J Orthop Sci (2003) 8:334–340

Journal of
Orthopaedic Science

Anteversion of the femoral neck in Indian dry femora

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Abstract The purpose of this study was to estimate the average angle of femoral neck anteversion in an Indian population. A total of 300 dry femora were classified by standard anatomical norms into male and female types and left-side and right-side types. They were evaluated by the Kingsley Olmsted and parallelograph methods, and the data were statistically analyzed. The average angles of anteversion obtained were 8.1° and 8.3° by the Kingsley Olmsted and parallelograph methods, respectively. The average female-type bone showed about 3° more anteversion than the male-type bone. The average left-sided bone showed about 1.6° more anteversion than the right-sided bone. A statistically significant difference existed between the sexes and the sides. The Kingsley Olmsted and parallelograph methods were found to be comparable with a correlation coefficient of 0.99. Altogether, 42.33%, 57.66%, and 79.00% of bones had readings of 5°–10°, 0°–10°, and 0°–15°, respectively. Thus, femoral neck anteversion has been found to be less in the Indian population than in Western populations.

Key words Femoral neck anteversion · Indian dry femora

Introduction

The angle of anteversion of the femoral neck varies widely, and racial variation is expected. Variable values of the anteversion in the literature have been reported without any mention of the impact of the origin of the population on such values.

It is important to know the angle of anteversion in a particular population, as the performance and longevity of the replaced joint during hip arthroplasty is determined by the position of the components relative to each other and relative to the bone.[2] No study has been reported on bones in India, where about one-sixth of the world's population live. The present study aimed to estimate the anteversion of the femoral neck in Indian dry femora.

Materials and methods

A total of 300 dry femora were collected from the bone banks of the Department of Anatomy of the Medical Colleges of Delhi and the Department of Anthropology, University of Delhi. These bones, collected from cadavers used by the respective departments, belonged to adults of Indian origin. No age data were available. The specimens were divided into right and left side and male and female types according to the standard anatomical norms.[3]

The angle of anteversion was measured by two methods: (1) the Kingsley Olmsted (KO) method[3]; and (2) the parallelograph method.[8] Three readings were taken for each bone by each method, and the average of three readings was taken as final for that bone by the particular method.

Kingsley Olmsted method

The femur was placed on a smooth horizontal surface (a glass sheet on a table). Two smooth blocks, 1 cm in thickness, were then placed: one underneath the femoral condyles and other underneath the posterior aspect of the greater trochanter. The angle of obliquity of the shaft is normally extremely small, which influences the measurement of anteversion angle by only 0.2°[3] and hence is disregarded. As the head was not centered on the neck of the femur in 61% of the bones, we also did not use the head to determine the true longitudinal axis of the neck.[3] The anteroposterior width of the neck was determined at the proximal and distal ends of the neck of the femur by vernier calipers. The center points of these two ends were then marked.

Offprint requests to: A.K. Jain
Received: August 20, 2002 / Accepted: January 13, 2003

A 1-mm Kirschner wire was placed along these two points using clay adhesive representing the central axis of the neck. This line was then continued to the surface supporting the bone. A devised protractor with a long metal arm was mounted on a base whose thickness was exactly the same as the block on which the femur was placed. By manipulating this metal arm of the protractor to the same level as the anteversion Kirschner wire under vision, they were made to overlap. The angle was then read on the protractor to estimate the true angle of anteversion (Fig. 1).

Parallelograph method

Two center points on the neck of the femur between its anterior and posterior surfaces were determined as with the KO method, and a 1-mm Kirschner wire was fixed over the line, joining them using clay adhesive. The femur was kept horizontal over a wet surface to determine the most posterior aspects of both femoral condyles. Another Kirschner wire was placed on the watermark on the posterior aspect of the condyles to obtain the bicondylar plane.

A special instrument called a parallelograph was used to measure the anteversion angle. It consisted of two metal bars, each having one pointed end. These bars were parallel to each other and horizontal to the ground. The lower bar also had a vertical bar on its pointed end. The lower, pointed portion of the vertical bar could make an impression on the paper on slight pressure when this instrument was kept on a paper sheet. This impression point on the paper represented the exact vertical drop of the pointed end of the uppermost horizontal bar, which was movable up and down and thus could be adjusted to the height of the points on the bone where the reading was to be taken.

