

Ellipse method for measuring Liaw's anteversion of the acetabular component after total hip arthroplasty

Kuei-Lin Yeh

Shin Kong Wu Ho Su Memorial Hospital

Tai-Yin Wu

Taipei City Hospital Zhongxiao Branch

Hsuan-Hsiao Ma

Taipei Veterans General Hospital

Sheng-Mou Hou

Shin Kong Wu Ho-Su Memorial Hospital

Chen-Kun Liaw (✉ d92008@yahoo.com.tw)

Taipei Medical University Shuang Ho Hospital

Research article

Keywords: anteversion measurement, ellipse method, total hip arthroplasty, Liaw's anteversion

Posted Date: June 16th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-35273/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published on October 8th, 2020. See the published version at <https://doi.org/10.1186/s12891-020-03669-5>.

Abstract

Background: Several cup anteversion measurements for post-operative total hip arthroplasty (THA) surgery have been described. We developed the standardized Liaw's trigonometric method to eliminate the influence of patient position, which is the most accurate method for cup anteversion measurement. We then developed an ellipse method using the Elliversion software and reported an interobserver error reduction in 2013. In our study, we attempted to apply this ellipse method in the clinic and compared its accuracy with the standard trigonometric version.

Methods: In the present study, we attempted to incorporate the ellipse method with Liaw's standardized anteversion in the simulated cup position. We measured standardized Liaw's anteversion for 434 radiographs in the clinic using the ellipse method. The Repeatedly Standard Deviation (RSD) was applied for accuracy evaluation. Furthermore, paired t-test was used for comparison with the interobserver and intraobserver errors.

Results: We found that the standardized Liaw's anteversion measured using the ellipse method showed lower repeated standard deviation than the radiographic version. RSD was 0.795 in the standardized Liaw's anteversion with ellipse method group. The p-values of the paired t-test were all higher than 0.05 when measuring the interobserver and intraobserver bias. It indicated that the ellipse method was a precise and simple tool for cup anteversion measurement.

Conclusion: We believe that this ellipse measurement can assist surgeons while placing the acetabulum cup into the precise position and enable early diagnosis of acetabulum loosening.

Background

Total hip arthroplasty (THA) is the definitive treatment for patients with end-stage hip osteoarthritis, femoral head avascular necrosis, and hip joint destruction from rheumatic arthritis or trauma [1]. With today's aging society, primary and revision THA surgeries are expected to increase over the next 20 years [2]. Implant stability and cup loosening will affect a large number of patients. Development of a precise measure to detect small changes in acetabular version would aid in early detection of cup loosening [3].

Proper cup orientation plays an important role in THA longevity, range of motion (ROM), and rate of dislocation [4, 5]. Abduction and anteversion are two important factors that determine orientation. The abduction angle is measured at the intersection of a line drawn along the long axis of the cup with a line drawn through the horizontal line of the pelvis. Cup anteversion can be measured in several different ways, including Fabeck's method, Pradhan's method, Widmer's method and Liaw's trigonometric method [6]. In addition, commercially available software such as OrthoView and TraumaCad are capable of measuring acetabular version; however, their application is often impractical due to high cost.

Computed tomography (CT) can also be used to measure cup anteversion [7]. However, due to the cost, radiation exposure, and low resolution obtained with CT [8], this method is seldom used to monitor cup

positioning after THA in most hospitals, including ours. Plain pelvic radiography is generally considered a more practical, low-cost, and low radiation-exposure method. The accuracy of radiography-based methods largely depends on patient positioning during radiograph acquisition, unlike CT-assisted methods. Therefore, we developed Liaw's trigonometric method to minimize the effect of patient positioning by accounting for variations in pelvic tilt, pelvic rotation, and component inclination; its high accuracy was also validated [9].

When viewing post-THA radiographs, the cup implant is obscured by the femoral head in most cases, which causes interobserver error. Therefore, we developed the ellipse method in 2013 to measure acetabular anteversion [10]. In this study, we used the ellipse method to measure Liaw's anteversion in a clinical setting and compared its accuracy with the standard trigonometric version. Our goal is to create a simple, reliable, and accurate method to precisely measure anteversion to aid in surgical decision-making regarding appropriate timing of THA revision.

