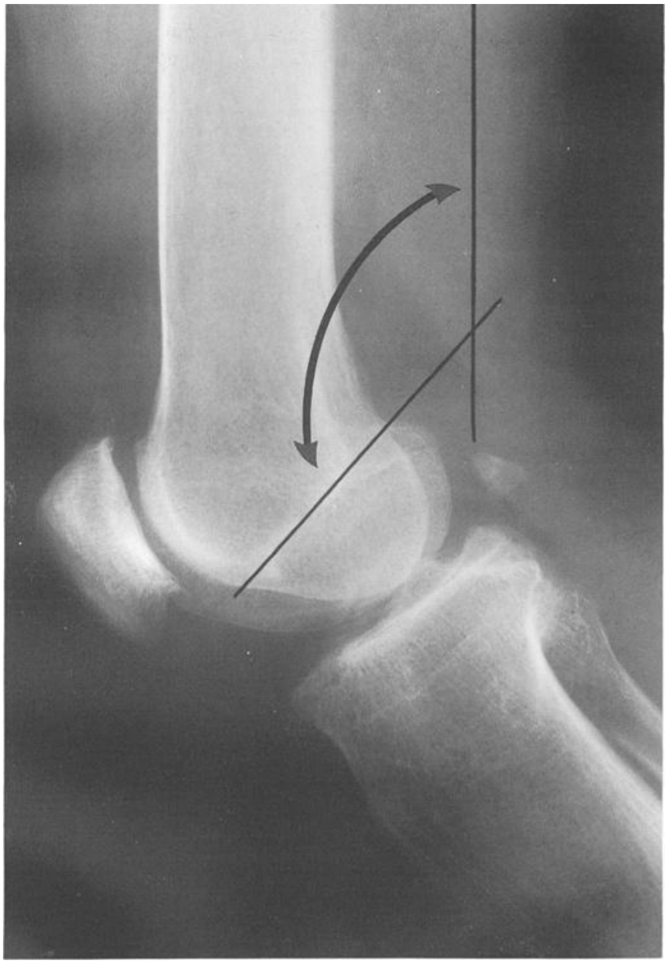

FIG. 3—*To indicate the intercondylar shelf angle, one mark should parallel the posterior shaft of the femur. The other is a "best fit" through Blumensaat's Line.*

the bone could then be rotated to a true lateral position. After some experimentation, it was apparent that the best placement of the femur was to have the medial femoral condyle up, away from the table. In this position, the femur could be rotated so that none of the lateral femoral condyle could be seen from a position directly above the table. This gave the best overall lateral image (Fig. 4).

Four femora were X-rayed at a time, over a cassette containing a sheet of 14 × 17 radiographic film. The identification number of each femur was marked with radiopaque letters at the time of exposure, and all four femora were exposed at 100 m.A. for 1/30 sec. at 54 k.V. The radiographs from this test sample were measured using the same method described for the patient sample.

The best radiographic technique for individual forensic cases is a simple laterally-directed x-ray beam. Lay the femur flat on top of a cardboard box or similar radiolucent platform, and expose the film as shown in Fig. 5*A*. If the femur is broken, or if there is significant articular trauma, a small piece of foam or cloth will support it well enough to get a good lateral view (Fig. 5*B*).

Results

Patient Sample

The data from the patient sample were entered into the University of Tennessee's VAX computer system. T-test procedures were used to find the mean, standard deviations, and p-values for race and sex. Sex was included as a variable in order to determine if the angle varied by sex as well as race. The results are shown in Fig. 6, and Table 1. A discriminant analysis was used [*10*] to determine the ability to classify race, given the angle. The overall White mean was 146 degrees and the Black mean was 138 degrees. The overall mean for females is 142.58 degrees and the overall mean for males is 142.54 degrees.

Skeletal Sample

The data from the skeletal sample were not initially entered into the computer system. This was designed to be a blind test of the ability to classify race based only on the intercondylar shelf angle. Since this was a relatively small sample, I divided the method of analysis into two different components in an attempt to find the optimal method of analysis (Table 2).

The first test included 46.3% of the sample and only involved those individuals whose notch angle was equal to or beyond the mean for each race. Those whose notch angle was 146 degrees or greater were classified as White. Those whose notch angle was 138 degrees or less were classified as Black. Twenty-eight individuals, or 90% of the individuals were correctly classified.

