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RADIOGRAPHIC MEASUREMENTS OF THE FEMORAL NECK ANTEVERSION

Comparison of Two Simplified Procedures

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A method for *in vivo* determination of the anteversion of the femoral neck in elderly or disabled patients with restricted hip mobility is described. Comparison is made with a different method for anteversion determination in a material of 20 normal hips and the results are discussed.

Key words: radiographic anteversion measurements of the femoral neck; femur, anteversion of

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By means of geometrical calculations in space femoral anteversion and femoral neck-shaft angle can be determined as reported by Ogata & Goldsand (1979). As with most other methods for radiographic anteversion determination *in vivo* a certain range of motion of the affected hip and knee is a prerequisite.

A modified technique is described for calculation of the same angles with the leg fixed in an approximately neutral position which allows for measurements in patients with restricted hip mobility including all cases of fractures of the hip, as an integrated part of the routine radiographic examination.

MATERIAL AND METHODS

With the patient in a supine position on the examination table and the affected limb fixed in an approximately neutral position one exposure is made of the hip with the central beam perpendicular to a true horizontal plane (AP-view) and one exposure is made over the knee with the central beam horizontal and perpendicular to the film plane and the long axis of the femur. One exposure is then made over the hip with the central beam horizontal in a cranial inclination of 30°. The extremity to be examined must not be permitted to change its position in any way between the exposures (Figure 1) (Norman).

By measuring the projected cervicofemoral angles in both projections of the hip the total neck-shaft angle and the orientation of the femoral neck in space can be calculated, provided the magnification factor is equal in both projections (Figures 2,3) (Ogata & Goldsand 1979).

Relating the orientation of the femoral neck in space to the rotation of the femur around its long axis will yield the true anteversion. Measuring the distance between the most dorsal points of both femoral condyles on the lateral view of the knee will allow for a fair approximation of this rotation as expressed by the formula $AE \approx |V_1|$ where AE represents the distance in millimeters between those points as measured on the lateral view of the knee and V_1 represents the inclination in degrees between the frontal plane of the femur, i.e. a plane touching the most dorsal aspects of both femoral condyles, and the horizontal plane. Due to the size and shape of adult femoral condyles the relation between AE and V_1 could more accurately be described by the formula $\sin |V_1| = AE/60$ where 60 represents the average distance in mm between the most dorsal points of the femoral condyles for moderate rotations, leading to the simpler approximation $|V_1| \approx AE$ according to Norman. In our experience this will not give rise to errors exceeding ±3° for rotations not exceeding 20°, provided the distance between the most dorsal points of the femoral condyles lies within the normal range, i.e. between 50 and 70 mm.

a

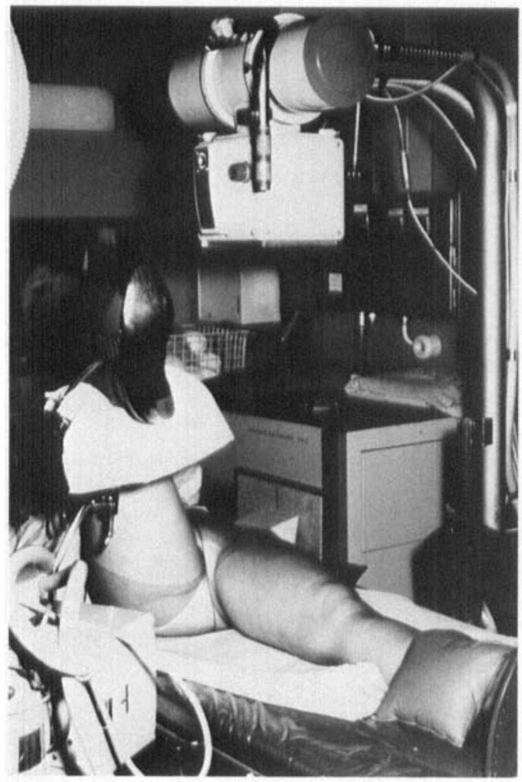

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Figure 1. a) With the leg fixed in an approximately neutral position radiographs in AP-projection of the hip and in lateral projection of the knee are obtained. In the AP-projection of the hip the film plane must be parallel to the table top and perpendicular to the central beam. In the lateral projection of the knee the central beam is horizontally oriented and perpendicular to the long axis of the femur and the film plane. b) With the leg in the same position a subsequent exposure is made of the hip in lateral projection. The central beam must be horizontal in a cranial inclination of 30° and the film plane vertically oriented and parallel to the lateral edge of the table.

