Measurement of the Acetabular Cup Anteversion on Simulated Radiographs

Chen-Kun Liaw, MD,*† [1] Rong-Sen Yang, MD, PhD,‡ [1]
Sheng-Mou Hou, MD, PhD, MPH,‡ Tai-Yin Wu, MD,§ and Chiou-Shann Fuh, PhD†

Abstract: Widmer (J Arthroplasty 2004;19:387) reported a protractor for measuring the anteversion of acetabular cups on radiographs but with limited precision. We intended to improve its precision by trigonometric mathematics. We measured the anteversion of the acetabular cups on 336 simulated radiographs using aforementioned 2 methods. The anteversion measured by Widmer's protractor ranged from 7° to 41° (mean ± SD = 28.0° ± 9.8°), and our methods, 5° to 51° (27.7° ± 13.2°). The mean ± SD of error by Widmer's protractor was 5.2 ± 2.5°, and our protractor, 0.8° ± 0.8° (Student t test, $P < .0001$). The interobserver study showed the difference between measurements less than 2° for each method. Therefore, the smaller error of our method than that of Widmer implicated a potentially precise measurement of the anteversion (level of evidence: diagnostic study, level II). **Key words:** hip arthroplasty, acetabulum, anteversion, protractor.

The anteversion of acetabulum is important for function after total hip arthroplasty. It is linked to stem anteversion and functional range of motion in the hip with intra and extraarticular impingement and their respective effects on wear, impingement, and instability. Previously reported methods can be classified into 3 groups, the computed tomographic methods [1,2], the trigonometric methods [3-8,13], and the protractor methods [9-11]. Olivecrona et al [2] measured the orientation of the acetabular cups on the computed tomographic images in 10 patients. Their results showed that the anteversion angles ranged from 0° to 52°, with an error of 2.9°, whereas the inclination angle ranged from 30° to 65° with an error of 1.5°.

With trigonometric method, the anteversion angles of the acetabular cups were measured using calculation equations (Appendix A). Liaw et al [10] applied this trigonometric method to measure the anteversion of the acetabular cups and got the mean ± SD of error with 1.2° ± 0.57°. In addition, Liaw et al used his own protractor method to get the mean ± SD of the error of 0.96° ± 0.74°. These protractor methods are more convenient than the others since they do not require a calculator or computer.

Furthermore, Liaw et al [10] incorporated the inverse trigonometric function into his own protractor. Practically, the most common disadvantages are to find the ends of long axis and short axis (S). Fabeck [9] applied direct measurement using a protractor that was designed without any incorporation of trigonometric function. However, the examiner usually has difficulty in following the long arc of the circles during the measurement. Widmer [11] invented his own

*From the *Department of Orthopaedics, Tao-Yuan General Hospital, Taoyuan, Taiwan ROC; †Institute of Computer Science and Information Engineering, National Taiwan University, Taipei, Taiwan ROC; ‡Department of Orthopaedics, College of Medicine, National Taiwan University and Hospital, Taipei, Taiwan ROC; and §Taipei City Hospital, Renai Branch, Taipei City, Taiwan ROC.*

[1] Chen-Kun Liaw and Rong-Sen Yang contributed equally to this work.

Submitted May 5, 2007; accepted October 28, 2007.

This study was supported by the grant NSC96-2320-B-087-001, Taiwan, ROC.

Reprint requests: Chiou-Shann Fuh, PhD, Department of Computer Science and Information Engineering, National Taiwan University, Taipei 106, Taiwan ROC.

0883-5403/07/2403-0020$36.00/0
doi:10.1016/j.arth.2007.10.029

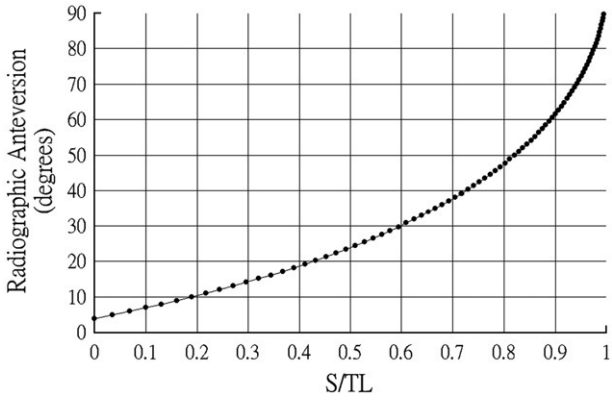

Fig. 1. The relationship between *S*/TL ratio and radiographic anteversion. This figure is derived from Eqs. (1) and (2), and the inclination angle is 45°.

protractor through his linear regression equation. The user can apply for direct measurement without the need of finding the ends of the long axis first. Widmer [11] mentioned that the only disadvantage is its imprecision that was due to oblique radiographic projection on various acetabulum abduction angles and the adoption of a linear regression equation. He did not recommend the usage of his own protractor if highly precise measurements are needed.