Methods

Subjects

All pelvic radiographs from patients who underwent THA in Shin-Kong Wu Ho-Su Hospital Hospital were retrospectively reviewed from September 2016 to September 2018. Exclusion criteria included poor quality radiographs (e.g., unclear pubic symphysis, teardrop, or sacrococcygeal junction), lack of at least two pelvic radiographs, obvious prosthetic cup loosening, history of cup loosening history, and previous revision THA surgery. This study was approved by the institutional review board of Shin-Kong Hospital, Taiwan (number 20181005R, Approval date: 2018/11/08).

Anatomic landmarks on radiographic images

With the ellipse method, radiographic landmarks play an important role and include the pubic symphysis, tear drop, and sacrococcygeal junction. The vector from the center of the sacrococcygeal junction to the upper pole of the symphysis pubis in the midline determines the radiographic pelvic axis. The line drawn through the bilateral teardrops is defined as the trans-teardrop line.

Anteversion equation

Both radiographic anteversion and Liaw's trigonometric anteversion were calculated for each patient in this study. Radiographic anteversion was defined by the equation of McLaren [11]:

Anteversion = $\arcsin(\text{short axis}/\text{long axis})$

Liaw's anteversion was defined as follows:

Anteversion = $\arcsin(\tan \beta_p)$

The angle β_p is the angle between a vector connecting the endpoints of the major and minor axes and the major axis of the component (Figure 1).

The standardized Liaw's trigonometric method was defined as follows: (see Equation 1 in the Supplementary Files)

In this equation, ssd is defined as the length from the upper pole of the symphysis pubis to the sacrococcygeal junction; h represents the horizontal displacement of the sacrococcygeal junction related to the upper pole of the symphysis pubis. The h is positive if the sacrococcygeal junction is between the acetabulum and the upper pole of symphysis pubis; otherwise, it is negative. The vertical displacement of the sacrococcygeal junction related to the upper pole of the symphysis pubis is defined as v . Similar to h , if the sacrococcygeal junction is above the upper pole of the symphysis pubis, v is positive. The u represents the radiographic (planar) anteversion angle. The inclination (abduction) angle is defined as w [9].

Software

Elliversion software was used to measure anteversion from Digital Imaging and Communications in Medicine files imported from our picture archiving and communication system (PACS). The software allows the user to apply an ellipse to the acetabulum and adjust it by altering the long and short axes. Since the curves cannot be drawn directly, the ellipse is separated into 64 parts (i.e., the ellipse is formed by 64 lines, and drawn as a 64-sided polygon). The endpoint of each line is calculated by the position and length of the long and short axes.

The entire ellipse was drawn by adapting the major axis and minor axis to match the ellipse with the cup implant image. In addition, the trans-teardrop line and the pelvic axis were drawn, followed by calculation of both radiographic and Liaw's anteversion (Figure 2).

Statistical analysis

Repeated standard deviation was used to compare radiographic and Liaw's anteversion. Lower RSD corresponds to greater precision. RSD was calculated using the following equation: (see Equation 2 in the Supplementary Files)

X_{ij} represents the result of the j th patient and the i th radiographic measurement. X_j represents the mean result of the j th patient and n_j represents the total number of measurements of the j th patient.

All anteversion measurements for each patient were performed by two different observers. The paired t -test was used to analyze inter- and intraobserver measurement differences. Statistical analysis was performed using SPSS software, version 1.0.0.1174 (IBM Corp., Armonk, NY, USA).

Results

We analyzed 434 radiographic images from 105 postoperative THA hips in 82 patients (53 female, 29 male; age range: 28–86 years). Of the 82 patients, 23 underwent bilateral THA. Tonnis grade II or III hip osteoarthritis was the indication for surgery in 54 patients; 28 underwent surgery for Ficat stage III or IV avascular necrosis of the femoral head.

