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Reproducible radiographs of acetabular prostheses

A method assessed in 35 patients

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35 patients with a smooth, threaded acetabular Mecron type prosthesis were examined with the aid of a table top with wiremarkers and a fixed 30-degree wedge to allow for reproducible positioning. Under fluoroscopic control, pelvic and spot films were made. The inter- and intraobserver variability of anteversion and inclination angle measurements of the prostheses had a standard deviation of less than 1 degree. The method can be applied to other acetabular prostheses as well.

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A change in position of the acetabular prosthesis is the only definite radiographic proof of loosening of the cup (O'Neill et al. 1984, Mjöberg 1986, Morscher 1992). Thus reproducible measurements of the position of the prosthesis are important. These can only be obtained if the position of the pelvis and the direction of the central beam are identical on sequential radiographic examinations (Goergen et al. 1975, Herrlin et al. 1988a,b,c, Russotti et al. 1991). We developed a simple method to make reproducible radiographs and tested the reproducibility.

Patients and methods

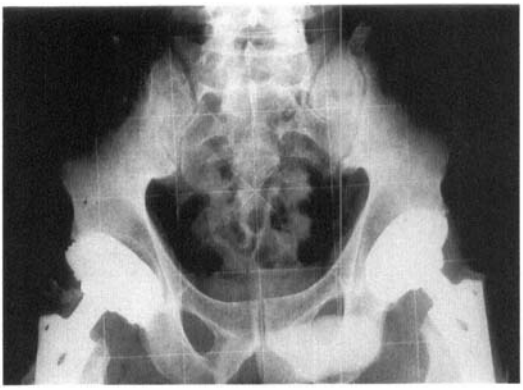
28 women and 7 men, mean age 70 years, with a threaded cementless acetabular prosthesis of the Mecron type as part of a total hip arthroplasty, participated on a voluntary basis. None of the patients had clinical symptoms. The patients were placed in the supine position on a table top, mounted on a Siregraph D2 (Siemens, Erlangen, Germany) containing iron markers. Sets of parallel ironwires are placed on the table top in the horizontal and vertical planes. The gap between the parallel wires is 5 cm. The target for the central beam is indicated by an X. At the distal part of the table top, a wedge of 30 degrees allows for constant hip flexion, thereby compensating possible limitation of extension of one of the hips in time. The focus-film distance is 135 cm. The patient is positioned under fluoroscopic control in such a way that the mid-vertical line intersects with the symphysis and aligns with the midline of the sacrum. The lower most horizontal line, which is at the beginning of the wedge, is projected at the distal part of both obturator foramina. This position is maintained during the whole procedure. An anterior-posterior (AP) pelvic view is made (Figure 1). Subsequently, the table is moved in such a way that the central beam is in the center of the ellipse formed by the projection of the upper side of the ring of the acetabular prosthesis. An AP spot film of the acetabulum is made, as well as a tangential spot film of the prosthesis, with angulation of the tube.

The anteversion and inclination angles are measured on the radiographs. The ratio between the short axis and long axis of the ellipse, which is a projection of the top side of the prosthesis on the AP spot - film, approximates to the sine of the anteversion angle (Appendix), which then can be calculated. The inclination angle can simply be measured on the tangential view with the help of the horizontal markers.

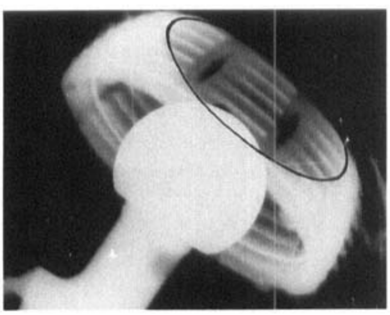
To test the interobserver variability, 10 patients were positioned and measured twice in the same session by 2 independent radiologists. To test the intraobserver variability, 15 patients were measured twice by the same radiologist, 3 and 6 months after surgery.

The measurements for the intra- and the interobserver variability were analyzed with the Student's *t*-test for paired samples.

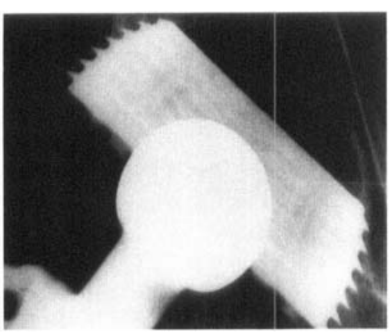
Figure 1. The radiographic method.



Positioning by fluoroscopy with wiremarkers in table top. Cross indicates position of central beam.



Spot film of acetabulum, central beam positioned in the center of ellipse formed by the top side of the metallic ring.



Tangential view with tube angulation.

Results

The correlations of the interobserver variability were 0.990 for the anteversion angle, and 0.987 for the inclination angle (Table 1). The corresponding correlations of the intraobserver variability were 0.997 and 0.993 (Table 2).