The study aims to investigate the relationship curve mathematically and to eliminate the error caused by oblique projection. The measured angles and the precision error will be compared with those of the results of Widmer [11].

Materials and Methods

At the given distance of 105 cm from x-ray tubes to subjects, Widmer [11] found a relationship between anteversion and the short axis and the total length (TL) of the projected cross-section of the cup along the short axis by linear regression [anteversion = 48.5 × (*S*/TL) − 0.3].

In our methods, we investigated the mathematical relationship between radiographic version β and *S*/TL ratio is shown in Eq. (1). The detailed deduction process was shown in Appendix A.

$$\beta = \sin^{-1}(S/l) = \sin^{-1}((S/TL - ratio)/(2 - (S/TL - ratio))) \quad (1)$$

To eliminate the error caused by oblique projection, we applied the Eq. (2). The detailed deduction process was shown in Appendix B.

$$\beta = \tan^{-1}(\tan(\tan^{-1}(\tan(\sin^{-1}((S/TL - ratio)/(2 - /TL - ratio))))\csc\gamma) + 5.46^{\circ})\sin\gamma) \quad (2)$$

Through Eq. 2, we reproduced the results of Widmer [11], which are shown in Fig. 1 and Table 1. The results were quite the same as the data shown by Widmer.

We further used the mathematic model to calculate the error of the Widmer [11] linear regression equation (Fig. 2) and improved the precision by the following 2 methods.

First, we applied the protractor on the hip-centered radiographs that eliminated the error caused by oblique projection. If we used the radiograph centered on the symphysis pubis for measurement, we corrected by Eq. (2).

Second, we improved the precision by a mathematic model. The method of Widmer [11] used linear regression method to approximate the curve. The precision was good in linear region of the whole curve but bad in the non-linear region. The

Table 1. The Relationship Between *S*/TL and Anteversion in Different Inclinations

Radiographic cup anteversion				
	Cup inclination			
S/TL	40°	45°	50°	55°
0	3.51587	3.866659	4.187843	4.477031
0.04	4.693584	5.04297	5.362842	5.650818
0.07	5.612107	5.959745	6.278064	6.56466
0.11	6.887252	7.231518	7.546915	7.830973
0.14	7.884051	8.224921	8.53742	8.818993
0.17	8.917967	9.254613	9.563543	9.842082
0.2	9.991429	10.32294	10.62757	10.90247
0.23	11.1071	11.43248	11.73199	12.0026
0.26	12.26792	12.58607	12.87957	13.14515
0.29	13.47711	13.78681	14.07333	14.33309
0.31	14.31186	14.61519	14.89646	15.15187
0.34	15.6098	15.90238	16.17482	16.4229
0.36	16.50749	16.79204	17.05789	17.30053
0.39	17.90606	18.17715	18.43199	18.66555
0.41	18.87536	19.13645	19.38314	19.60998
0.43	19.87613	20.12635	20.36418	20.58374
0.46	21.44033	21.67245	21.89557	22.10306
0.48	22.5281	22.74687	22.95917	23.15779
0.5	23.65447	23.85878	24.05936	24.2484
0.52	24.8219	25.01055	25.19848	25.37717
0.54	26.0331	26.20483	26.37909	26.54662
0.56	27.29106	27.44451	27.60403	27.75954
0.58	28.5991	28.73282	28.87644	29.01901
0.6	29.9609	30.07333	30.19982	30.32845
0.62	31.38057	31.47005	31.57809	31.69174
0.63	32.11352	32.19087	32.28916	32.3949
0.65	33.6288	33.6805	33.75821	33.84723
0.67	35.21463	35.23872	35.29429	35.36536
0.68	36.03593	36.04545	36.08934	36.15094
0.7	37.73971	37.71844	37.73767	37.77929
0.71	38.62412	38.58662	38.59284	38.62393
0.73	40.4635	40.39172	40.37051	40.37939
0.74	41.42091	41.33107	41.2954	41.29258

By Eqs. (1) and (2), the relationship between S/TL ratio and anteversion is shown. These results are similar to the report of Widmer [11].