ANTEVERSION OF THE ACETABULAR CUP

MEASUREMENT OF ANGLE AFTER TOTAL HIP REPLACEMENT

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We describe a new method for the accurate measurement of the angle of anteversion of an acetabular cup from standard anteroposterior radiographs, and provide the conversion tables required. The effect of the centring of the radiograph is discussed and a method of distinguishing between anteversion and retroversion by using a caudally directed x-ray beam is described.

Dislocation is an ominous complication of total hip replacement; its reported incidence ranges from 0.6% (Etienne, Cupic and Charnley 1978) to 7.0% (Ritter 1976). Ali Khan, Brakenbury and Reynolds (1981) stated that the commonest surgical error leading to dislocation was a badly placed acetabular cup. This supports an earlier statement by Lewinnek *et al.* (1976), who found a definite association between anterior dislocation and anteversion of the cup. A review of the literature reveals no easy method of evaluating the anteversion of the acetabular cup; it may even be difficult to determine whether the cup is retroverted or anteverted.

This paper has three purposes:

1. To describe a simple, rapid method of determining the angle of version of an acetabular cup from standard radiographs.
2. To present a reliable method of determining if a cup is anteverted or retroverted.
3. To evaluate the effect of centring on the result of a hip radiograph.

Definitions. Anteversion of the acetabular component of a total hip replacement can be defined in either of two ways, depending on the plane chosen to define the axis about which the rotation of the component is measured. In the true anatomical sense, anteversion can be defined relative to the transverse plane of the body. This plane is used by the Aufranc-Turner cup positioner and we define this as *true* anteversion. Alternatively, anteversion can be defined in relation to the plane oblique to the true transverse plane, in which the cup itself has been set.

Anteversion or retroversion of the acetabular component in this plane produces a somewhat different relative angle. The Charnley-Müller positioner sets anteversion in this way, which we define as *planar* anteversion.

The relationship between these two measurements of acetabular anteversion depends on the vertical tilt of the cup relative to the transverse plane as seen on an anteroposterior radiograph. This angle of tilt is measured between a line joining the ischial tuberosities and a line through the long axis of the wire marker of the cup. It can be measured directly, and is usually about 45° (Fig. 1). The two types of anteversion can be related to one another geometrically and, with the assistance of a computer, a table of the possible combinations of these angles can be printed (Table I). This shows, for example, that a measured planar anteversion of 13° with a vertical tilt of 43° has a true anteversion of 10°.

MEASUREMENT AND CALCULATIONS

Planar anteversion. The acetabular component of a total hip replacement commonly has a metal ring in its periphery. When this ring is viewed at an angle, it will project as an ellipse. This projection can be mathematically proven to follow the general formula for all ellipses.

In Figure 2

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1, \quad (1)$$

where a = the major axis, and b = the minor axis, and x and y are the co-ordinates of any point on the ellipse. The addition of the radio-opaque femoral component unfortunately obscures the minor axis b of the ellipse and makes direct measurement of it impossible. Other authors (Lewinnek *et al.* 1976; Visser and Konings 1981) have drawn in the obscured parts of the curves and then used a variety of mathematical formulae to calculate the angle of anteversion. Since the results all depended on a subjectively determined value for b , an unacceptable amount of human error was introduced.

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Fig. 1

Diagram to show the angle of vertical tilt of the acetabular cup, that is the angle between a line joining the ischial tuberosities and one through the long axis of the ellipse projected by the wire marker.

Fig. 2

An ellipse to show the major axis a , the minor axis b and the paths traced by co-ordinates x and y .

Fig. 3

An ellipse with a circle superimposed to represent the femoral head. This obscures the minor axis. A, B, C, D and E are the points from which the measurements detailed in the text should be taken.

However, in Figure 3 consider any line EBD drawn at right angles across an ellipse, where Y' is the distance DE , and X' is the distance AB . Then in formula 1 above: a , the major axis $= AC$ and the true co-ordinates for points D and E are

$$x = \frac{a}{2} - X' \quad \text{and} \quad y = \frac{Y'}{2}.$$

These values of a , x and y can be substituted into the general formula and solved to give b the only remaining unknown. It would be tedious to calculate from the formulae for each case. Instead a computer has been used to calculate the planar anteversion for all possible values of X' and Y' . In Table II, X' and Y' are each entered as a ratio of AC , the apparent diameter of the ring, in order to correct for the size of the cup. It is then possible to read the planar anteversion directly from the table.

