■ HIP

Reliability and validity of measuring version of the acetabular component

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A variety of radiological methods of measuring version of the acetabular component after total hip replacement (THR) have been described. The aim of this study was to evaluate the reliability and validity of six methods (those of Lewinnek; Widmer; Hassan et al; Ackland, Bourne and Uhthoff; Liaw et al; and Woo and Morrey) that are currently in use. In 36 consecutive patients who underwent THR, version of the acetabular component was measured by three independent examiners on plain radiographs using these six methods and compared with measurements using CT scans. The intra- and interobserver reliabilities of each measurement were estimated. All measurements on both radiographs and CT scans had excellent intra- and interobserver reliability and the results from each of the six methods correlated well with the CT measurements. However, measurements made using the methods of Widmer and of Ackland, Bourne and Uhthoff were significantly different from the CT measurements (both p < 0.001), whereas measurements made using the remaining four methods were similar to the CT measurements. With regard to reliability and convergent validity, we recommend the use of the methods described by Lewinnek, Hassan et al, Liaw et al and Woo and Morrey for measurement of version of the acetabular component.

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The orientation of the acetabular component in total hip replacement (THR) is defined by abduction, which is the angle between the face of the implant and the transverse axis; and version, which is the angle between the axis of the component and the coronal plane of the patient.[1-3] Whereas abduction can easily be measured on anteroposterior (AP) radiographs, version is more difficult to measure. Version of the acetabular component can be measured accurately using CT scans, and there are a variety of methods of measuring it on plain AP or cross-table lateral radiographs.[1-11] An ideal method should be both accurate and reproducible. Few studies have compared the reliability and validity of different methods of measuring version on plain radiographs.[12-14] The aim of this study was to compare six current methods of measurement.

Materials and Methods

This prospective study was approved by our institutional review board, and informed consent was obtained from the patients. A power study using a Bonett's approximation,[15] and an intraclass correlation coefficient (ICC) at a target value of 0.8 and 95% confidence interval (CI) of 0.2 indicated that 36 hips were required.

A total of 36 consecutive patients who underwent primary cementless THR between August and October 2010 were recruited. There were 19 men and 17 women with a mean age of 52.5 years (27 to 74) (Table I).

Image acquisition. Radiographs taken six weeks after THR were used to measure version of the acetabular component. All radiographs were taken in the same department using a standardised protocol. AP radiographs of the hip were obtained in the supine position at a source-to-film distance of 110 cm with the x-ray beam centred on the superior aspect of the pubic symphysis and perpendicular to the patient. Cross-table lateral radiographs were taken with the contralateral hip flexed at 90°. The direction of the x-ray beam was parallel to the examination table and 45° cephalad to the long axis of the body. The film was held perpendicular to the examination table using a cassette holder.[6,16] All images were digitally acquired using the Picture Archiving and Communication System (PACS) (Impax: Agfa, Antwerp, Belgium), and all measurements on radiographs were subsequently made on a 19 inch LCD monitor using PACS software.

CT scans were obtained three to seven days after THR with a 64-channel multi-detector CT system (Brilliance 64; Philips Medical

Table I. Summary of patients (THR, total hip replacement)

Characteristics	
Gender (male:female)	19:17
Mean age (yrs) (range)	52.5 (27 to 74)
Indication for THR (n, %)	
Osteonecrosis	26 (*72.2*)
Primary osteoarthritis	3 (*8.3*)
Secondary osteoarthritis	7 (*19.4*)

Systems, Best, The Netherlands). The standard acquisition protocols were as follows: for 64-channel MDCT a collimation of 0.625 mm was used; the field of view at acquisition was 30 cm; and slice thickness was 0.67 mm with 0.33 mm increments (50% section overlap). This high-resolution isotropic CT volume allowed image reformation in any desired plane without degradation of image quality.

Measurement of acetabular component version on plain radiographs. Version was measured using six currently used methods on plain radiographs,[1,2,5,6,8,9] as well as on CT scans. To avoid confusion before measuring the version, three consensus-building sessions were held by three orthopaedic surgeons (JHN, YCH and YKL), during which the definitions of each method of radiological measurement were identified and clarified.

Lewinnek's method. [2]

$$\text{Version} = \arcsin (D1 / D2)$$

D1 is the distance of the short axis of an ellipse drawn perpendicular to the long axis of the acetabular component; D2 is the distance of the long axis, which is considered the maximal diameter of the implant[2] (Fig. 1a).