The bone with two Kirschner wires (along the neck axis and along the bicondylar line) was clamped to a universal clamp stand. This set, along with the parallelograph, was kept on a piece of white paper sheet. The pointed end of the upper movable bar of the parallelograph was adjusted so it touched one end of the Kirschner wire. The vertical bar was pressed to obtain an impression of the vertical drop of this end of the Kirschner-wire on the paper sheet. The impression of the vertical drops of all four ends of the two Kirschner wires was thus obtained as four points on the sheet (A_1, A_2, B_1, B_2) (Fig. 2a). Two points were joined by a pencil to obtain the impression of the whole Kirschner wire. Two such lines were obtained, one each for the two Kirschner wires. These lines were intersected by

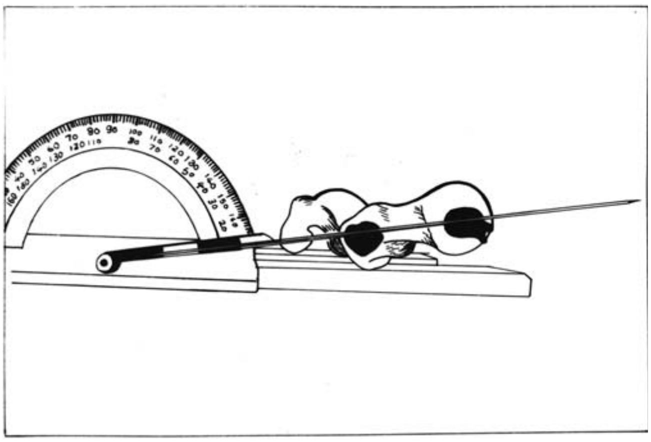
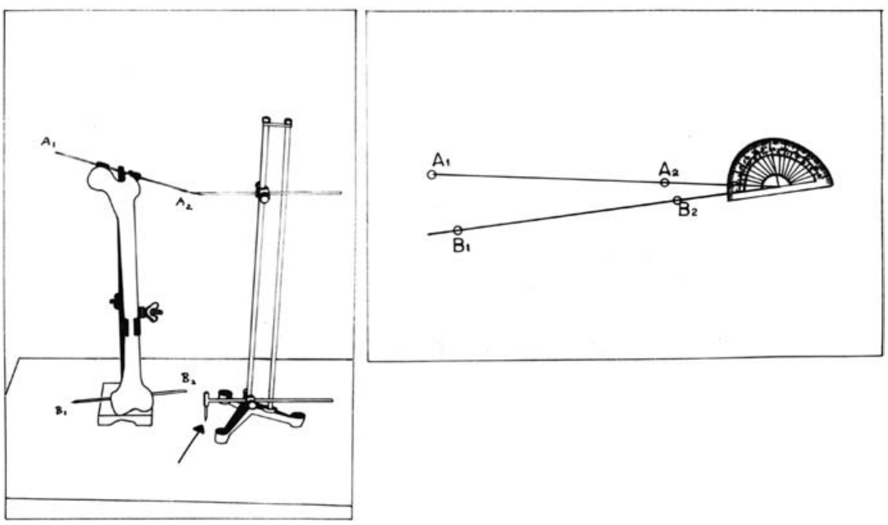


Fig. 1. Measurement of the anteversion angle by the Kingsley Olmsted (KO) method using the protractor. Its long metal arm overlaps the anteversion Kirschner wire (along the central axis of the neck) at eye level



a b

Fig. 2. a Measurement of anteversion angle by the parallelograph method via the impression of the end of the Kirschner wire on the paper sheet (*arrow* shows impression of A_2). Using a similar procedure, four points (A_1, A_2, B_1, B_2) representing the ends of the two Kirschner wires (one along the neck axis and another along the posterior aspect of both condyles) are obtained. **b** Measurement of anteversion angle using a protractor. This angle is formed when the two lines (representing the two Kirschner wires) are made to intersect

Table 1. Statistical analysis of 300 dry femora

Femur specimen type	No. of bones	Mean (°)		Median (°)		Mode (°)		SD (°)		Maximum and minimum (°)			
										KO		P	
		KO	P	KO	P	KO	P	KO	P	Max	Min	Max	Min
Total	300	8.1	8.3	8.2	8.2	7.2	7.3	6.6	6.7	36.7	−17.2	40.7	−17.7
M	240	7.5	7.7	7.7	8.0	7.2	7.3	6.6	6.6	28.3	−17.2	26.3	−17.7
F	60	10.5	10.8	9.3	9.3	7.2	9.3	6.1	6.3	36.7	−1.3	40.7	−1.3
R	147	7.3	7.5	7.2	7.3	7.2	7.3	6.7	6.6	28.3	−13.3	26.3	−14.3
L	153	8.9	9.2	8.3	9.2	7.2	7.3	6.5	6.6	36.7	−17.2	40.7	−17.7
RM	122	7.0	7.1	7.2	7.3	7.2	7.3	7.0	6.9	28.3	−13.3	26.3	−14.3
RF	25	9.2	9.4	8.3	8.7	7.8	8.0	4.8	4.6	22.3	−1.3	21.7	−1.3
LM	118	8.1	8.4	8.2	8.8	12.2	8.0	6.2	6.3	24.5	−17.2	24.7	−17.7
LF	35	11.5	11.8	9.7	9.7	7.2	9.3	6.8	7.2	36.7	−0.7	40.7	0.3

