Original Article

Positioning of the acetabular component in cemented prostheses – radiographic calculation

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ABSTRACT

Objective: to assess the reliability of the inclination angle and anteversion of acetabular cup component in patients with idiopatic osteoarthritis of the hip, aseptic necrosis and hip neck fracture using trigonometric formula and plain radiographs. *Methods*: 66 patients underwent cemented total arthroplasty of 72 hips. The inclination of acetabular component was measured using plain radiograph. The acetabular component anteversion was measured using trigonometric formula. *Results*: it was observed that, in the osteoarthritic hips, hip neck fracture and aseptic necrosis, the degree of agreement was highly significant ($p < 0.0001$), in the measurements of anteversion and inclination angles, among the three assessments, from intra as well as inter-observers. All the agreement pairs were of excellent degree (ICC > 0.80). *Conclusion*: using plain radiographs and trigonometric formula, the method resulted to be highly accurate and reliable. Besides being easy to be calculated. No significant variation was found in the anteversion and inclination angles when compared with osteoarthritis of the hip, aseptic necrosis and hip neck fracture.

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Introduction

The positions of the components in total hip arthroplasty in relation to the femur and pelvis is important with regard to the prognosis for the surgery.[1] The inclination and anteversion of the acetabular component were defined by Murray,[2] in relation to three different perspectives: radiographic, surgical and anatomical. The present study analyzed only the radiographic angle, which is the inclination between the longitudinal and acetabular axes that is projected onto the coronal plane. Several studies in the literature have demonstrated the importance of achieving appropriate inclination and anteversion, and of making measurements on these.[2-10] A variety of mathematical, trigonometric and fluoroscopic methods have been described for determining the position of the acetabular component on conventional radiographs.[2,3,7,9,11,12] Lewinnek et al.[13] proposed that the ideal radiographic image would be an acetabular component with anteversion of 15° (SD 10°) and abduction of 40° (SD 10°) with the aim of preventing impact and dislocation.

The aim of the present study was to measure the reliability of the inclination and anteversion angles of the acetabular component in patients with idiopathic hip osteoarthrosis, aseptic necrosis and femoral neck fracture who underwent cemented total hip arthroplasty, through using a trigonometric formula for measuring the anteversion and through using direct measurement of the acetabular inclination angle on conventional radiographs.

Methods

Between March 2009 and January 2011, 66 patients were treated with total hip arthroplasty, among which there were 12 bilateral and 60 unilateral cases, thus totaling 72 hips. Forty-eight patients of mean age 67.6 years presented hip osteoarthrosis. Sixteen patients of mean age 72.7 years presented femoral neck fractures, and eight patients of mean age 52.5 years presented aseptic necrosis. All the patients were treated with cemented total arthroplasty, both for the acetabular and for the femoral component, with use of the Hardinge direct lateral access.

The inclusion factors were that these should be patients presenting idiopathic hip osteoarthrosis, aseptic necrosis and femoral neck fractures who were treated with total hip arthroplasty using a cemented acetabular component that had a circumferential metal rim around the entire edge of the acetabular polyethylene (BaumerR). The exclusion factors were that these should not be patients who presented acetabular revision components, hip dysplasia, previous acetabular fractures or osteometabolic diseases.

The first postoperative radiograph was selected and the position of the acetabular component was measured in accordance with Murray's technique.[2] All the patients were positioned in dorsal decubitus with the radius centered over the public symphysis, to show both hips (foramen obturatum the same on both sides) and including the proximal third of the femur. The inclination of the acetabular component was measured using the angle between a line joining the ischial tuberosities and a line crossing the long axis of the acetabular component, determined by means of the axis of the major diameter that is formed by the projection of the metal rim on the radiograph (Fig. 1). The anteversion of the acetabular component was measured using Pradhan's technique.[11] A point M was marked at one-fifth of the distance along the maximum length of the diameter (D) of the ellipse projected on the ring of the acetabular dome (Fig 2). The perpendicular distance (p) was measured from the point M to the rim. Thus, the formula was:

Planar anteversion = arc sin* (p/0.4D)

*arc sin = trigonometric function involving operations with radian degrees.