In practice then, the measurements required are AB (which is X'), DE (which is Y') and AC (the major axis of the ellipse). In Table II, only the two ratios AB/AC and DE/AC are needed. All other calculations have been

Fig. 4

Radiograph of the experimental model, to show the points from which measurements are taken.

included in the computer program, so that the angle of planar anteversion θ can be read directly. For example, in the original radiograph of Figure 4, AC measured 56 mm. The line DE , drawn perpendicular to AC , measured 11 mm and AB was 14 mm. Then

$$\frac{AB}{AC} = \frac{14}{56} = 0.25 \quad \text{and} \quad \frac{DE}{AC} = \frac{11}{56} = 0.20.$$

Entering Table II at $X'/AC = 0.25$ and $Y'/AC = 0.20$ gives the angle of planar anteversion, which is 13° .

To test the accuracy of the method, the pelvis of a skeleton was fixed in position on a radiographic table and an acetabular cup was held in place with a clamped cup-positioning device. The planar anteversion of the cup was directly measured with set squares and protractors.

Radiographs were then taken in the anteroposterior plane, with the tube centred firstly over the hip itself (Fig. 4) and secondly over the symphysis pubis. From the tables, the angles of planar anteversion were obtained for each of the positions of centring and compared with the

Fig. 5
10 ANTEVERSION

Fig. 6
10 RETROVERSION

Figures 5 and 6- Normal radiographs centred on the hip show similar images.

Fig. 7
10 ANTEVERSION
Ellipse CLOSES

Fig. 8
10 RETROVERSION
Ellipse OPENS

Figures 7 and 8- Radiographs with beam directed 10° caudally.

direct measurement (Table III). Only when the beam was centred over the hip could anteversion be measured accurately from the film. When the radiograph was centred over the symphysis, an error was produced because the x-ray beam was oblique in relation to the opening of the ellipse. This error has been shown to be as much as 5°, depending on the angle of the cup. The beam must be centred over the acetabulum for accurate radiological assessment, whatever method is used for assessment of angles. When the central beam passes through the hip, the method which has been described is highly accurate.

Any question that the cup might be retroverted rather than anteverted can be resolved by directing the beam to 10° caudal angulation. If the cup is anteverted, the ellipse will close. If the cup is retroverted, the ellipse will open. An example of this is shown in Figures 5 to 8. The very similar radiographs in Figures 5 and 6 were taken with the cup anteverted and retroverted, respectively. This is made clear in Figures 7 and 8 which were taken with the beam directed 10° caudally. The anteverted ellipse closes (Fig. 7) and the retroverted ellipse opens up.

DISCUSSION

A variety of complex methods have been proposed to measure the angle of anteversion of an acetabular cup.

Lewinnek *et al.* (1976) used draughtsman's curves to draw in the parts of ellipse obscured by the femoral component; this method is subjective and may be inaccurate.

Visser and Konings (1981) also estimated the position of the ellipse, but reported no check on the efficacy of their formula. Ghelman (1979) used fluoroscopy and multiple imaging to record the apparent angle of anteversion, then used tables to estimate the true anteversion. This method involves more time, prolonged radiation and is a special procedure performed by a radiologist.

Schneider *et al.* (1982) took multiple anteroposterior radiographs at various degrees of obliquity until the lines of the ellipse overlapped, and then made corrections for the obliquity of the beam. This method needs more time, more radiation, and some guesswork to make the lines overlap. Woo and Morrey (1982) felt that the method of Lewinnek needed very carefully standardised radiographs. They attempted to estimate anteversion from lateral radiographs, but admitted that this was not accurate.

The results for films centred over the hip (Table III) show that our method is highly accurate, and the speed of calculation is a positive factor in making the method practicable for routine use. Although the derivation is arduous, the computer print-out in Table II makes it possible for an orthopaedic surgeon to measure planar anteversion from a single film in less than two minutes.