KO, Kingsley Olmsted method; P, parallelograph method; M, male; F, female; RM, right male; RF, right female; R, right; L, left; LM, left male; LF, left female

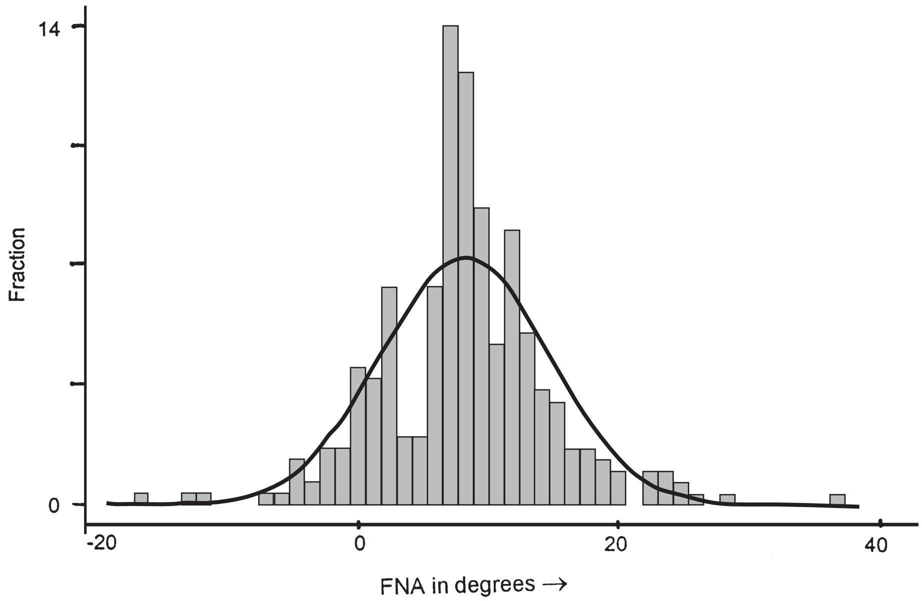


Fig. 3. Histogram and curve graph by the KO method. *Fraction*, fraction of total cases; *FNA*, femoral neck anteversion

extending them in either direction as necessary. The angle formed between these lines (the femoral neck axis and the bicondylar line) represented the angle of anteversion and was measured using a simple protractor (Fig. 2b).

Results

The readings for 300 dry bones as measured by the KO and parallelograph methods were statistically analyzed (Table 1; Figs. 3, 4). The mean angle of anteversion of the femoral neck was 8.1° with a standard deviation (SD) of 6.6° by the KO method and 8.3° (SD 6.7°) by the parallelograph method. The median value for both methods was 8.2°. The mode value was 7.2° by the KO method and 7.3° by the parallelograph method. The mean value of the male type was 7.5° (SD 6.6°) by the KO method and 7.7° (SD 6.6°) by the parallelograph method. The mean value of the female type was 10.5° (SD 6.1°) by the KO method and 10.8° (SD 6.3°) by the parallelograph method. The mean value for the right side was 7.3° (SD 6.7°) by the KO method and 7.5° (SD 6.6°) by the parallelograph method. The mean value for the left side was 8.9° (SD 6.5°) by the KO method and 9.2° (SD 6.6°) by the parallelograph method. The range (mean ± 2 SD) obtained by the KO method was −5.1° to +21.4° and by the parallelograph method −5.0° to +21.7°.