Fig. 1 - Measurement of the inclination angle of the acetabular component. (a) – line tangential to the ischial tuberosities; (b) – line through the axis of the major diameter formed by the projection of the metal rim on the radiograph; (c) – acetabular inclination angle.
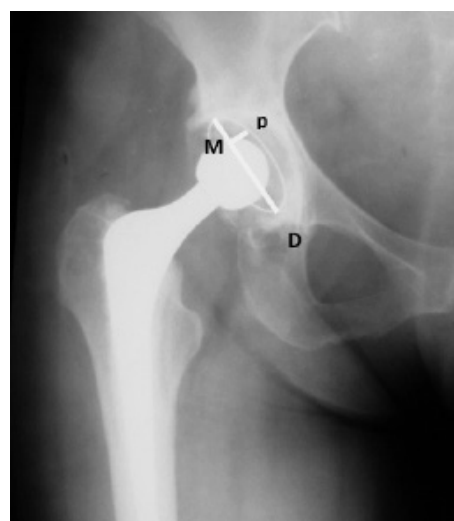
Fig. 2 - Measurement of the acetabular component by means of a trigonometric formula. Line D – distance of the maximum length of the diameter of the ellipse projected on the ring of the acetabular dome; point M – point marked at one-fifth of the distance of the maximum length of the diameter (D) of the ellipse projected on the ring of the acetabular dome; perpendicular distance (p) – perpendicular measurement from the point M to the metal ring.

To analyze the inter and intra-observer reproducibility, each acetabulum was measured in random order by three orthopedic surgeons at different times while the result was kept concealed.

Table 1 provides a general description of the sample of 72 hips that were studied. Tables 2 and 3 show the mean ± standard deviation, minimum and maximum for the anteversion and inclination angles, respectively, for each observer (Observer 1, Observer 2 and Observer 3) and the first and second measurements.

Table 1 - General description of the sample.

Variable	Category	n	%
Age (years)	67.1 ± 14.2 (30 - 91)		
Etiology	Arthrosis	48	66.7
	Hip fracture	16	22.2
	Aseptic necrosis	8	11.1
Side	Right	38	52.8
	Left	34	47.2

Source: Hospital Santa Teresa.
SD: standard deviation; age is expressed as the mean ± SD (minimum - maximum).

Table 2 - General description of the anteversion angle (degrees).

Observer	Measurement	Mean ± SD			Minimum	Maximum
Observer 1	AA 1	13.2	±	7.4	0	34.9
	AA 2	13.0	±	7.4	2.7	32.6
Observer 2	AA 1	13.2	±	7.5	0	33.3
	AA 2	12.2	±	7.0	0	29.2
Observer 3	AA 1	14.2	±	7.4	2.6	31.9
		11.4	±	6.6	0	30.0

Source: Hospital Santa Teresa.
AA1 – Anteversion angle of the first measurement;
AA2 – Anteversion angle of the second measurement.

Table 3 - General description of the inclination angle (degrees).

Observer	Measurement	Mean ± SD			Minimum	Maximum
Observer 1	AI 1	42.6	±	9.0	22	64
	AI 2	42.8	±	9.1	24	62
Observer 2	AI 1	42.6	±	8.6	24	62
	AI 2	43.8	±	8.2	24	64
Observer 3	AI 1	42.5	±	8.8	22	64
	AI 2	42.3	±	8.7	22	60

Source: Hospital Santa Teresa.
AI1 – Inclination angle of the first measurement;
AI2 – Inclination angle of the second measurement.

Methodology

The statistical analysis comprised the intraclass correlation coefficient (ICC) for evaluating the intra and inter-observer agreement of the measurements of the anteversion and inclination angles, and one-way ANOVA[14] to investigate whether there was any significant difference in angles between the three types of etiology. The criterion for determining significance was taken to be the level of 5%. The statistical analysis was processed using the SPSS version 17.0 statistical software.

Result

The intra and inter-observer reliability was assessed using the intraclass correlation coefficient (ICC), which ascertained whether there was any significant agreement in the measurements on the anteversion angle (AA) and inclination angle (AI) between the three evaluators (Obs 1, Obs 2 and Obs 3).

It is known that the closer the ICC is to one, the stronger (or more perfect) the agreement is between the observers. In this case, the observers would be similar regarding numerical (quantitative) values. On the other hand, the closer to zero (0) the ICC is, the greater the disagreement is, i.e. the values are not reproduced and the differences are not random.

Through a variety of studies and simulations, it can be said that:

$ICC \leq 0.20 \rightarrow$ no agreement
$0.20 < ICC \leq 0.40 \rightarrow$ weak agreement
$0.40 < ICC \leq 0.60 \rightarrow$ moderate agreement
$0.60 < ICC \leq 0.80 \rightarrow$ good agreement
$ICC > 0.80 \leq$ very good agreement (excellent)

When strong agreement (ICC > 0.80) predominates in a study, the 95% confidence interval (95% CI) of the ICC is used as a differential, i.e. a narrow interval expresses greater precision. On the other hand, a wide interval expresses low precision, which is thus less reliable.