For the second test, the entire sample was classified. The sectioning point for this test was 141 degrees. Individuals with a notch angle of 142 degrees or greater were classified as White

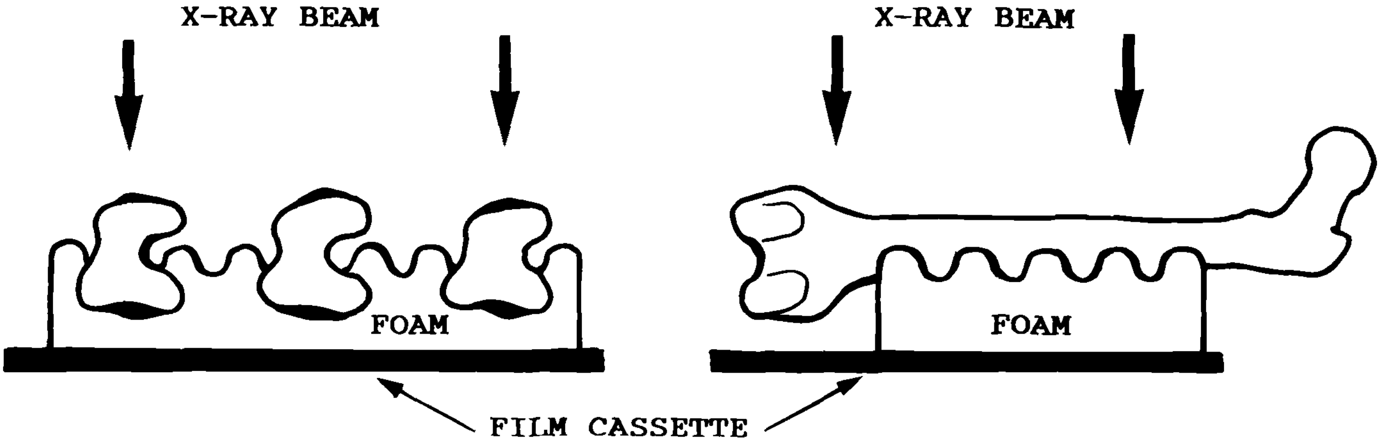

FIG. 4—*Several femora can be X-rayed at one time by positioning them as shown.*

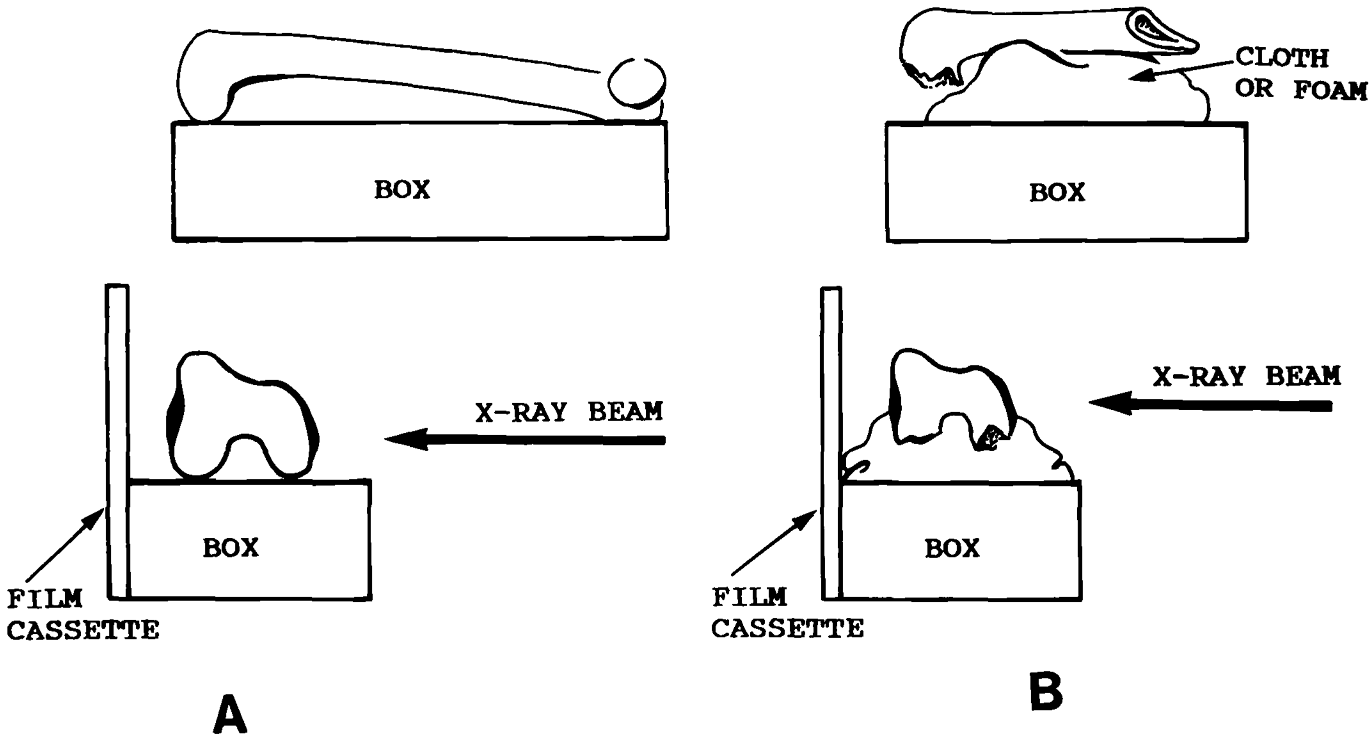

FIG. 5A—*A single femur should be positioned on top of a radiolucent box.* B—*A broken or partial femur can be propped on foam or cloth.*