The RSDs of the radiographic and Liaw's anteversion measurements were 1.802° and 0.795°, respectively (Table 1). Thus, Liaw's anteversion seems to be more precise. There were no significant interobserver differences in the standardized Liaw's anteversion measurement group ($p = 0.325$) or radiographic anteversion group ($p = 0.644$). Intraobserver differences in each group were not significant either ($p = 0.488$ and $p = 0.502$, respectively).

Table 1
Repeated standard deviation of the anteversion methods of measurement

	RSD
Standardized Liaw's anteversion using the ellipse method	0.795
*Standardized Liaw's anteversion without the ellipse method	0.99
Radiographic anteversion using the ellipse method	1.802
*data from our previous 2008 study [9]	

RSD, repeated standard deviation

Discussion

Long-term outcome of THA is closely related to the orientation of the implanted cup. Cup movement and malpositioning can cause impingement, dislocation, limited ROM, and increased polyethylene wearing post-operatively [12–15]. Plain radiographs are widely used for clinical follow-up and assessment of cup angular position. They are practical for clinical use due to low cost and minimal radiation exposure. Anteversion and inclination are relevant measurements that evaluate cup position. Although cup inclination is easily measured, anteversion can be difficult to ascertain from pelvic radiographs.

For some orthopedic surgeons, the clinical value of precisely measuring acetabular anteversion is doubtful. However, precise measurements can detect small but significant cup movement and possibly minimize the incidence of cup loosening and prosthetic hip dislocation. Until recently, there has been no precise cup anteversion measurement; in addition, the optimal anteversion angle remains controversial. Although a previous study claimed that there is no absolute ideal anteversion angle, most surgeons recommend between 5° and 30° [16]. Another important factor related to THA revision is change in

acetabular component orientation [17, 18]. For accurate evaluation of acetabular anteversion, CT examination or cross-table lateral radiography is required.

Several previous studies have reported that implanted cup measurements can be calculated using CT or plain radiography [19, 20]. The CT-assisted method is recommended to measure cup orientation due to its good inter- and intraobserver reliability [8]. In addition, it has a high level of precision regardless of patient positioning during image acquisition [21]. However, practicality in clinical use is an issue due to its high cost and level of radiation exposure. Radiation exposure is 16.7 times higher for pelvic CT (10 mSV) than pelvic radiography (0.6 mSV); in addition, the cost is 13.3 times higher (pelvic x-ray, NT450, about \$14.7 USD; pelvic CT, NT6000, about \$196.5 USD, 2019 Taiwan Health Insurance) (<http://www.nhi.gov.tw>). Thus, the benefit of plain radiography over CT is obvious [21]. After THA, we routinely follow plain pelvic radiographs longitudinally and compare the films over time. Radiographs are readily available, consistent, reproducible, economical, quick, and easy to interpret [22].

Cup anteversion is difficult to measure for several reasons. Patient positioning during film acquisition affects the measurement due to variations in pelvic tilt, pelvic rotation, and component inclination. Accuracy depends on using standardized patient positions. Additionally, due to recent advances in prosthetic materials, there are many different types of liners, such as ceramic, metallic, and polyethylene. Presence of a ceramic or metal liner may cause difficulty in measuring the edge of the acetabular component. Nonetheless, there are numerous methods of measurement [3, 6, 23]. Some studies have determined anteversion angle with fluoroscopy or multiple radiographs. The reliability and accuracy of these various radiological methods have not been studied in depth and previous studies have shown conflicting results [5, 24, 25]. However, Liaw's method currently has the smallest error rate [3, 26]. In this study, RSD was lower for Liaw's method than the radiographic method, indicating better accuracy.

In our previous study, the RSD of Liaw's anteversion without using the ellipse method was 0.99° [9]. In this study, we used the ellipse method and found that the RSD was 0.795° , an even better precision, indicating better accuracy obtained using the ellipse method. In addition, two times of RSD represented the meaningful and significantly different data within the 95% confidential interval. Thus, once the anteversion we measured is 1.59° different from average anteversion on serial pelvic radiographs, it indicates significant change in cup anteversion. Detecting small changes in anteversion on plain radiographs can help alert regarding cup loosening.