Retroversion was observed in 28 bones (9.33%) by the KO method and in 30 bones (10%) by the parallelograph method. Neutral or almost neutral version (−1° to +1°) was found in 22 bones (7.33%) by the KO

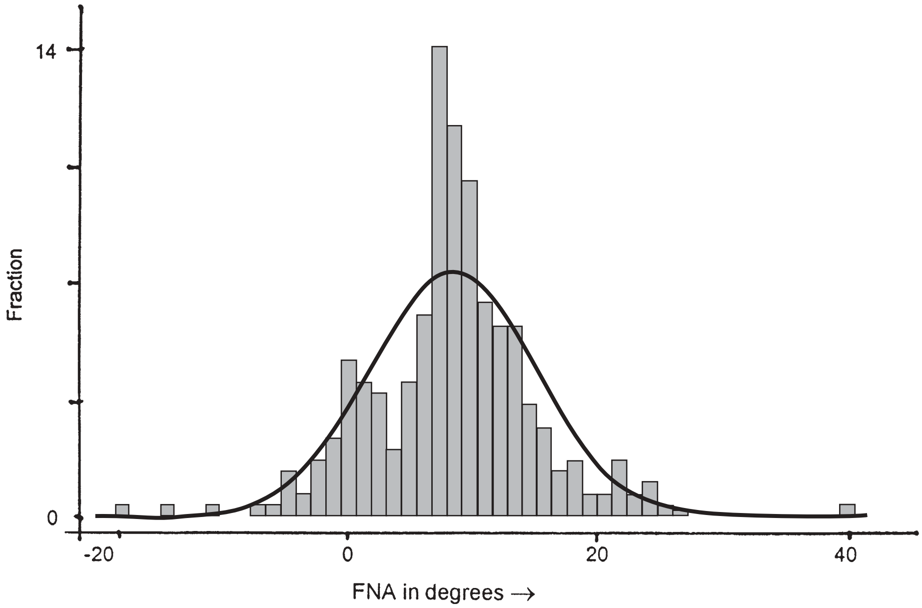


Fig. 4. Histogram and curve graph by the parallelograph method

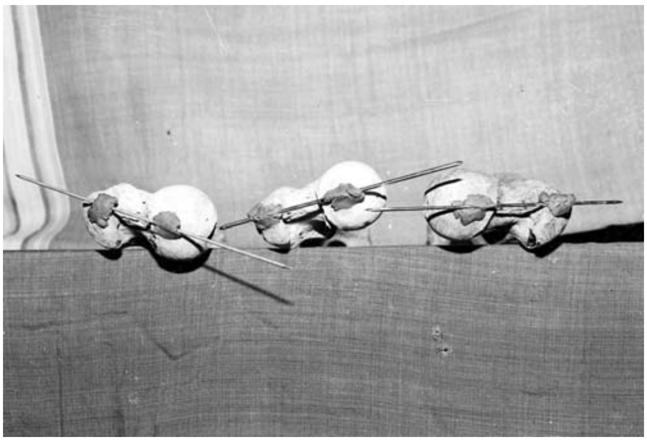


Fig. 5. Retroversion (−17°), normal anteversion (9°), and neutral version (0° ± 1°) of three specimens

method and 20 bones (6.67%) by the parallelograph method (Fig. 5). Altogether, 15.33% of the bones were in the range of 0°–5° by the KO method, as were 13.67% by the parallelograph method. In addition, 57.66% of the bones were in the range of 0°–10° by the KO method, as were 56.34% by the parallelograph method. Approximately 79% of the bones were in the range of 0°–15° by the KO method, as were 78.67% by the parallelograph method. Almost 42% of bones were in the range of 5°–10°. Altogether, 67% bones had anteversion of less than 10° by the KO method and 66.34% by the parallelograph method (Table 2).

Comparison of methods

By comparing the mean reading of the KO method with that of the Parallelograph method, the mean of difference was −0.2° (SD 0.7°). The maximum difference was +3.7° and the minimum difference −4.0°. The agreement limit of difference (mean ± 2 SD) was found to be 1.3° to −1.7°, which we believe is within the permissible range. The correlation coefficient obtained for the two methods was 0.99 (Fig. 6).

Tests of significance

Statistical analysis using the unpaired *t*-test was done between the sexes and the sides. The means for the female-type bones were higher than those for the male-type bones by 3.0° and 3.5° by the KO and parallelograph methods, respectively. The means for the left-sided bones were higher than those for the right-sided bones by 1.6° and 1.7° by the KO and parallelograph methods, respectively. A statistically significant difference was found between the sides and the sexes by both methods (Table 3).