Table 1. Interobserver variability. Anteversion (α) and inclination (I) angles measured by 2 independent observers (1 and 2). 10 patients

N	α 1	α 2	I 1	I 2
1	20.5	20.0	43	45
2	19.0	18.0	45	45
3	18.5	18.0	44	44
4	24.0	24.0	57	57
5	31.0	31.0	44	44
6	11.5	12.5	51	52
7	18.5	20.0	49	51
8	11.5	11.0	43	42
9	10.0	10.0	38	38
10	26.5	24.5	49.	50

Table 2. Interobserver variability. Anteversion (α) and inclination angles (I) measured by 1 observer, with a 3-month-interval between the first (α 1, I 1) and second (α 2, I 2) measurements

N	α 1	α 2	I 1	I 2
1	31.0	31.5	44	43
2	34.5	34.5	45	44
3	24.0	24.0	48	48
4	18.5	19.0	44	45
5	24.5	22.0	58	57
6	24.0	24.0	57	57
7	32.5	32.5	38	37
8	19.5	20.0	45	45
9	31.5	31.5	50	50
10	16.0	15.5	51	51
11	1.5	1.5	31	31
12	24.0	25.0	48	48
13	3.5	3.5	50	52
14	18.0	18.0	44	44
15	29.0	29.0	40	40

Discussion

The reproducibility of measurements of total hip prostheses is ignored by some (Mendes et al. 1973, Gore et al. 1982, Söreide et al. 1982, Callaghan et al. 1985, Brand et al. 1986, Herrlin et al. 1988a,b, Thorén et al. 1989, Kobayashi et al. 1990, Carret et al. 1991), and acknowledged by others (Clarke et al. 1976, Gore et al. 1977, Collet et al. 1985). This subject is relevant, however, since it has aroused the interest of many researchers. Nunn et al. (1989) tested the reproducibility of their measurements of the inter-teardrop distance, the vertical distance from the head center to the inter-teardrop line and the horizontal distance from the head center to the ipsilateral teardrop, and found an accuracy of 3 mm. Only distances and no angles were measured. Wetherell et al. (1989) tested the reproducibility of several different measurements on a dry-bone study, and found that measurements from the acetabular margin line and the obturator/brim line were most accurate and easy to reproduce. Computed tomography cannot be used because of artifacts secondary to the metallic prosthesis (Fishman et al. 1986). A good reproducible method is roentgen stereogrammetry using tantalum bone markers in the pelvis and proximal femur as well as on the prosthesis (Mjöberg et al. 1986, Djerf et al. 1987, Kärrholm 1989, Selvik 1989, Franzén et al. 1990, Snorrason 1990). The distance between the tantalum markers can be calculated by a computer. This method has not gained wide support, because of disadvantages such as the necessity of implantation of tantalum markers, stereo-radiography and computer availability (Nunn et al. 1989, Wetherell et al. 1989).

The wire markers or grids we apply have been used before by Shine and O'Neill in 1978 and by Amstutz et al. in 1986. However, these authors put the grid between the patient and the tube. By placing the wire markers in a tabletop underneath the patient, the position of the markers becomes constant on every radiograph and the distance between the markers and the film is much smaller, resulting in decreased divergence.

A tangential view of the acetabular prosthesis, obtained with angulation, is valuable for measuring the inclination angle when horizontal wire markers are used. In addition, it provides a good view of the reaction of the bone surrounding the prosthesis. At the same time the direction of the tube angulation will give some information about anteversion or retroversion of the prosthesis. But measuring the anteversion angle by means of tube angulation (Ghelman et al. 1979) is inaccurate because the tube moves in a circular way and at the same time the film underneath the patient moves in a linear way. As a consequence, the ratio between the object-film distance and the focus-object distance will change with the amount of angulation. The flexed position of the hips does not limit the evaluation of the femoral component.

The ellipse formed by the projection of the acetabulum prosthesis for measuring the anteversion angle has been used before, by calculating the ratio of the short and long axes (McLaren 1973, Petterson et al. 1982, Seradge et al. 1982, Gebauer et al. 1983), or by using it in geometrically more complicated calculations (Visser et al. 1982). It is important that the central beam is positioned in the center of the ellipse, otherwise the problem becomes geometrically very complicated (Seradge et al. 1982). We used the ellipse formed by the upper side of the titanium ring, present in the threaded acetabular prosthesis. Positioning of the central beam is easy, using magnified fluoroscopy with diafragmation.

Table 3. Comparison of α and I-means measurements by the paired samples *t*-test

	Mean difference	SD	95% CI for mean difference	Corr.
Interobserver (n 10)				
α	0.38	0.98	-0.30–1.06	0.990
I	0.45	0.90	-2.27–1.19	0.987
Intraobserver (n 15)				
α	0.03	0.77	-0.39–0.46	0.997
I	0.10	0.81	-0.35–0.55	0.993

One should be aware of the fact that the anteversion angle measured is not the absolute anteversion but a relative one because of the absence of the horizontal axis in this plane on A-P radiographs. Changes in the anteversion angle, however, can be measured accurately with this method. When the patient is properly positioned, the inclination angle measured is the actual inclination angle.