In recent studies, an increasing number of computer-assisted orthopedic systems to guide placement of prosthetic components in THA have been described [27]. Imageless navigation was developed in 2006 and has proved to be as reliable as CT-assisted navigation for positioning the acetabular component. However, previous navigation system studies have only focused on position of the implanted cup during implantation. Postoperative position has not been studied due to lack of an accurate method to detect small amounts of cup movement. However, precise position measurement can be performed now and it is time to re-evaluate its importance. In addition, our results showed no significant interobserver and

intraobserver differences for standardized Liaw's anteversion measurements. Our findings indicate reliability, simplicity, and precision of the ellipse method

Some researchers may question why we merely compared Liaw's method with the radiographic version instead of other anteversion measurements. The reason is that only the standardized Liaw's anteversion measurement corrects for patient positioning during film acquisition. Without standardizing, the accuracy of measurement is similar. Thus, we chose radiographic anteversion as defined by McLaren as the comparison [11].

The accuracy of our method for measuring anteversion has been doubted in several previous studies which found a mean anteversion difference of 4.1° between Liaw's method and CT measurement ($p < 0.001$) [5]. In some cases, a ceramic or metal liner was used, which causes the acetabular component border to appear ambiguous and cup identification difficult on radiographs; thus, defining the apex of the ellipse was difficult. If the border of the implanted cup on radiography is not clear, anteversion cannot be accurately measured by Liaw's method; however, the ellipse method corrects this shortcoming.

Though the ellipse method seems to be impeccable, there are some limitations. A high quality pelvic anteroposterior radiograph is required. In addition, the images should have clear delineation of the pubic symphysis, sacrococcygeal junction, as well as the teardrops bilaterally. If these anatomic landmarks are not clearly visible, the ellipse method cannot be used.

In conclusion, the standardized Liaw's anteversion measurement using the ellipse method is the most precise anteversion measurement to date. The method is simple, reliable, and precise. Change in anteversion $> 1.59^\circ$ on serial pelvic radiography indicates cup movement and allows detection of early cup loosening. Widespread clinical use of Liaw's method is warranted.

Declarations

Declarations

Ethics approval and consent to participate

This study was approved by the institutional review board of Shin-Kong Wu Ho-Su Hospital, Taiwan (number 20181005R, Approval date: 2018/11/08). Patient consent to participate was waived as this is a retrospective study.

Consent for publication

Patient consent for publication was waived as this is a retrospective study.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

K-LY made substantial contributions to conception and design of the study, acquisition of data, analysis and interpretation of data, and was a major contributor in writing the manuscript. T-YW and H-HM participated in drafting the article and revising it critically for important intellectual content. C-KL performed the software development. C-KL and S-MH gave final approval of the manuscript revisions and final version for submission. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

Authors' information

None

References

- [1] Dimitriou D, Tsai TY, Li JS, Nam KW, Park KK, Kwon YM. In vivo kinematic evaluation of total hip arthroplasty during stair climbing. *J Orthop Res* 2015;33:1087–93.
- [2] Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007;89:780–5.
- [3] 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 Relat Res* 2006;451:134–9.
- [4] Gandhi R, Marchie A, Farrokhyar F, Mahomed M. Computer navigation in total hip replacement: a meta-analysis. *Int Orthop* 2009;33:593–7.
- [5] Nomura T, Naito M, Nakamura Y, Ida T, Kuroda D, Sakamoto T, et al. An analysis of the best method for evaluating anteversion of the acetabular component after total hip replacement on plain radiographs. *Bone Joint J* 2014;96-B:597–603.
- [6] Widmer KH. A simplified method to determine acetabular cup anteversion from plain radiographs. *J Arthroplasty* 2004;19:387–90.
- [7] Arai N, Nakamura S, Matsushita T, Suzuki S. Minimal radiation dose computed tomography for measurement of cup orientation in total hip arthroplasty. *J Arthroplasty* 2010;25:263–7.