Discussion

It is important to know the angle of anteversion in a particular population. The accurate estimation of femoral neck anteversion in living subjects has always been difficult, with many shortcomings and lack of reproducibility.[1] Although newer methods using computed tomography (CT) have been shown to be ± 1° accurate, there is no universal consensus for locating the femoral neck axis and the femoral condylar axis.[4] Hence estimation of anteversion on dry bone is still considered the most accurate method. Its greatest drawback is that involvement of femora from some of

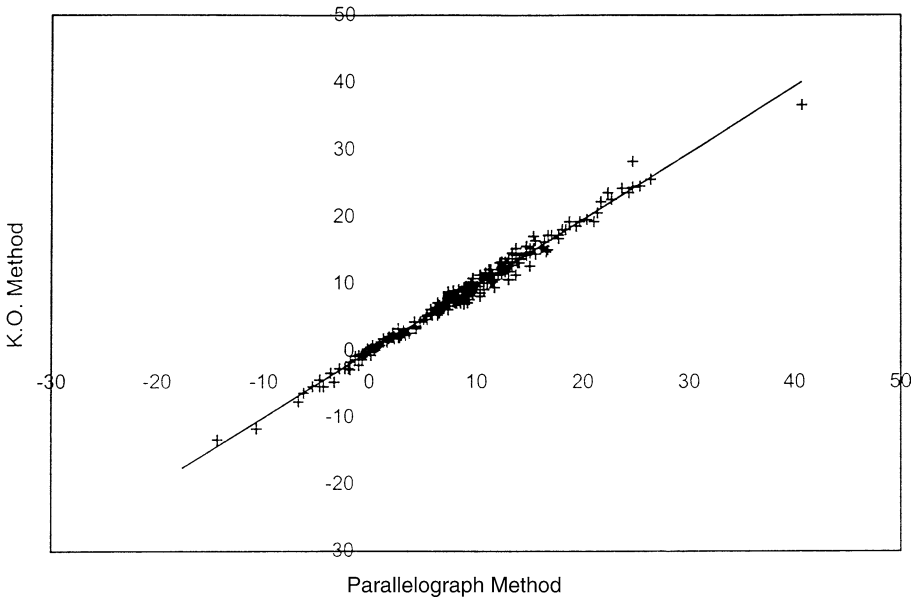


Fig. 6. Correlation coefficient was 0.99

Table 2. Distribution of anteversion angle

Angle	KO method (n = 300)		Parallelograph method (n = 300)		Percentage in original KO study (n = 630)
	No. of bones	%	No. of bones	%	
<0	28	9.33	30	10.00	14.8
−1° to +1°	22	7.33	20	6.67	NC
0°–5°	46	15.33	41	13.67	20.3
5°–10°	127	42.33	128	42.67	26.8
10°–15°	64	21.33	67	22.33	19.2
0°–10°	173	57.66	169	56.34	47.1
0°–15°	237	79.00	236	78.67	66.3
5°–15°	191	63.66	195	65.00	46.0
>15°	35	11.67	34	11.33	18.9
>20°	13	4.33	15	5.00	7.5
Max. reading	36.160°		40.670°		38°
Min. reading	−17.170°		−17.670°		−20°
SD	6.646°		6.662°		NC

NC, no comment; SD, standard deviation

Table 3. Unpaired *t*-test for sides and sexes

Variable	No.	Mean	SD	SEM	*P*
Kingsley Olmsted					
Male	240	7.5	6.6	0.430	0.002*
Female	60	10.5	6.1	0.787	
Right	147	7.3	6.7	0.556	0.042*
Left	153	8.9	6.5	0.524	
Parallelograph					
Male	240	7.7	6.6	0.427	0.001*
Female	60	10.8	6.3	0.818	
Right	147	7.5	6.6	0.545	0.024*
Left	153	9.2	6.6	0.536	

SEM, standard error of the mean
* Significant

the skeletons with pathological conditions cannot be ruled out, which may influence the statistical analysis.[1] Still it may be used as a profile of the angle of anteversion in a particular population.

Various methods have been used by investigators to determine the angle of anteversion, and wide variation has been documented for the mean anteversion angle. The source of error may be the precise location of the axes. The KO series, the largest so far, is considered the most accurate to date.[6] The parallelograph method, though indirect, uses scientific rationale and precise instruments. We chose to study the bone by two methods to determine if any significant difference is present by these two methods, even when using the same defined axes. Most of the earlier investigators used the center of the head, which might have led to the differences in their estimates.

Precise determination of the central axis of the neck was done by vernier calipers, although the axis seen by direct visualization most of the time coincided with the true central axis. We also faced certain difficulties measuring some bones: Those with less anteversion or mild retroversion rested on the lesser trochanter, and those having significant retroversion rested on the condyles and the head, rather than on the greater trochanter. By manipulating the block, the bones could be made to rest on the greater trochanter, and readings could be taken. The head was also found to be compensating by tilting for excessive anteversion or retroversion of the neck, again justifying not using it for measurement.