Widmer's method. [17]

$$\text{Version} = \arcsin (\text{Short axis (S)} / \text{Total length (TL)})$$
$$= 48.05 \times (S / TL) - 0.3 \ (\text{if } 0.2 < S/TL < 0.6)$$

The short axis is the same distance as D1 above. Total length is the entire distance of the projected cross section of the acetabular component along the short axis (Fig. 2). This method shows linear correlation in the range of S / TL between 0.2 and 0.6. We used the second equation[6] (Fig. 1b).

Hassan et al's method. [8]

$$\text{Version} = \arcsin [(h/D) / \surd([m/D] - [m^2/D^2])]$$

In this method three measurements (*D*, *m* and *h*) should be made. *D* represents the maximum diameter of the acetabular component, *m* is the distance along *D* that is not obscured by the femoral head, and *h* is the length of the perpendicular dropped from the endpoint of the distance *m* to the acetabular rim[8] (Fig. 1c).

Ackland, Bourne and Uhthoff's method. [9]

$$\text{Version} = \arcsin [2y / 2\surd(2ax - x^2)]$$

Here, *a* is the distance of the long axis of the acetabular component (AC), *x* is the distance (AB) along the line AC. An arbitrary tangent is drawn at a right angle to the diameter, and *y* is the distance from the two-cup rims along this tangent (DE)[9] (Fig. 1d).

Liaw et al's method . [5]

$$\text{Version} = \sin^{-1} \tan \beta$$

This is a method that uses the β angle formed by the long axis of the component (AB) and the line connecting the top point of the ellipse and the end-point of the long axis (AC)[5] (Fig. 1e).

Woo and Morrey's method. [1] This method uses cross-table lateral radiographs to measure version of the component, whereas the other methods use AP radiographs. This method needs no equations and distinguishes between anteversion and retroversion. The angle is directly measured between a line perpendicular to the table and a line tangential to the opening face of the acetabular component. This angle is defined as anteversion from a cross-table lateral view[1,16] (Fig. 1f).

Measurement of acetabular version on CT scan. In this study, the following methods, which were modified from Murray's concept,[3] were used to measure acetabular version. The largest section of the acetabular component was selected in CT axial view. We then drew circles along the margin of the implant or of the acetabulum to set the true centre of both hips. We drew a first line connecting the centres of the two hips and a second line perpendicular to the first. Finally, we drew a third line from the most anterior point of the component to its most posterior point. We then measured the angle between the second and third lines and calculated the version. The version from CT scans was regarded as the reference standard for acetabular version[18] (Fig. 2).

Assessment of reliability and convergent validity. Reliability was defined as the consistency of the measurement. The six methods used to measure on plain radiographs were performed by three examiners (JHN, YCH and YKL) and each method independently used the same protocol.

The intra-observer reliability of each method was assessed using the values measured by one examiner (JHN), who performed the reassessment three weeks later.[19] The inter-observer reliability of each method was assessed by the same three examiners. All measurements were made without any knowledge of the patient's clinical information or the findings of the other examiners. The radiographs and scans were presented to each examiner in random order by a research assistant who did not participate in the reliability sessions.

Convergent validity was defined as proximity to the reference standard. It was assessed for each method by comparing the means of each method and means on CT scans. Correlations between the measurements on radiographs and those on CT scans were also analysed.

Statistical analysis. The ICCs and their 95% CIs were used to summarise the interobserver reliability in a single measurement. The ability of a test to show intra- and inter-observer reliability was evaluated using the two-way random effects model assuming a single measurement and absolute agreement. An ICC of 1 means perfect reliability and an ICC of 0 means the opposite.

To determine the convergent validity of each method on radiographs with the CT measurements, paired *t*-tests and