Tables 4 to 6 show the ICC with its respective 95% CI and the descriptive level (p value) for each pair of observers. The anteversion and inclination angles were studied for the whole sample (n = 72) and separately according to the pathological condition: arthrosis (n = 48), hip fracture (n = 16) and aseptic necrosis (n = 8), respectively.

Among the 74 hips studied, there was highly significant intra and inter-observer agreement (p < 0.0001) in the measurements of the anteversion and inclination angles between the three evaluators. All the pairs of agreement were of excellent degree (ICC > 0.80).

It was observed that, in relation to the hips with arthrosis, there was highly significant intra and inter-observer agreement (p < 0.0001) in the measurements on the anteversion and inclination angles between the three evaluators. All the pairs of agreement were of excellent degree (ICC > 0.80).

Among the hips with fractures, there was highly significant intra and inter-observer agreement (p < 0.0001) in the measurements of the anteversion and inclination

Table 4 - Agreement analysis for the anteversion and inclination angles, for the total sample (n = 72).

Measurement	Analysis	Observers	ICC	95% CI	p value
Anteversion angle (AA)					
		Obs1 x Obs1	0.951	0.92 - 0.97	< 0.0001
	Intra-observer	Obs2 x Obs2	0.842	0.76 - 0.90	< 0.0001
		Obs3 x Obs3	0.860	0.79 - 0.91	< 0.0001
		Obs1 x Obs2	0.932	0.89 - 0.96	< 0.0001
	Inter-observer (measurement 1)	Obs1 x Obs3	0.944	0.91 - 0.97	< 0.0001
		Obs2 x Obs3	0.917	0.87 - 0.95	< 0.0001
		Obs1 x Obs2	0.901	0.85 - 0.94	< 0.0001
	Inter-observer (measurement 2)	Obs1 x Obs3	0.919	0.88 - 0.95	< 0.0001
			0.900	0.85 - 0.94	< 0.0001
Inclination angle (AI)					
		Obs1 x Obs1	0.956	0.93 - 0.97	< 0.0001
	Intra-observer	Obs2 x Obs2	0.917	0.87 - 0.95	< 0.0001
		Obs3 x Obs3	0.942	0.91 - 0.96	< 0.0001
		Obs1 x Obs2	0.942	0.91 - 0.96	< 0.0001
	Inter-observer (measurement 1)	Obs1 x Obs3	0.958	0.93 - 0.97	< 0.0001
		Obs2 x Obs3	0.936	0.90 - 0.96	< 0.0001
		Obs1 x Obs2	0.921	0.88 - 0.95	< 0.0001
	Inter-observer (measurement 2)	Obs1 x Obs3	0.946	0.92 - 0.97	< 0.0001
			0.911	0.86 - 0.94	< 0.0001

Source: Hospital Santa Teresa.
ICC: intraclass correlation coefficient; 95% CI: 95% confidence interval for the ICC; Obs: Observer.

Table 5 - Agreement analysis for the anteversion and inclination angles in the hips with arthrosis (n = 48).

Measurement	Analysis	Observers	ICC	95% CI	p value
Anteversion angle (AA)					
		Obs1 x Obs1	0.963	0.94 - 0.98	< 0.0001
	Intra-observer	Obs2 x Obs2	0.864	0.77 - 0.92	< 0.0001
		Obs3 x Obs3	0.860	0.76 - 0.92	< 0.0001
		Obs1 x Obs2	0.934	0.89 - 0.96	< 0.0001
	Inter-observer (measurement 1)	Obs1 x Obs3	0.946	0.91 - 0.97	< 0.0001
		Obs2 x Obs3	0.923	0.87 - 0.96	< 0.0001
		Obs1 x Obs2	0.902	0.83 - 0.94	< 0.0001
	Inter-observer (measurement 2)	Obs1 x Obs3	0.918	0.86 - 0.95	< 0.0001
			0.897	0.82 - 0.94	< 0.0001
Inclination angle (AI)					
		Obs1 x Obs1	0.946	0.91 - 0.97	< 0.0001
	Intra-observer	Obs2 x Obs2	0.900	0.83 - 0.94	< 0.0001
		Obs3 x Obs3	0.940	0.90 - 0.97	< 0.0001
		Obs1 x Obs2	0.929	0.88 - 0.96	< 0.0001
	Inter-observer (measurement 1)	Obs1 x Obs3	0.945	0.90 - 0.97	< 0.0001
		Obs2 x Obs3	0.928	0.88 - 0.96	< 0.0001
		Obs1 x Obs2	0.909	0.84 - 0.95	< 0.0001
	Inter-observer (measurement 2)	Obs1 x Obs3	0.937	0.89 - 0.96	< 0.0001
			0.898	0.83 - 0.94	< 0.0001

Source: Hospital Santa Teresa. ICC: intraclass correlation coefficient; 95% CI: 95% confidence interval for the ICC; Obs: Observer.