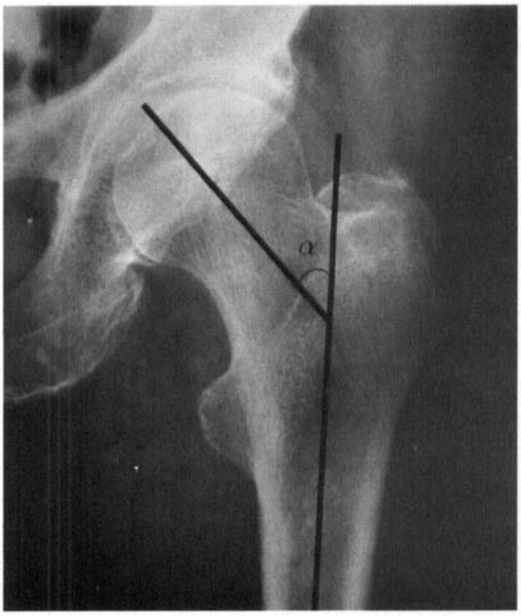
During a 1-month period in 1982, in all patients over 50 years of age referred for radiographic examination of one hip, the contralateral hip was examined as well, according to the method described. Only radiographically normal hips were included in the study, resulting in 20 normal appearing hips where anteversion measurements were carried out.

In all cases calculation of the theoretically different anteversion angle as defined by Norman was carried out as well and correlated to the angle described (Student paired t-test). The former angle is defined as the inclination of a plane through the middle axis of the femur and the center point of the femoral head in relation to the frontal plane of the femur (Figure 4) (Norman 1965, 1966, and personal communication). By measuring the distance between the center of the femoral head and the middle axis of the proximal femur shaft in both AP- and lateral views of the hip the corresponding angle in space can easily be calculated provided the magnification is equal in both projections (Figures 4,6).

Relating this inclination to the rotation of the femur around its long axis in the same way as described above will yield the anteversion as defined by Norman (Figure 4).

RESULTS

The mean value of anteversion, calculated with our method, was slightly but significantly lower than as calculated according to Norman's method. Only in two cases was the anteversion value calculated with our method, higher (Table 1 and Figure 7).



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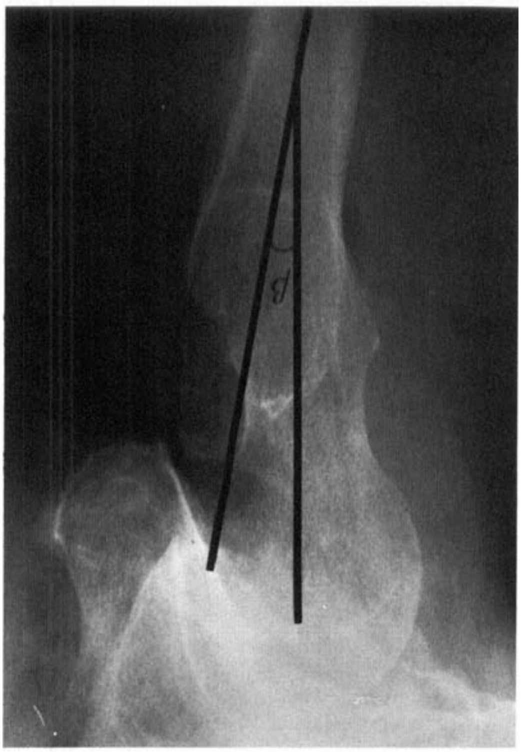