Most authors have cited the angle of anteversion to be greater than what we have found, with a range from −25° to +50° in adults.[1,9] The combined statistics of five of the major reports where the number of bones were specified (n = 1526)[3,5,7] showed the variation to be −20° to +50°, with an average angle of torsion of +11.22°.[1] Kingsley and Olmsted[3] (n = 1630) did not use any point on the head and reported the mean anteversion angle as 8.021°. The rest of the investigators used a head–neck axis and had a combined average of 14.09° (n = 806). Our mean by the KO method was 8.1° and by the parallelograph method 8.3°, which is close to that of the KO series.

Similarities and differences were drawn in comparison to the KO series to point out the characteristics of Indian bones (Table 2). Although most authors have reported retroversion to be unusual,[3] it was a common finding in our series. Almost one out of ten bones (9.33%) displayed retroversion compared to 14.8% in the KO series. Similarly, 11.67% cases had anteversion of more than 15° compared to 18.9% in the KO series. Near neutral version (0° ± 1°) was found in 7.33% of the cases in our series, whereas no such finding was reported in the KO or any other series. Thus retroversion and excessive anteversion (>15%) appear almost a similar incidence, though bones having these extreme readings were higher in the KO series. More than half (57%) of the Indian bones were between 0 and 10°, and 79% were between 0° and 15°. This was lower in the KO series: 47% between 0° and 10° and 66% between 0° and 15°. Most Indian bones were between 5° and 10° (42%), whereas only 26.8% of the bones were in this range seen in the KO series. Thus, a larger percentage of Indian bones have a lesser degree of anteversion than those in the Western data. The angle of anteversion in our series ranged from −5.1° to 21.4° (mean ± 2 SD). The maximum reading was +36.7° and the minimum −17.2° compared to +38° and −20°, respectively, in the KO series. Kingsley and Olmsted calculated only the mean and range (maximum and minimum). No standard deviation was documented. The mean alone is not sufficient to determine the true distribution of the angle of anteversion in a total set of bones. Because some values at both extremes of the data may influence the mean, we have defined our range as the mean ± 2 SD for clinical purpose.

A statistically significant difference was found for the angle of anteversion between the male- and female-type bones and the right- and left-sided bones. The average female-type bone was about 3° higher than the average male-type bone. Parsons et al.[5] had also documented anteversion to be greater in females. Similarly, Kingsley and Olmsted[3] observed a negligible difference (0.081°), and Yoshioka et al.[9] found a difference of 1°. However, no tests of significance were done in these series. The average angle of the right-sided bone was about 1.6° lower than that of the left-sided bone. This is in contrast to the KO series, where the angle of anteversion of the right-sided bone was higher than that of the left-sided bone by 1.07°.

Because Indians are more apt to participate in floor-level activities, in contrast to persons in the West, our hips have to be evolutionally different from theirs. Thus, the same procedure produces a different outcome in our population. Hence a population-specific protocol and assessment criteria must be devised. The correction of anteversion can be planned only if normal values for our population are known. A femoral component of a total hip replacement should be in an anteversion angle that closely represents the anteversion angle for the Indian population to achieve the best surgical results. With about one-sixth of the world's population living in India and with the increasing demand for total hip replacement, this anteversion angle becomes more significant. Therefore, our study was undertaken to ascertain the average angle of anteversion of the femoral neck in Indian subjects.

Conclusions

The average angle of anteversion obtained on dry bone was 8.1° (SD 6.6°) by the Kingsley and Olmsted method and 8.3° (SD 6.6°) by the parallelograph method. The parallelograph and Kingsley and Olmsted methods were found to be comparable, with a correlation coefficient of 0.99. The angles of anteversion of the femoral neck in 15.33%, 57.66%, and 79.00% of cases were in the range of 0°–5°, 0°–10°, and 0°–15°, respectively (KO). Altogether, 9.33% of the cases showed retroversion and 11.67% had anteversion of more than 15° (KO). Statistically significant differences were found between the male- and female-type bones and the right- and left-sided bones. The male-type bone showed about 3° less anteversion than the female-type bone (KO). The right-sided bones had about 1.6° less anteversion than the left-sided bones (KO). The femoral neck anteversion angle has been found to be less in Indian bones than in Western bones.

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