Table 6 - Agreement analysis for the anteversion and inclination angles in the fractured hips (n = 16).

Measurement	Analysis	Observers	ICC	95% CI	p value
Anteversion angle (AA)					
	Intra-observer	Obs1 x Obs1	0.903	0.75 - 0.97	< 0.0001
		Obs2 x Obs2	0.709	0.36 - 0.89	0.001
		Obs3 x Obs3	0.837	0.60 - 0.94	< 0.0001
	Inter-observer (measurement 1)	Obs1 x Obs2	0.915	0.78 - 0.97	< 0.0001
		Obs1 x Obs3	0.930	0.82 - 0.98	< 0.0001
		Obs2 x Obs3	0.863	0.66 - 0.95	< 0.0001
	Inter-observer (measurement 2)	Obs1 x Obs2	0.848	0.63 - 0.94	< 0.0001
		Obs1 x Obs3	0.902	0.75 - 0.96	< 0.0001
			0.882	0.70 - 0.96	< 0.0001
Inclination angle (AI)					
	Intra-observer	Obs1 x Obs1	0.957	0.88 - 0.99	< 0.0001
		Obs2 x Obs2	0.943	0.85 - 0.98	< 0.0001
		Obs3 x Obs3	0.946	0.86 - 0.98	< 0.0001
	Inter-observer (measurement 1)	Obs1 x Obs2	0.957	0.89 - 0.99	< 0.0001
		Obs1 x Obs3	0.981	0.95 - 0.99	< 0.0001
		Obs2 x Obs3	0.934	0.83 - 0.98	< 0.0001
	Inter-observer (measurement 2)	Obs1 x Obs2	0.935	0.83 - 0.98	< 0.0001
		Obs1 x Obs3	0.969	0.92 - 0.99	< 0.0001
			0.942	0.85 - 0.98	< 0.0001

Source: Hospital Santa Teresa. ICC: intraclass correlation coefficient; 95% CI: 95% confidence interval for the ICC; Obs: Observer.

angles between the three evaluators, except for the intra-observer agreement of Observer 2 for the anteversion angle (ICC = 0.709; p = 0.001). All the pairs of agreement were of excellent degree (ICC > 0.80), except for the intra-observer agreement of Observer 2. In addition, it was seen that the confidence intervals of the ICC for the measurements on the anteversion angle were wider (less precise) than those of the inclination angle.

We investigated whether there were any differences in the anteversion and inclination angles between the three etiologies (arthrosis, neck fracture and necrosis). Tables 7 and 8 show the mean, standard deviation (SD) and median of the anteversion and inclination angles, respectively, according to the etiology and the corresponding descriptive level (p value) for one-way ANOVA.[14] In this analysis, the mean from six evaluations on each angle was used as the comparison measurement.

It was observed that there was no significant difference at the 5% level, in the anteversion angle (p = 0.12) and inclination angle (p = 0.16), between the etiologies in this study sample.

Table 7 - Anteversion angle (in degrees) according to etiology.

Etiology	n	Mean ± SD	Median	p value [a]
Arthrosis	48	13.9 ± 7.5	12.9	
Fracture	16	11.7 ± 5.5	11.2	0.12
Necrosis	8	8.8 ± 4.6	9.0	
Total	72	12.9 ± 7.0	12.0	

Source: Hospital Santa Teresa.
SD: standard deviation; [a] one-way ANOVA.

Table 8 - Inclination angle (in degrees) according to etiology.

Etiology	n	Mean ± SD	Median	p value [a]
Arthrosis	48	44,1 ± 8,5	43,9	
Fracture	16	40,0 ± 7,6	39,8	0,16
Necrosis	8	40,2 ± 9,4	38,4	
Total	72	42,8 ± 8,5	41,8	

Source: Hospital Santa Teresa.
SD: standard deviation; [a] one-way ANOVA.

Discussion

Radiography is the most important means for making diagnoses after total hip arthroplasty. It is a low-cost examination and can be done in any hospital. While the inclination of the acetabulum can be measured by means of conventional radiographs, calculation of the anteversion still presents problems, and even more so when done in cases of different pathological conditions.

The methods described for evaluating anteversion involve complex mathematical and trigonometric equations for ellipses. McLaren[15] described anteversion as a function of a coefficient with minimum and maximum diameters of an ellipse. He prepared a reference table for each degree of anteversion. Visser et al.[7] described a complex trigonometric formula using a system of Cartesian coordinates on a projected ellipse. They did not record the efficiency of their methods.