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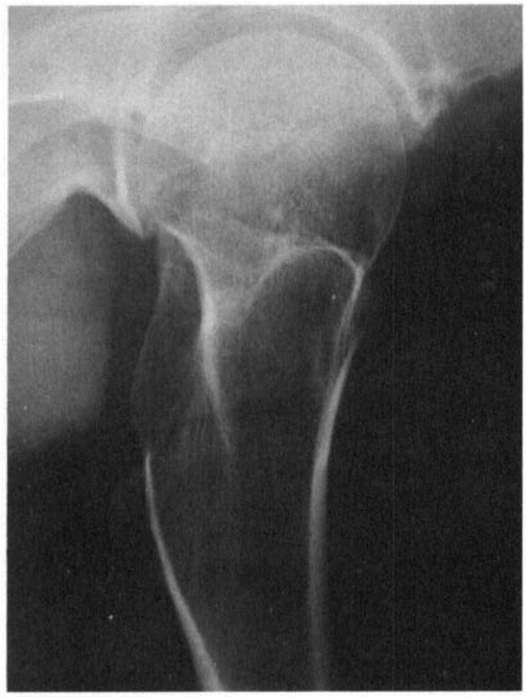

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Figure 2. a) The projected cervicofemoral angle in AP-projection, α. b) The projected cervicofemoral angle in the lateral projection, β. Angles anterior to the mid axis of the femoral shaft are assigned positive value. Angles posterior to the mid axis of the femoral shaft are assigned negative value. Due to the orientation of the central beam and the film plane in relation to the object, the femoral neck is projected elongated on the film plane thereby facilitating the definition of its middle axis. c) Lateral view of proximal femur in a standard projection. Due to the orientation of the central beam and film plane in relation to the object the femoral neck is projected shortened on the film plane and its middle axis less easily defined.

Table 1. Anteversion values

	Anteversion values according to our method	Anteversion values according to Norman's method
Mean	28°	33°
Median	29°	32°
S.D.	9°	7°
Sample size	20	20

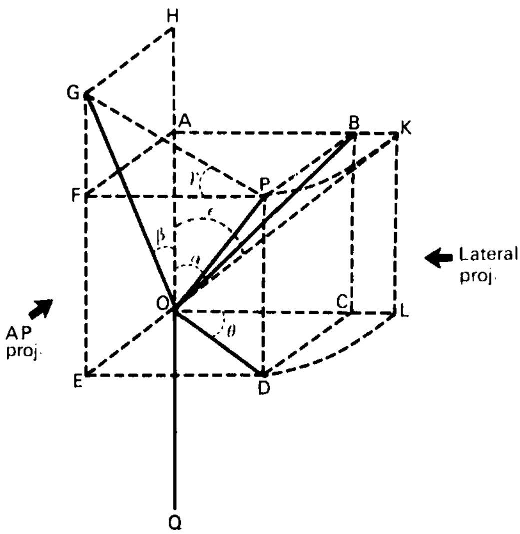


Figure 3. ABCO, Parallel to the film plane in AP-projection. GEOH, Parallel to the film plane in lateral projection. OP, middle axis of femoral neck. OQ, middle axis of femoral shaft. The relation between the anteversion in space θ, the projected cervicofemoral angle in AP-projection α, the projected cervicofemoral angle in the lateral view β, and the cranial inclination γ of the central beam in the lateral projection can be expressed as follows:

$$\tan\theta = \frac{CD}{CO} = \frac{AF}{AB} = \frac{\bar{GH}\tan\gamma}{GF} =$$

$$\frac{(AH + AO)\tan\beta\tan\gamma}{AH} = \tan\beta\tan\gamma +$$

$$\frac{AO}{AH}\tan\beta\tan\gamma = \tan\beta\tan\gamma + \frac{\tan\beta}{\frac{AB}{AO}} =$$

$$\tan\beta\tan\gamma + \frac{\tan\beta}{\tan\alpha}$$

As have been pointed out by Ogata et al. the true cervicofemoral angle ε can be expressed by the following relationship:

$$\tan\varepsilon = \frac{AK}{AO} = \frac{OD}{AB\cot\alpha} =$$

$$\frac{OC\operatorname{cosec}\theta}{AB\cot\alpha} = \frac{\operatorname{cosec}\theta}{\cot\alpha} = \frac{\tan\alpha}{\cos\theta}$$

With an ordinary pocket calculator with trigonometrical functions these calculations will be carried out in less than 30 s.