This method can also be utilised to measure the anteversion of a metal-backed cup since the radiographic shadow will include on one side exactly one-half of an ellipse, as is clearly shown in Figure 9. The long axis of the ellipse (*AC*) can be drawn in and the line *BD* erected at right angles. The line *BD* is then one-half of *Y'* and can be doubled for substitution in the same calculations and tables.

Fig. 9

Radiograph of a metal cup showing the points from which measurements should be taken for the calculation of anteversion.

Table I. *True* anteversion in degrees derived from *planar* anteversion and the vertical tilt of the acetabulum (see Figure 1)

Planar anteversion (degrees)	Vertical tilt (degrees)																			
	10	13	16	19	22	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67
2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1
3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1	1
4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2	2
5	5	5	5	5	5	5	5	4	4	4	4	4	3	3	3	3	3	2	2	2
6	6	6	6	6	6	5	5	5	5	5	5	4	4	4	4	3	3	3	3	2
7	7	7	7	7	7	6	6	6	6	6	5	5	5	5	4	4	4	3	3	3
8	8	8	8	8	7	7	7	7	7	6	6	6	6	5	5	5	4	4	4	3
9	9	9	9	9	8	8	8	8	7	7	7	7	6	6	6	5	5	4	4	4
10	10	10	10	9	9	9	9	9	8	8	8	7	7	7	6	6	5	5	4	4
11	11	11	11	10	10	10	10	9	9	9	8	8	8	7	7	6	6	5	5	4
12	12	12	12	11	11	11	11	10	10	10	9	9	8	8	7	7	6	6	5	5
13	13	13	13	12	12	12	12	11	11	10	10	10	9	9	8	8	7	6	6	5
14	14	14	13	13	13	13	12	12	12	11	11	10	10	9	9	8	8	7	6	6
15	15	15	14	14	14	14	13	13	13	12	12	11	11	10	9	9	8	7	7	6
16	16	16	15	15	15	15	14	14	13	13	12	12	11	11	10	9	9	8	7	6
17	17	17	16	16	16	15	15	15	14	14	13	13	12	11	11	10	9	8	8	7
18	18	18	17	17	17	16	16	16	15	15	14	13	13	12	11	11	10	9	8	7
19	19	19	18	18	18	17	17	16	16	15	15	14	13	13	12	11	10	9	9	8
20	20	20	19	19	19	18	18	17	17	16	16	15	14	13	13	12	11	10	9	8
21	21	21	20	20	20	19	19	18	18	17	16	16	15	14	13	12	11	11	10	9
22	22	21	21	21	21	20	20	19	19	18	17	16	16	15	14	13	12	11	10	9
23	23	22	22	22	21	21	21	20	19	19	18	17	16	16	15	14	13	12	11	9