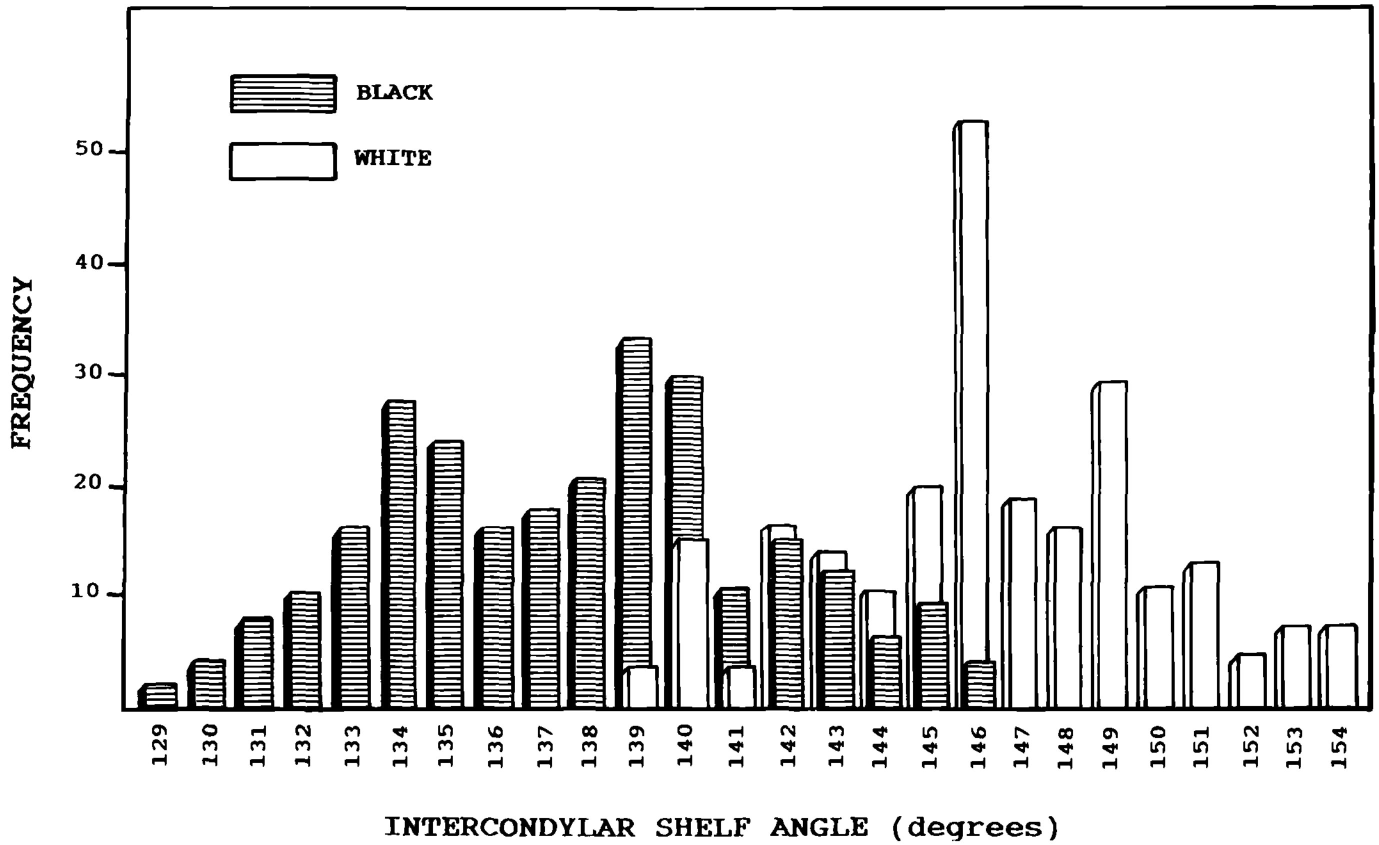

FIG. 6—*Histogram of the intercondylar shelf angles in a sample of 423 femora. The mean for Blacks is 137.8 and the mean for Whites is 146.2. The sectioning point is 141. Eighteen percent of the sample overlapped across the sectioning point.*

TABLE 1—*Variation in the intercondylar shelf angle by race and sex.*

All by race	*N*	MEAN	SD
B	183	137.831	4.18248
W	240	146.175	4.28711
$P < .0000$			
Correct classification = 83%			
All by sex	*N*	MEAN	SD
F	188	142.585	6.30662
M	235	142.549	5.61142
$P = .9503$			
Females by race	*N*	MEAN	SD
B	80	137.163	4.14131
W	108	146.602	4.31026
$P < .0000$			
Correct classification = 88%			
Males by race	*N*	MEAN	SD
B	103	138.349	4.16029
W	132	145.826	4.25252
$P < .0000$			
Correct classification = 83%			

TABLE 2—*Results of the blind test on the skeletal sample.*

	I >145=W <139=B	II 142 & OVER = W
Total classified	31	67
% of total Sample	46	100
Correct classification	28	57
Incorrect classification	3	10
Percent correct	90	85

and those with a notch angle of 141 degrees or less were classified as Black. Fifty-seven individuals, 85% of the entire sample were correctly classified.

In the test for interobserver error, the variation among the observers averaged less than 1 degree. Three people (a radiology resident, myself, and another anthropology Ph.D. student) independently marked and measured the intercondylar shelf angle on 23 patient radiographs, according to the method described earlier. The lines were removed from the radiographs between each observer's measurements.

Discussion

The intercondylar shelf angle shows variation between American Whites and Blacks and is an effective new method for post-cranial metric analysis.

There are, however, several factors that need to be discussed in regard to the measurement and analysis of the angle as well as the angle itself.

First of all, the measurement of the radiographs in the patient sample was based on lateral radiographs of the knees of living patients. In the clinical situation, the leg and knee are positioned in reference to specific anatomical landmarks and the rotation of the entire limb can be controlled. With this amount of control, the alignment of the leg and femur almost always results in a "true lateral" radiograph, and the position of Blumensaat's line is consistently correct. The lateral radiographic method shown in Fig. 5 is the only way to consistently achieve a "true lateral" with a single femur specimen.