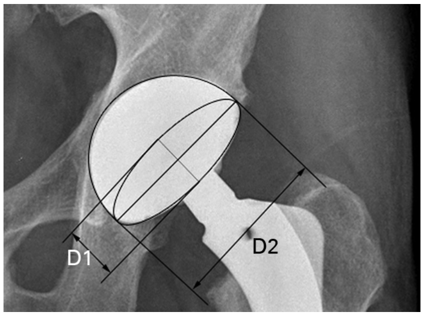

Fig. 1a

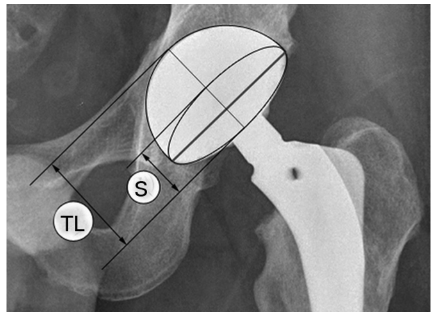

Fig. 1b

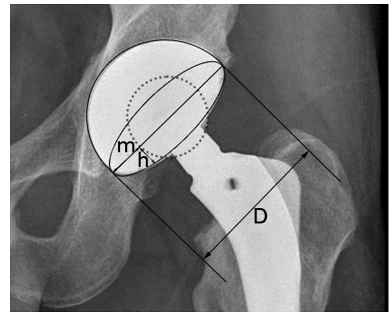

Fig. 1c

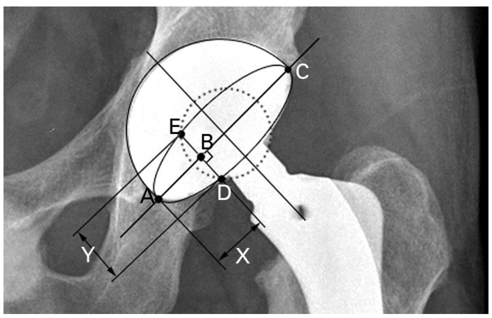

Fig. 1d

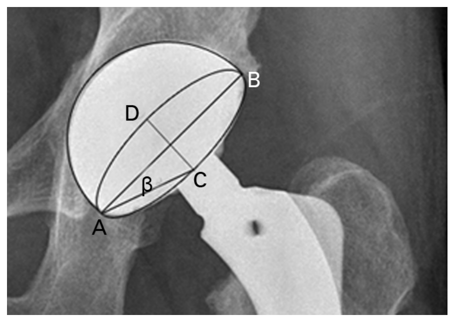

Fig. 1e

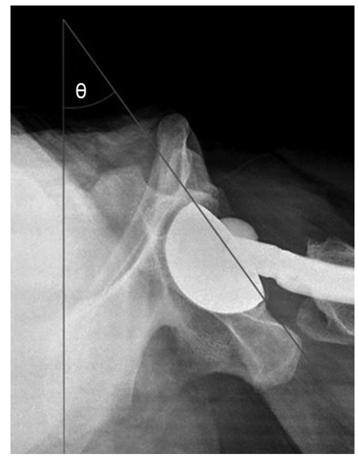

Fig. 1f

Assessment parameters for measuring version on plain radiography, using a) Lewinnek's method,[2] b) Widmer's method,[17] c) Hassan et al's method,[8] d) Ackland, Bourne and Uhthoff's method,[9] e) Liaw et al's method for anteroposterior radiographs,[5] and f) Woo and Morrey's method for cross-table lateral radiographs.[1]

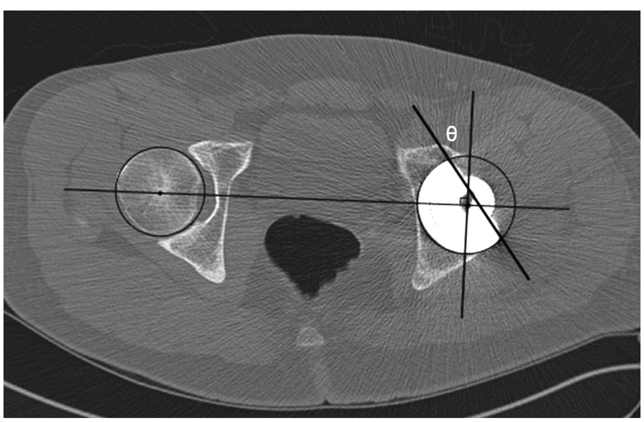

Fig. 2

Assessment parameters for measuring version on CT scans.

Pearson's correlation coefficients were used. Pearson's correlation coefficient was characterised as poor (0.00 to 0.20), fair (0.21 to 0.40), moderate (0.41 to 0.60), good (0.61 to 0.80) or excellent (0.81 to 1.00).

Statistical analyses were conducted using SPSS for Windows version 15.0 (SPSS Inc., Chicago, Illinois) and statistical significance was set at $p < 0.05$.

Results

Reliability. In all six radiological measurements the intra- and interobserver reliabilities were > 0.90. Those of CT measurements were 0.954 (95% CI 0.909 to 0.976) and 0.982 (95% CI 0.970 to 0.990) (Table II).

Convergent validity. The radiological measurements of all six methods showed good positive correlations with the CT measurements.

Whereas measurements made using Lewinnek's method,[2] Hassan et al's method,[8] Liaw et al's method[5] and Woo and Morrey's method[1] were similar to the CT measurements, those made by Widmer's method[17] and those by Ackland, Bourne and Uhthoff's method[9] were significantly different from the CT measurements (both $p < 0.001$, paired *t*-test) (Table III).