Ghelman[16] used fluoroscopy by changing the direction of the X=ray ampulla from cephalic to caudal and observed the angle of the tube in the sagittal plane when the two halves of the ellipse were superimposed, which was when the X-rays were tangential to the opening of the acetabular dome. This author defined this process as the version angle. Schneider et al.[17] used a similar technique, but obtained several images until the wire circle of the acetabulum became tangential. These methods involved repeated irradiation, with greater cost and time.

Lewinnek et al.[13] proposed a safe radiographic range for the position of the acetabular dome with an anteversion of 15° (SD 10°) and abduction of 40° (SD 10°), but based only on nine dislocations. In order to prevent impact and dislocation, McCollum and Gray[18] determined that the safe range for the position of the dome was from 30° to 50° of abduction and 20° to 40° of horizontal flexion. Dorr and Wan[19] considered that poor positioning of the dome would be an anteversion of less than 15° or greater than 30° and an abduction angle greater than 55°. To obtain true anteversion values, they added 5° to the angle measured on the anteroposterior radiograph of the pelvis. Khan[20] radiographically graded the anteversion of acetabular components that exceeded 15° and considered that they were too vertical if the abduction angle exceeded 50°. Biedermann et al.[21] demonstrated that there was no safe range for the position of the acetabular component and that anteversion of 15° and inclination of 45° presented the least risk of dislocation when an anterolateral access was used. Paterno et al.[22] were unable to establish any association between the anteversion or inclination angle of the acetabular component and the risk of dislocation. Thus, they concluded that the importance of the inclination angle as a risk factor for dislocation might have been exaggerated in preliminary studies.

Ackland et al.[9] described a method using a mathematical formula for calculating the minor axis of the ellipse in order to avoid "unacceptable subjective human errors." They considered that it was too laborious to calculate each case through this formula and therefore used a computer program to make future estimates. They drew up a table to read the degrees of anteversion. However, the formula used was not shown. Hassan et al.[23] described a complex mathematical formula for evaluating planar anteversion and attested it through the intra-observer reliability. Pradhan[11] described a method based on the elementary geometry of circles and triangles, and developed a simple formula that could be used to determine the planar anteversion using a pocket calculator.

The results from different studies cannot be compared with each other because of the various definitions of anteversion that are used. Some authors have not used standard measurements or well-documented radiographic measurements, thus preventing precise measurement of the angling of the acetabular component.[21]

It was demonstrated in the present study that measurement of the anteversion and of the acetabular inclination angle, when the X-ray ampulla was correctly centered over the hip, and with use of the trigonometric formula, was highly accurate and easy to calculate and presented high reliability.

According to the literature, the inclination angle ranges from 33° to 50° and the anteversion angle from 15° to 30°. In this study, the mean inclination angle of the total sample was 43° and the mean anteversion angle was 13°. The mean anteversion angle in the hip arthrosis cases was 14°, in the hip fracture cases 12° and in the aseptic necrosis cases 9°. The mean inclination angle in the hip arthrosis cases was 43°, in the hip fracture cases 41° and in the aseptic necrosis cases 41°. Therefore, as demonstrated in the results, there was no significant variation in the inclination angle. However, regarding the anteversion angle, there was a tendency towards differences in angle between the different pathological conditions.

It was observed that the degree of agreement of measurements of anteversion and inclination angles between the three evaluators in the intra and inter-observer assessments was highly significant ($p < 0.0001$), in all three pathological conditions (hip arthrosis, femoral neck fracture and aseptic necrosis). All the agreement pairs were of excellent degree (ICC > 0.80), except for the intra-observer agreement for Observer 2 regarding the anteversion angle in hip fractures (ICC = 0.709; $p = 0.001$). In the present sample, there was no significant difference in anteversion angle ($p = 0.12$) and inclination angle ($p = 0.16$) between the etiologies. However, the major limitation of this study was the presence of only small numbers of patients with femoral neck fracture and aseptic necrosis. It is worth emphasizing that this method cannot be used in arthroplasty cases that use a metal back or surfaces other than polyethylene, and when the latter is used, it needs to be cemented and have a metal rim along the entire acetabular edge, in order to enable measurement.

Conclusion

Using conventional radiographs and a trigonometric formula, the method was shown to be highly accurate, easy to calculate and very reliable. There was no significant variation in the anteversion and inclination angles when compared with regard to hip arthrosis, aseptic necrosis and femoral neck fracture.

Conflicts of interest

The authors declare that there was no conflict of interests in conducting this study.

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