24	24	23	23	23	22	22	21	21	20	20	19	18	17	16	15	14	13	12	11	10
25	25	24	24	24	23	23	22	22	21	20	20	19	18	17	16	15	14	13	12	10
26	26	25	25	25	24	24	23	23	22	21	20	20	19	18	17	16	14	13	12	11
27	27	26	26	26	25	25	24	24	23	22	21	20	19	18	17	16	15	14	13	11
28	28	27	27	27	26	26	25	25	24	23	22	21	20	19	18	17	16	14	13	12
29	29	28	28	28	27	27	26	25	25	24	23	22	21	20	19	18	16	15	14	12
30	30	29	29	29	28	28	27	26	26	25	24	23	22	21	20	18	17	16	14	13
31	31	30	30	30	29	29	28	27	26	26	25	24	23	22	20	19	18	16	15	13
32	32	31	31	31	30	30	29	28	27	27	26	25	23	22	21	20	18	17	15	14
33	33	32	32	32	31	30	30	29	28	27	26	25	24	23	22	20	19	17	16	14
34	34	33	33	33	32	31	31	30	29	28	27	26	25	24	23	21	20	18	16	15
35	35	34	34	34	33	32	32	31	30	29	28	27	26	25	23	22	20	19	17	15
36	36	35	35	34	34	33	33	32	31	30	29	28	27	25	24	23	21	19	18	16
37	37	36	36	35	35	34	34	33	32	31	30	29	28	26	25	23	22	20	18	16
38	38	37	37	36	36	35	35	34	33	32	31	30	28	27	26	24	22	21	19	17
39	39	38	38	37	37	36	36	35	34	33	32	31	29	28	26	25	23	21	20	18
40	40	39	39	38	38	37	37	36	35	34	33	32	30	29	27	26	24	22	20	18
41	41	40	40	39	39	38	38	37	36	35	34	32	31	30	28	27	25	23	21	19
42	42	41	41	40	40	39	38	38	37	36	35	33	32	31	29	27	26	24	22	19
43	43	42	42	41	41	40	39	39	38	37	36	34	33	31	30	28	26	24	22	20
44	44	43	43	42	42	41	40	40	39	38	36	35	34	32	31	29	27	25	23	21
45	45	44	44	43	43	42	41	41	40	39	37	36	35	33	32	30	28	26	24	21
46	46	45	45	44	44	43	42	42	41	40	38	37	36	34	33	31	29	27	24	22
47	47	46	46	45	45	44	43	43	42	41	39	38	37	35	33	32	30	27	25	23
48	48	47	47	46	46	45	44	44	43	42	40	39	38	36	34	32	30	28	26	23
49	49	48	48	47	47	46	45	45	44	43	41	40	39	37	35	33	31	29	27	24
50	50	49	49	48	48	47	46	46	45	44	42	41	40	38	36	34	32	30	28	25
51	51	50	50	49	49	48	47	47	46	45	43	42	41	39	37	35	33	31	28	26
52	52	51	51	50	50	49	48	48	47	46	44	43	42	40	38	36	34	32	29	27
53	53	52	52	51	51	50	50	49	48	47	45	44	43	41	39	37	35	33	30	27
54	54	53	53	52	52	51	51	50	49	48	47	45	44	42	40	38	36	34	31	28
55	55	54	54	53	53	52	52	51	50	49	48	46	45	43	41	39	37	35	32	29