With the method tested, it is possible to obtain measurements with a low intra- and interobserver variability, resulting in a standard deviation of less than ± 1 degree for the inclination and anteversion angles (Table 3). This is well within the standard deviation of ± 2 degrees that is considered accurate (Seradge et al. 1982). However, the need for fluoroscopic positioning can be a disadvantage in some cases.

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Appendix

With the central beam positioned in the center of the ellipse formed by the projection of the top side of the ring of the prosthesis the anteversion angle can be calculated using trigonometry (Figure 2)

Focus–film distance (SC') = 135 cm
Average diameter of the cup (AB) = 50 mm
Average hip–film distance (CC') = 165 mm (18)
α = anteversion angle XCA

$$CX = CY = AC \times \cos\alpha$$

And

$$AX = AC \times \sin\alpha$$

Further

$$SX = SC - CX$$

Now

$$AX / A'C' = SX / SC'$$

Hence

$$AC \times \sin\alpha / A'C' = (SC - AC \times \cos\alpha) / SC' \Rightarrow$$

$$A'C' = AC \times SC' \times \sin\alpha / (SC - AC \times \cos\alpha)$$

Also

$$C'B' = AC \times SC' \times \sin\alpha / (SC + AC \times \cos\alpha)$$

And it follows that

$$A'B' = AC \times SC' \times \sin\alpha \times (1 / (SC - AC \times \cos\alpha) + 1 / (SC + AC \times \cos\alpha))$$

$$A'B' = AC \times SC' \times \sin\alpha \times 2SC / (SC^2 - AC^2 \times \cos^2\alpha)$$

$$AC = AB / 2 \Rightarrow$$

$$A'B' = AB \times SC' \times SC \times \sin\alpha / (SC^2 - AB^2 \times \cos^2\alpha / 4)$$

Using

$$D'E' = DE \times SC' / SC = AB \times SC' / SC$$

It follows that

$$A'B' / D'E' = SC^2 \times \sin\alpha / (SC^2 - AB^2 \times \cos^2\alpha / 4) = R$$

Finally

$$\sin\alpha = R \times ((4SC^2 - AB^2 \times \cos^2\alpha) / 4SC^2)$$

$$\sin\alpha = R \times (1 - AB^2 \times \cos^2\alpha / 4SC^2)$$

$$\Upsilon^2 = AB^2 \times \cos^2\alpha / 4SC^2$$

$$\Upsilon = AB \times \cos\alpha / 2SC$$

If $AB \ll SC \Rightarrow \Upsilon \ll 1$, *thereby* $\sin\alpha \approx R$

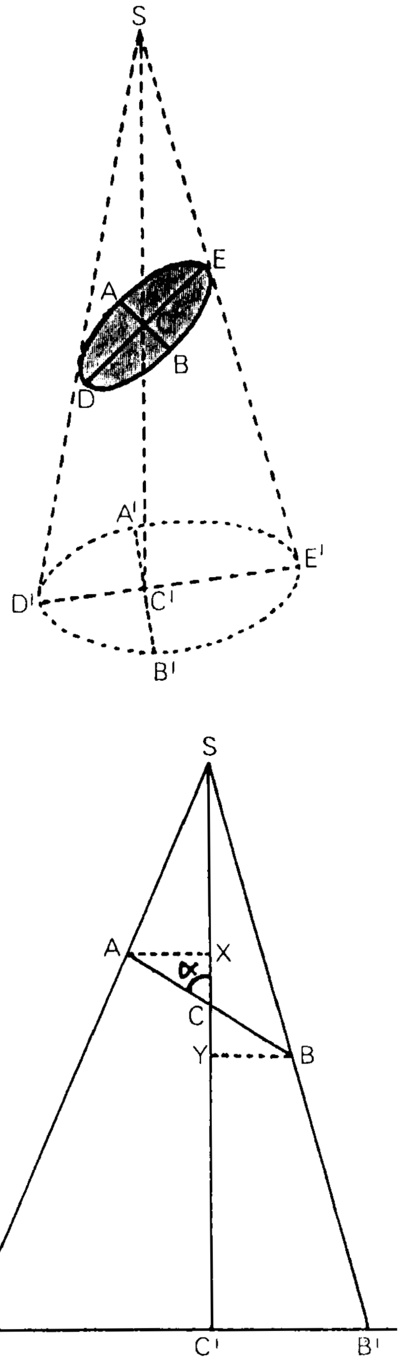

Figure 2. Projection of the ring of the prosthesis (ABDE) on the film (A′, B′, D′, E′). AB = DE = diameter of the ring, S focus, α anteversion angle.