The primary problem still lies with the analysis of those individuals whose intercondylar shelf angle approaches or overlaps the sectioning point. This overlap in measurements between the two races is a typical problem in forensic identification.

In spite of these problems, however, there are some advantages to this new method. One advantage of this method is that measurement of the intercondylar notch angle is a relatively easy and straight-forward procedure. Once the landmarks are located and marked, the angle is simply measured with a goniometer, protractor, or any similar device.

Another advantage is that fragmentary femora can be measured, and the angle of the intercondylar notch is not affected by periarticular arthritis or articular trauma.

The intercondylar shelf angle is also not affected by the size, length, or overall curvature of the femur. The femora of Blacks are generally longer [*11*] and have less anterior curvature than those of Whites [*4*] so when the anterior outlet is measured with the femur lying on a flat surface (as described by Baker et al.), the degree of curvature would undoubtedly create a corresponding change in height [*5*]. The question of curvature of the femur was considered as a possible variable in the measurement of the intercondylar shelf angle, and was dismissed. When curvature of the femur is included in the angle analysis, it increases the difference between races. A more anterior bow, typical of Whites, creates a more acute angle, and vice-versa.

Summary

The intercondylar shelf angle is a radiographic feature of the distal femur that can be used to help determine the race of an individual. Any criteria, especially in the post-cranial skeleton that can be used to help determine the race of an individual should be considered valuable.

In addition to the ability to classify Whites and Blacks, a primary advantage of this method is that it is a single measurement that is easy to obtain, and it is not dependent on the size of the femur. This measurement can be taken regardless of periarticular pathology or trauma to the articular surfaces. For some forensic cases it will also be an advantage to be able to examine the distal femur with radiographs that can be obtained through any amount of soft tissue.

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