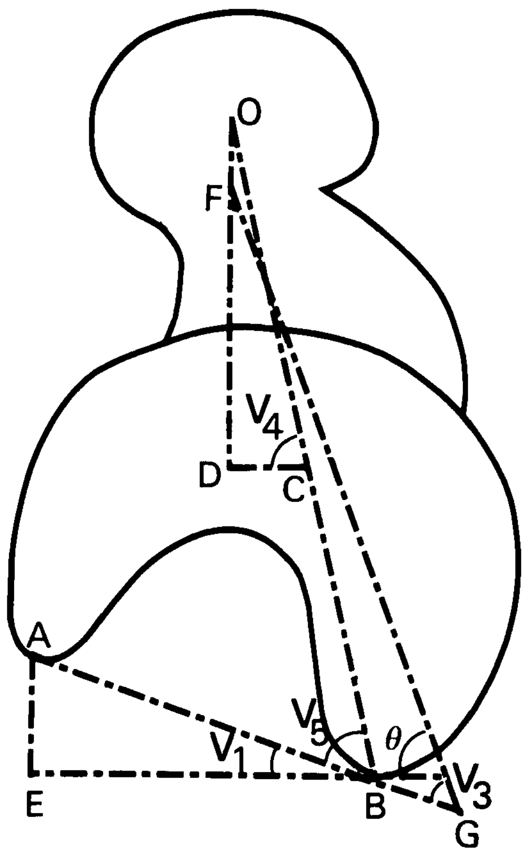


Figure 4. Axial projection of the femur. GF, middle axis of femoral neck. The middle axis of the femoral neck bisects the neck at the base and at the head junction in both AP- and lateral projections. θ, The anteversion angle in space (see Figure 3). V_1, degrees of rotation of the femur around its long axis at the time of the examination. Positive value for external rotations, negative value for internal rotations. Sin $|V_1| = AE/AB$. In adults AB is considered to be approximately 60 mm which leads to the simpler approximation sin $|V_1| \approx AE/60$ or $|V_1| \approx AE$ where V_1 is expressed in degrees of 360 and AE represents the distance in mm between the most dorsal aspect of each femoral condyle as visualized on the lateral view of the knee (Norman).
In children or in adults with abnormal size and shape of the femoral condyles these approximations are invalid. In these cases it is recommended that the leg is rotated to a neutral position, i.e. $V_1 = 0$ under fluoroscopic control or in an external rotation device and the examination of the hip undertaken in this position.
V_3, True anteversion of the femoral neck. V_3 is obtained by the relation $V_3 = \theta - V_1$ where θ is derived from the relation $\tan\theta = \tan\beta\tan\gamma + \tan\beta/\tan\alpha$ and $|V_1| \approx AE$.
V_4, anteversion in space as defined by Norman (1965, 1966, Personal communication). Positive value for ang-

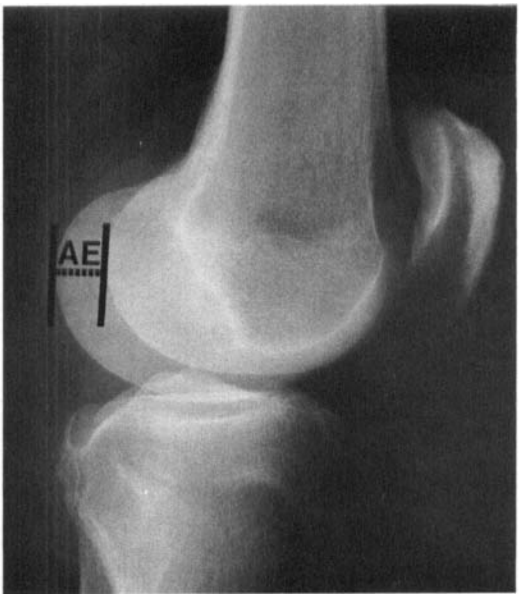
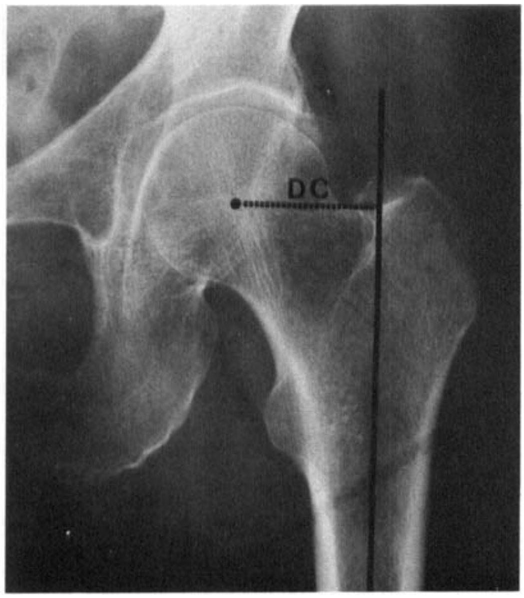