- [8] Olivecrona H, Weidenhielm L, Olivecrona L, Beckman MO, Stark A, Noz ME, et al. A new CT method for measuring cup orientation after total hip arthroplasty: a study of 10 patients. *Acta Orthop Scand* 2004;75:252–60.
- [9] Liaw CK, Yang RS, Hou SM, Wu TY, Fuh CS. A simple mathematical standardized measurement of acetabulum anteversion after total hip arthroplasty. *Comput Math Methods Med* 2008;9:105–19.
- [10] Liaw CK, Wu TY, Hou SM, Yang RS, Shih KS, Fuh CS. Computerized ellipse method for measuring acetabular version after total hip replacement - A precision study using synthetic and real radiographs. *Comput Aided Surg* 2013;18:195–200.
- [11] McLaren RH. Prosthetic hip angulation. *Radiology* 1973;107:705–6.
- [12] Woo RY, Morrey BF. Dislocations after total hip arthroplasty. *J Bone Joint Surg Am* 1982;64:1295–306.
- [13] Kennedy JG, Rogers WB, Soffe KE, Sullivan RJ, Griffen DG, Sheehan LJ . Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. *J Arthroplasty* 1998;13:530–4.
- [14] Jolles BM, Zangger P, Leyvraz PF. Factors predisposing to dislocation after primary total hip arthroplasty: a multivariate analysis. *J Arthroplasty* 2002;17:282–8.
- [15] Widmer KH, Zurfluh B. Compliant positioning of total hip components for optimal range of motion. *J Orthop Res* 2004;22:815–21.
- [16] Charnley J. Total hip replacement by low-friction arthroplasty. *Clin Orthop Relat Res* 1970;72:7–21.
- [17] D'Lima DD, Urquhart AG, Buehler KO, Walker RH, Colwell Jr CW. The effect of the orientation of the acetabular and femoral components on the range of motion of the hip at different head-neck ratios. *J Bone Joint Surg Am* 2000;82:315–21.
- [18] Biedermann R, Tonin A, Krismer M, Rachbauer F, Eibl G, Stöckl B. Reducing the risk of dislocation after total hip arthroplasty: the effect of orientation of the acetabular component. *J Bone Joint Surg Br* 2005;87:762–9.
- [19] Mian SW, Truchly G, Pflum FA. Computed tomography measurement of acetabular cup anteversion and retroversion in total hip arthroplasty. *Clin Orthop Relat Res* 1992:206–9.
- [20] Kalteis T, Handel M, Herold T, Perlick L, Paetzel C, Grifka J. Position of the acetabular cup – accuracy of radiographic calculation compared to CT-based measurement. *Eur J Radiol* 2006;58:294–300.
- [21] McArthur B, Cross M, Geatrakas C, Mayman D, Ghelman B. Measuring acetabular component version after THA: CT or plain radiograph? *Clin Orthop Relat Res* 2012;470:2810–8.

- [22] Park YS, Shin WC, Lee SM, Kwak SH, Bae JY, Suh KT. The best method for evaluating anteversion of the acetabular component after total hip arthroplasty on plain radiographs. *J Orthop Surg Res* 2018;13:66.
- [23] Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am* 1978;60:217–20.
- [24] Marx A, Knoch MV, Pförtner J, Wiese M, Saxler G. Misinterpretation of cup anteversion in total hip arthroplasty using planar radiography. *Arch Orthop Trauma Surg* 2006;126:487–92.
- [25] Penney GP, Edwards PJ, Hipwell JH, Slomczykowski M, Revie I, Hawkes DJ. Postoperative calculation of acetabular cup position using 2-D-3-D registration. *IEEE Trans Biomed Eng* 2007;54:1342–8.
- [26] Nho JH, Lee YK, Kim HJ, Ha YC, Suh YS, Koo KH. Reliability and validity of measuring version of the acetabular component. *J Bone Joint Surg Br* 2012;94:32–6.
- [27] Jolles BM, Genoud P, Hoffmeyer P. Computer-assisted cup placement techniques in total hip arthroplasty improve accuracy of placement. *Clin Orthop Relat Res* 2004:174–9.