Discussion

The version and the inclination of the acetabular component in THR are crucial for movement and stability and to reduce wear.[1,2,4,20] The ideal version remains controversial.

Table II. Intra- and interobserver reliability of measurements on CT and radiography (ICC, intraclass correlation coefficient; CI, confidence interval)

	Intra-observer reliability		Inter-observer reliability	
	ICC	95% CI	ICC	95% CI
CT	0.954	0.909 to 0.976	0.982	0.970 to 0.990
Lewinnek[2]	0.938	0.864 to 0.970	0.943	0.907 to 0.968
Widmer[17]	0.920	0.866 to 0.956	0.961	0.940 to 0.975
Hassan et al[8]	0.893	0.746 to 0.950	0.936	0.892 to 0.964
Ackland, Bourne and Uhthoff[9]	0.914	0.817 to 0.958	0.865	0.747 to 0.930
Liaw et al[5]	0.915	0.834 to 0.957	0.929	0.884 to 0.960
Woo and Morrey[1]	0.993	0.986 to 0.996	0.955	0.926 to 0.974

Table III. Validity of three examiners' mean (standard deviation, SD) measurements of each method compared with the mean CT measurement using Pearson's correlation coefficient and paired *t*-tests

	Mean (SD) anteversion (°)	p-value	Correlation coefficient	p-value
CT	26.80 (7.85)			
Lewinnek[2]	26.90 (6.19)	0.901	0.788	< 0.001
Widmer[17]	19.14 (3.32)	< 0.001	0.786	< 0.001
Hassan et al[8]	26.11 (5.26)	0.425	0.764	< 0.001
Ackland, Bourne and Uhthoff[9]	15.66 (3.53)	< 0.001	0.763	< 0.001
Liaw et al[5]	28.48 (6.25)	0.058	0.763	< 0.001
Woo and Morrey[1]	28.08 (6.27)	0.171	0.721	< 0.001

Charnley[21] recommended no anteversion, but most studies recommend between 5° and 30° of anteversion.[2,22-24]

Various methods have been developed to measure version of the acetabular component, using radiographs, fluoroscopy or CT scans.[25,26] Fluoroscopic methods involve time and radiation and CT measurements are expensive and involve a considerable amount of radiation. Accordingly, radiological methods are widely used even though they require complicated calculations or the use of conversion tables. However, only a few studies have assessed the reproducibility and accuracy of radiological methods.[12-14]

We used version measured on CT[18,27] as the reference standard, rather than anatomical version, which is practically unmeasurable. Previous studies have shown that version of the acetabular component could be measured accurately using CT scans.[3,18,27]

Our study shows four radiological methods, Lewinnek's,[2] Hassan et al's[8] and Liaw et al's,[5] which use AP radiographs, and Woo and Morrey's,[1] which requires cross-table lateral radiographs, to be reliable and valid for measuring anteversion.

However, the three measurements on AP radiographs have some limitations that should be addressed. First, retroversion cannot be detected on AP radiographs. To differentiate between ante- and retroversion, additional oblique or cross-table lateral radiographs are required.[9] Secondly, it is difficult to identify the apex of the ellipse on AP radiographs when a ceramic or metal liner is used and when the implant is excessively anteverted.[8] When a cemented ultra-high molecular-weight polyethylene acetabular component, with a radio-opaque circumferential wire, is used, it is easy to identify the apex of the ellipse in AP radiographs.[2,4,9]

It is easy to measure acetabular anteversion using Woo and Morrey's method[1] because it requires no equations or conversion tables. This method can also differentiate ante- and retroversion. It is widely used because it is convenient and fast, and is also safer and more economical than CT. However, it is inaccurate when the pelvis is tilted and when the contralateral hip joint or the lumbar spine is stiff.[16]

We could not explain why Widmer's method[17] and Ackland, Bourne and Uhthoff's method[9] appeared inaccurate in our study. These two methods use linear regression to approximate the complicated non-linear relationship, which might have resulted in an inaccuracy, as previous studies have pointed out.[5,6,28]

Despite their problems, these four methods of measurement using plain radiographs seem to be reproducible and accurate.