Figure 5. In normally configurated adult femoral condyles the distance AE in millimeters between the most dorsal points of the femoral condyles on the lateral view of the knee can be considered equal to the degree of rotation of the femur around its long axis (see legend to Figure 4) (Norman).

les anterior to C (mid axis of femoral shaft). Negative values for angles posterior to C.
V_4 is easily calculated by the relation $\tan V_4 = OD/DC$ where OD represents the distance between the center of the femoral head and the mid axis of the femoral shaft as measured on the lateral view of the hip and DC represents the same distance as measured on the AP-view. OD has a positive value when the distance is anterior to the mid axis of the femoral shaft and a negative value when it is located posterior to the mid axis of the femoral shaft.
V_5, True anteversion as defined by Norman. V_5 is easily calculated by the relation $V_5 = V_4 - V_1$.
Example: In the examination of a hip α is measured to 40°. β is measured to 18°. It is located anterior to the mid axis of the femoral shaft and thus assigned a positive value. AE is measured to 8 mm with an inward rotation on the lateral view of the knee in an adult with normally configurated femoral condyles. The angle V_1 is thus assigned the value −8°. The cranial inclination of the central beam in the lateral projection of the hip is 30°. $\tan \theta = \tan 18 \tan 30 + \tan 18/\tan 40 = 0.5748$ $\theta = 29.8 \approx 30°$. The true anteversion $V_3 = 30 - (-8) = 38$.



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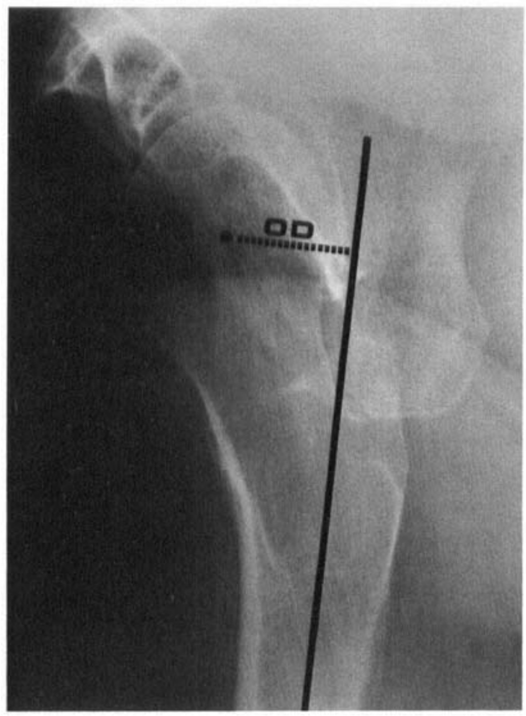

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Figure 6 a) and b). By measuring the distance between the center of the femoral head and the middle axis of the proximal femoral shaft in frontal (DC) and lateral (OD) projection of the hip the anteversion angle in space according to Norman can easily be calculated (see legend to Figure 4).