Figures

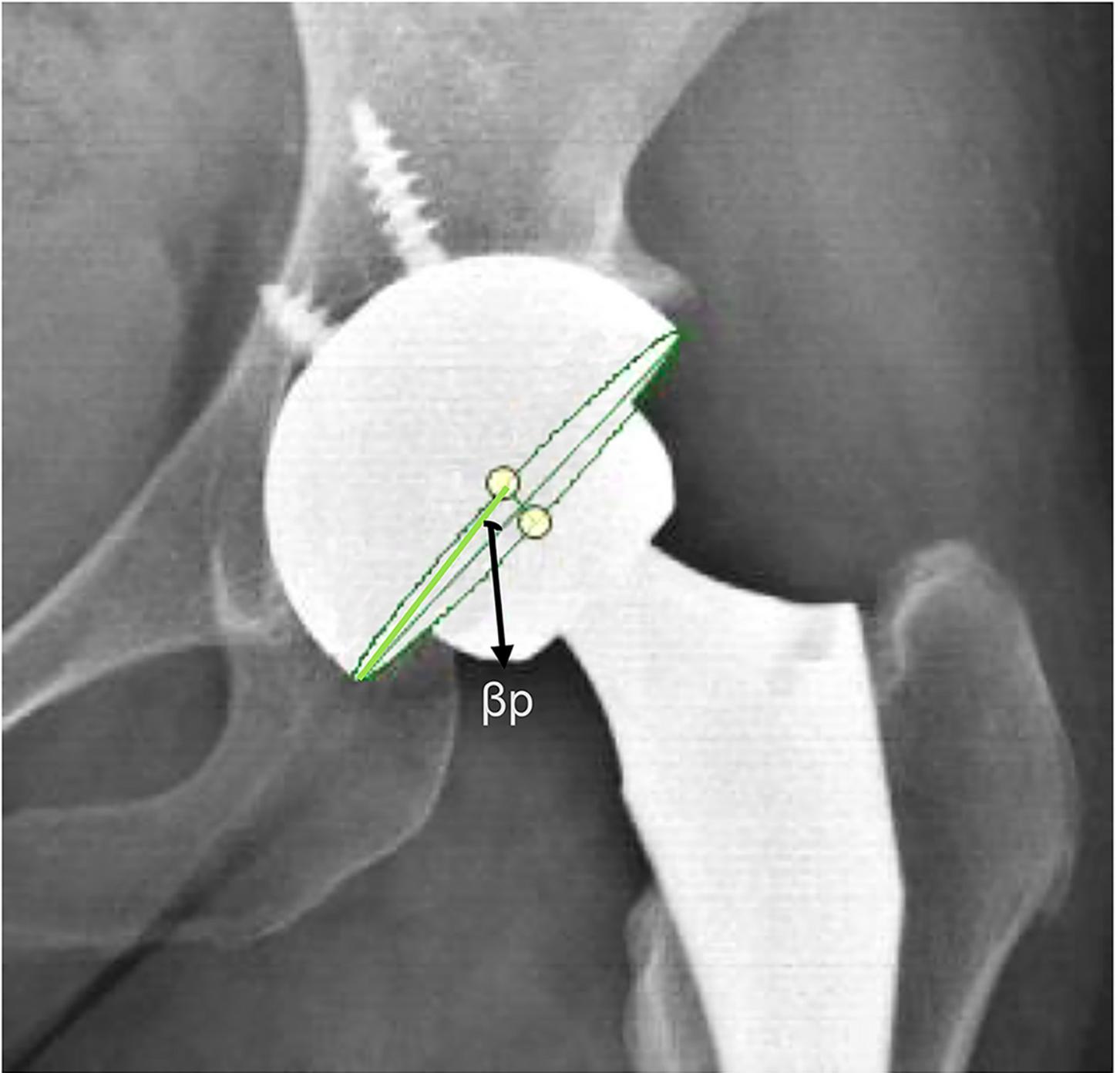


Figure 1

Liaw's anteversion = $\arcsin(\tan \beta_p)$. Angle β_p is the angle between the major axis of ellipse, and the two endpoint connection of the major and minor axes.