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References

1. **Woo RY, Morrey BF.** Dislocations after total hip arthroplasty. *J Bone Joint Surg [Am]* 1982;64-A:1295–1306.
2. **Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR.** Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg [Am]* 1978;60-A:217–220.
3. **Murray DW.** The definition and measurement of acetabular orientation. *J Bone Joint Surg [Br]* 1993;75-B:228–232.
4. **McLaren RH.** Prosthetic hip angulation. *Radiology* 1973;107:705–706.
5. **Liaw CK, Hou SM, Yang RS, Wu TY, Fuh CS.** A new tool for measuring cup orientation in total hip arthroplasties from plain radiographs. *Clin Orthop* 2006;451:134–139.

6. **Widmer KH.** A simplified method to determine acetabular cup anteversion from plain radiographs. *J Arthroplasty* 2004;19:387–390.

7. **Pradhan R.** Planar anteversion of the acetabular cup as determined from plain anteroposterior radiographs. *J Bone Joint Surg [Br]* 1999;81-B:431–435.

8. **Hassan DM, Johnston GH, Dust WN, Watson LG, Cassidy D.** Radiographic calculation of anteversion in acetabular prostheses. *J Arthroplasty* 1995;10:369–372.

9. **Ackland MK, Bourne WB, Uhthoff HK.** Anteversion of the acetabular cup: measurement of angle after total hip replacement. *J Bone Joint Surg [Br]* 1986;68-B:409–413.

10. **Pettersson H, Gentz CF, Lindberg HO, Carlsson AS.** Radiologic evaluation of the position of the acetabular component of the total hip prosthesis. *Acta Radiol Diagn (Stockh)* 1982;23:259–263.

11. **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:556–559.

12. **Ghelman B, Kepler CK, Lyman S, Della Valle AG.** CT outperforms radiography for determination of acetabular cup version after THA. *Clin Orthop* 2009;467:2362–2370.

13. **Penney GP, Edwards PJ, Hipwell JH, et al.** Postoperative calculation of acetabular cup position using 2-D-3-D registration. *IEEE Trans Biomed Eng* 2007;54:1342–1348.

14. **Marx A, von Knoch M, Pförtner J, Wiese M, Saxler G.** Misinterpretation of cup anteversion in total hip arthroplasty using planar radiography. *Arch Orthop Trauma Surg* 2006;126:487–492.

15. **Bonett DG.** Sample size requirements for estimating intraclass correlations with desired precision. *Stat Med* 2002;21:1331–1335.

16. **Arai N, Nakamura S, Matsushita T.** Difference between 2 measurement methods of version angles of the acetabular component. *J Arthroplasty* 2007;22:715–720.

17. **Widmer KH, Grützner PA.** Joint replacement-total hip replacement with CT-based navigation. *Injury* 2004;35(Suppl 1):84–89.

18. **Olivecrona H, Weidenhielm L, Olivecrona L, et al.** A new CT method for measuring cup orientation after total hip arthroplasty: a study of 10 patients. *Acta Orthop Scand* 2004;75:252–260.

19. **McKelvie SJ.** Does memory contaminate test-retest reliability? *J Gen Psychol* 1992;119:59–72.

20. **Ritter MA.** Dislocation and subluxation of the total hip replacement. *Clin Orthop* 1976;121:92–94.

21. **Charnley J.** Total hip replacement by low-friction arthroplasty. *Clin Orthop* 1970;72:7–21.

22. **Coventry MB.** Late dislocations in patients with Charnley total hip arthroplasty. *J Bone Joint Surg [Am]* 1985;67-A:832–841.

23. **Harris WH.** Advances in surgical technique for total hip replacement: without and with osteotomy of the greater trochanter. *Clin Orthop* 1980;146:188–204.

24. **Seki M, Yuasa N, Ohkuni K.** Analysis of optimal range of socket orientations in total hip arthroplasty with use of computer-aided design simulation. *J Orthop Res* 1998;16:513–517.

25. **Ghelman B.** Three methods for determining anteversion and retroversion of a total hip prosthesis. *AJR Am J Roentgenol* 1979;133:1127–1134.

26. **Gore DR, Murray MP, Gardner GM, Sepic SB.** Roentgenographic measurements after Muller total hip replacement: correlations among roentgenographic measurements and hip strength and mobility. *J Bone Joint Surg [Am]* 1977;59-A:948–953.

27. **Di Schino M, Baudart F, Zilber S, Poignard A, Allain J.** Anterior dislocation of a total hip replacement: radiographic and CT-scan assessment: behavior following conservative management. *Orthop Traumatol Surg Res* 2009;95:573–578.

28. **Liaw CK, Yang RS, Hou SM, Wu TY, Fuh CS.** Measurement of the acetabular cup anteversion on simulated radiographs. *J Arthroplasty* 2009;24:468–474.