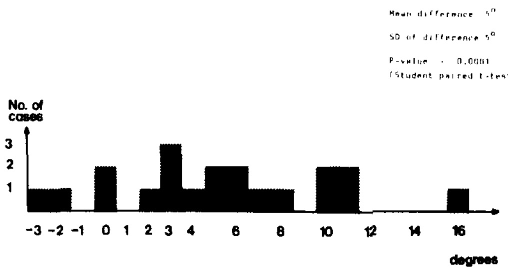

Figure 7. Anteversion according to Norman's method minus anteversion according to our method.

DISCUSSION

Various methods for anteversion measurements of the femoral neck have been proposed (Dunlap et al. 1953, Gillström et al. 1979, Henriksson 1980, Ogata & Goldsand 1979, Reikerås & Høiseth 1982, Reikerås et al. 1982). In contrast to most of these the methods described here have the common advantage of being practicable in patients with restricted mobility of the hip to be examined. The seemingly complex calculations involved in our method may at first appear discouraging. However, with a pocket calculator with trigonometrical functions these calculations are completed within 30 s.

The anteversion angle as defined by Norman suffers from the theoretical disadvantage of not being absolutely linked to the degree of anterotation of the head and neck segment since translations and tilting might affect the measurements as well (Herrlin et al. 1981). A common disadvantage of both methods involves the problem of defining an appropriate axis of the femur due to its antecurvation.

In this study we utilized the axis connecting the center points of the femur at the level of the lower insertion of the lesser trochanter and at a level 8 cm distal to this for both methods since these points are included on standard radiographs of the hip.

The method designed by Norman offers no problems in defining the proximal point of reference. The definition of a middle axis of the femoral neck in our method involves some difficulties. We used the line that bisects the neck at the junction with the head and at the junction with the larger and lesser trochanter. In standard projections such a line is hard to delineate (Figure 2c). In order to overcome this our method includes a projected elongation of the femoral neck in the lateral projection (Figure 2b).

The small but significant difference in anteversion found in our material between the two methods employed reflects a difference in the concept of anteversion inherent in the methods. In order for the angles to coincide the femoral head must be positioned symmetrically around the middle axis of the femoral neck. Based upon the results of our study, in most cases the center of the head thus is located slightly anterior to the middle axis of the femoral neck (Figure 7).

Differences in representation of the middle axis of the femoral shaft as well as of the middle axis of the femoral neck may account for most of the difference in anteversion found in our material as compared with others' (Dunlap et al. 1953, Reikerås & Høiseth 1982, Reikerås et al. 1982). Due to the antecurvation of the femoral shaft and the asymmetry of the femoral neck, these structures cannot be inequivocally defined.

REFERENCES

Dunlap, K., Shands, A. R., Hollister, L. C., Gaul, J. S. & Streit, H. A. (1953) A new method for determination of torsion of the femur. *J. Bone Joint Surg.* **35**-A, 289.

Gillström, P., Olerud, S. & Stark, A. (1979) Utåtrotationsfelställning vid Enderspikning. *Läkartidningen* **19**, 1837.

Henriksson, L. (1980) Measurement of femoral neck anteversion and inclination. *Acta Orthop. Scand.*, Suppl. 186.

Herrlin, K., Egund, N., Andersson, S. & Walloe, A. (1982) Anteversion measurements in trochanteric fractures of the femur. *Acta Radiol.* **23**, in press.

Norman, O. (1965) Beskrivande geometri som hjälpmedel vid bestämning av collum-anteversions- och diafysvinkeln samt frakturvinkeln. *Nord. Med.* **73**, 446.

Norman, O. (1966) Röntgenologisk bestämning av collumanteversionsvinkeln och dess praktiska tillämpning. *Nord. Med.* **75**, 318.

Ogata, K. & Goldsand, E. M. (1979) A simple biplanar method of measuring femoral anteversion and neck-shaft angle. *J. Bone Joint Surg.* **61**-A, 846.

Reikerås, O. & Høiseth, A. (1982) Femoral neck angles in osteoarthritis of the hip. *Acta Orthop. Scand.* **53**, 781–784.

Reikerås, O., Høiseth, A., Reigstad, A. & Fønstelien, E. (1982) Femoral neck angles. A specimen study with special regard to bilateral differences. *Acta Orthop. Scand.* **53**, 775–780.

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