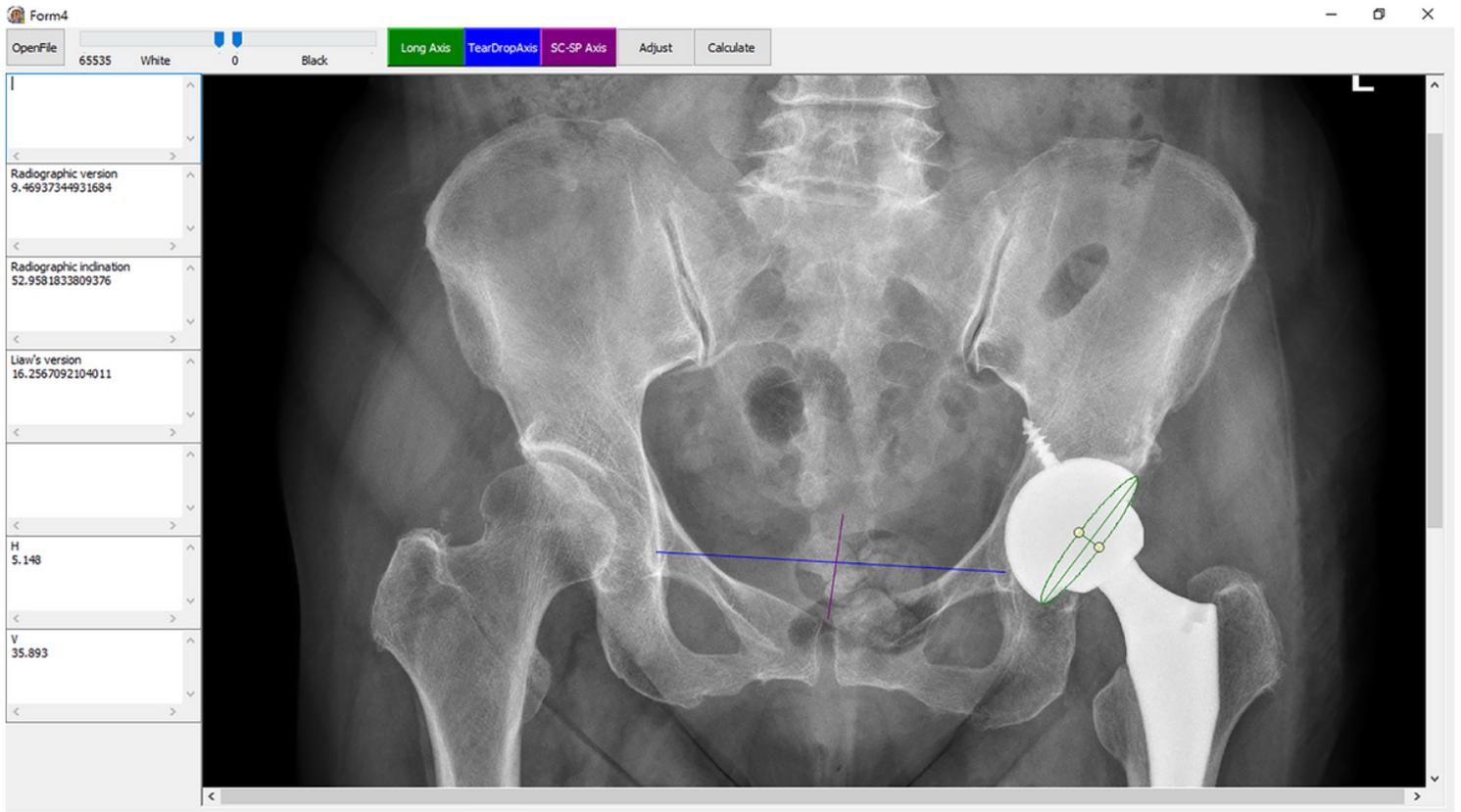


Figure 2

Ellipse method to measure the cup anteversion. The green line represents the cup margin of the cup, which is drawn by adapting the major and minor axes. The purple line represents the radiographic pelvic axis. The blue line represents the trans-teardrop line.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [STROBEchecklistv4combined24.pdf](#)
- [Equations.pdf](#)