Conclusions. The method presented in this paper uses a standard anteroposterior film centred over the hip to determine the degree of version and, if necessary, a second radiograph taken with the tube angled 10° caudally to distinguish between retroversion and anteversion. This avoids the need for special views and for additional radiation.

The definitions given in this paper are simple but important. Reports have often quoted "ideal" angles of anteversion for the acetabular component. In future these angles should be recorded as either *true* anteversion or *planar* anteversion. Either method of reporting is, of course, acceptable as long as the difference and the relationship between the two are clearly understood.

Table II. Angle of *planar* anteversion according to the ratios AB/AC and DE/AC (where $AB=X'$ and $DE=Y'$)

	X' AC																
Y' AC	0.38	0.36	0.34	0.32	0.30	0.28	0.26	0.24	0.22	0.20	0.18	0.16	0.14	0.12	0.10	0.08	0.06
0.02	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2
0.04	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4
0.06	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	6	6
0.08	5	5	5	5	5	5	5	5	5	6	6	6	6	7	7	8	8
0.10	6	6	6	6	6	6	6	7	7	7	7	7	8	8	9	10	11
0.12	7	7	7	7	7	8	8	8	8	8	9	9	9	10	11	12	13
0.14	8	8	8	8	9	9	9	9	9	10	10	10	11	12	12	13	15
0.16	9	9	10	10	10	10	10	11	11	11	12	12	13	13	14	15	17
0.18	11	11	11	11	11	11	12	12	12	13	13	14	14	15	16	17	19
0.20	12	12	12	12	12	13	13	13	14	14	14	15	16	17	18	19	22
0.22	13	13	13	13	14	14	14	15	15	15	16	17	17	18	20	22	24
0.24	14	14	14	15	15	15	16	16	16	17	17	18	19	20	22	24	26
0.26	15	16	16	16	16	16	17	17	18	18	19	20	21	22	24	26	29
0.28	17	17	17	17	17	18	18	19	19	20	20	21	22	24	26	28	31
0.30	18	18	18	18	19	19	20	20	21	21	22	23	24	26	27	30	34
0.32	19	19	19	20	20	20	21	21	22	23	24	25	26	27	29	32	36
0.34	20	21	21	21	21	22	22	23	23	24	25	26	28	29	32	35	39
0.36	22	22	22	22	23	23	24	24	25	26	27	28	29	31	34	37	42
0.38	23	23	23	24	24	24	25	26	26	27	28	30	31	33	36	39	44
0.40	24	24	25	25	25	26	26	27	28	29	30	31	33	35	38	42	47
0.42	25	26	26	26	27	27	28	29	29	30	32	33	35	37	40	44	51
0.44	27	27	27	28	28	29	29	30	31	32	33	35	37	39	43	47	54
0.46	28	28	29	29	30	30	31	32	33	34	35	37	39	42	45	50	58
0.48	29	30	30	30	31	32	32	33	34	35	37	39	41	44	48	53	62
0.50	31	31	31	32	32	33	34	35	36	37	39	41	43	46	50	56	67
0.52	32	32	33	33	34	35	35	36	38	39	41	43	45	49	53	60	73
0.54	33	34	34	35	35	36	37	38	39	41	42	45	47	51	56	64	84
0.56	35	35	36	36	37	38	39	40	41	43	44	47	50	54	60	69	
0.58	36	37	37	38	38	39	40	41	43	44	46	49	52	57	63	75	
0.60	38	38	39	39	40	41	42	43	45	46	49	51	55	60	67	90	
0.62	39	40	40	41	42	43	44	45	47	48	51	54	58	63	73		
0.64	41	41	42	42	43	44	45	47	49	51	53	56	61	67	80		
0.66	42	43	43	44	45	46	47	49	51	53	56	59	64	72			
0.68	44	44	45	46	47	48	49	51	53	55	58	62	68	78			
0.70	46	46	47	48	49	50	51	53	55	58	61	66	73				
0.72	47	48	49	49	51	52	53	55	57	60	64	70	79				
0.74	49	50	50	51	52	54	55	58	60	63	68	74					
0.76	51	52	52	53	55	56	58	60	63	67	72	82					
0.78	53	53	54	55	57	58	60	63	66	70	77						
0.80	55	55	56	58	59	61	63	66	69	75	90						

Table III. Actual *planar* anteversion in degrees at various angles of vertical tilt, compared with the results obtained by the method described in the text, with the beam centred first on the symphysis pubis and then on the hip itself

Measured planar anteversion	Vertical tilt	Centred on symphysis		Centred on hip	
		Calculated anteversion	Error	Calculated anteversion	Error
-11	45	-14	3	-11	0
0	45	-3	3	0	0
13	45	11	2	13	0
32	45	28	4	32	0
14	20	11	3	14	0
13	58	8	5	12	1

REFERENCES

- Ali Khan MA, Brakenbury PH, Reynolds ISR. Dislocation following total hip replacement. *J Bone Joint Surg [Br]* 1981;**63 B**:214-8.
- Etienne A, Cupic Z, Charnley J. Postoperative dislocation after Charnley low-friction arthroplasty. *Clin Orthop* 1978;**132**:19-23.
- Ghelman B. Radiographic localization of the acetabular component of a hip prosthesis. *Radiology* 1979;**130**:540-2.
- Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip replacement arthroplasties. *J Bone Joint Surg [Am]* 1976;**60 A**:217-20.
- Ritter MA. Dislocation and subluxation of the total hip replacement. *Clin Orthop* 1976;**121**:92-4.
- Schneider R, Freiburger RH, Ghelman B, Ranawat CS. Radiologic evaluation of pain and joint prosthesis. *Clin Orthop* 1982;**170**:156-68.
- Visser JD, Konings JG. A new method for measuring angles after total hip arthroplasty: a study of the acetabular cup and femoral component. *J Bone Joint Surg [Br]* 1981;**63 B**:556-9.
- Woo RYG, Morrey BF. Dislocations after total hip arthroplasty. *J Bone Joint Surg [Am]* 1982;**64 A**:1295-1306.