Accuracy of Planar Anteversion Measurements in Anteroposterior Radiographs

Gwang Chul Lee
Chosun University Hospital
Sang Hong Lee
Chosun University Hospital
Sin Wook Kang
Chosun University Hospital
Hyung Suk Park
Chosun University Hospital
Suenghwan Jo (jo.suenghwan@chosun.ac.kr)
Chosun University Hospital https://orcid.org/0000-0001-7262-710X

Research article

Keywords: anteversion, inclination, hip-centered anteroposterior, pelvis anteroposterior, total hip replacement

Posted Date: August 28th, 2019

DOI: https://doi.org/10.21203/rs.2.13668/v1

Version of Record: A version of this preprint was published on December 5th, 2019. See the published version at https://doi.org/10.1186/s12891-019-2979-0.

Abstract

Introduction Number of methods has been suggested to measure anteversion in the simple AP radiograph and a few studies have validated their accuracy and reliability. In the current study, we compared six widely used anteversion measurement methods using two different radiographs (conventional pelvis AP vs hip centered AP) in order to determine which measurement method and which radiograph provides highest accuracy and reliability. Material and methods We developed custom made two planar anteversion measurement models for the validation. Each models are designed for Pelvis AP and hip AP. The radiographs were taken with the both models' inclination changing from 10° to 70° at 10° increments and for each inclination angles, anteversion was changed from 0° to 30° at 5° increments. Therefore, the x-ray of the two models were taken in 49 scenarios. The measurements were done independently by two orthopaedic surgeons blinded from each other using 6 methods : 1) Pradhan et al, 2) Lewinak et al, 3) Widmer et al, and 4) Liaw et al. 5) Hassan et al, 6) Ackland et al. Result The highest accuracy was found when Liaw method was used in hip centered AP radiograph which showed difference of 1.37° ± 1.73. Also, regardless of the type of the radiographs, Pradhan, Lewinnek, Liaw all showed relatively high accuracy. However, substantial difference was found when Widmer, Hassan, Ackland method were utilized regardless of the type of radiograph used. When the anteversion were measured in the inclination between 30° and 50°, Pradhan's method in pelvis AP showed the highest accuracy (1.23° ± 0.92°). Also, we found no significant difference when measured anteversions were compared between Pelvis AP and hip centered AP. Conclusion The study indicates that the Pradhan, Liaw and Lewinnek method may provide the relatively accurate anteversion measurement regardless of the type of the radiographs. Also, it would be unnecessary to take the hip centered AP radiographs in addition to the pelvis AP radiographs for the purpose of measuring anteversion.

Background

Accurate positioning of the implanted prosthesis after total hip replacement (THR) is critical to achieving an optimal outcome as the postoperative complications including polyethylene liner wear, impingement, and instability are largely attributed to malposition of the acetabular cup (1-5). The appropriateness of the acetabular cup position is determined by measuring inclination and anteversion. While measurement of inclination is relatively straightforward and can be done using a simple pelvis anteroposterior (AP) radiographs, controversies remain regarding the measurement of the anteversion of the acetabular component.

Measurement of anteversion using cross-table hip lateral view is one of the most commonly used methods (2, 6, 7). However, this method could provide inaccurate measurement in patients with joint contracture or lumbar stiffness or if the hip lateral radiograph is inadequately taken (8-10). As such, a number of methods have been suggested to measure anteversion in the simple AP radiograph and several studies have validated their accuracy and reliability (11-13). However, which anteversion measuring formula provides the most accurate anteversion measurement remains controversial.

The current study compared six widely used anteversion measurement methods using two different radiographs (conventional pelvis AP vs. hip-centered AP) to determine which measurement method and which radiograph provided the highest accuracy and reliability. We developed a custom-made planar anteversion measurement model for validation.

Methods

A 54-mm acetabular cup (Trilogy, Zimmer, Indiana, USA) was attached to the custom-made anteversion measurement model that enabled control of inclination and anteversion (Figure 1). The model had two axes which represented inclination and anteversion and a goniometer was attached to each axis for precise control of changes in both inclination and anteversion. The cup was fixed to the plexiglass plate at 10 cm height to represent the normal height of the hip joint in the supine position (Model A). Another model with the same cup and design was manufactured (Model B) and was fixed to the plexiglass plate 9.9 cm lateral and 4.9 cm distal to the first model. The distance between the two models represented the distance from the center of the triangle formed by the anterior superior iliac spine (ASIS) and symphysis pubis, which is typically used for conventional pelvis AP radiographs, and the hip joint. Thus, an X-ray beam directed toward Model A represented the simple X-ray of hip-centered AP radiograph, while the image in Model B represented the acetabular cup in conventional pelvis AP radiographs. The radiographs were taken with both models' inclinations changing from 10° to 70° at 10° increments; for each inclination angle, the anteversion was changed from 0° to 30° at 5° increments. Therefore, X-rays of the two models were taken in 49 scenarios.

All images were digitally acquired using a Picture Archiving and Communication System (INFINITT PACS system, Seoul, South Korea) and all measurements on radiographs were subsequently made using PACS software. The measurements were done independently by two orthopedic surgeons blinded from each other using the six methods described by Pradhan et al (14), Lewinnek et al (1), Widmer et al (15), Liaw et al (16). Hassan et al (17), and Ackland et al (18). Before measuring the anteversion, the two evaluators held a consensus-building session and clarified the definitions for each measurement methods. All measurements were blinded from each other, and the measurements were repeated after 2 months to calculate intra-observer correlations.

Anteversion measurement methods (Figure 3)

1) Pradhan's method (14): Anteversion = arcsin (p/0.4D) (Figure 3a)

In which D is the maximum distance across the long axis of the ellipse of the component, A is a line drawn perpendicular to the long axis and intersecting the rim of the component beginning at a point one-fifth of the total distance of the longitudinal line, and P is the distance along this perpendicular line from the longitudinal line to the rim.

2) Lewinnek's method (1) = arcsin (D1/D2) (Figure 3b)

In which *D1* is the distance across the short axis of an ellipse drawn perpendicular to the long axis of the acetabular component and *D2* is the distance of the long axis, which is considered the maximal diameter of the implant.

3) Widmer's method (15) = arcsin(Short axis[S]/Total length[TL] (Figure 3c)

In which *S* is the short axis of the ellipse and *TL* is the total length of the projected cross-section of the component along the short axis. This method shows a linear correlation for values of *S/TL* between 0.2 and 0.6.

4) Liaw's method (16) = sin-1 tan β (Figure 3d)

In which β is the angle formed by the long axis of the component (the line from point A to B) and the line connecting the top point of the ellipse and the endpoint of the long axis (the line from point A to C).

5) Hassan's method (17) = $[\arcsin [(h/D) / \sqrt{([m/D] - [m^2/D^2])}]$ (Figure 3e)

In which *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.

6) Ackland's method (18) = $\arcsin [2y / 2\sqrt{(2Dx - x^2)}]$ (Figure 3f)

In which *D* is the distance of the long axis of the acetabular component and *x* is the distance along the line *AB*. 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.

Statistics

Reliability was defined as the consistency of the measurements, while accuracy was defined as the proximity to the reference anteversion angle. The reference anteversion was defined as the anteversion measured by the protractor of the manufactured model. Reliability tests were performed on interobserver and intraobserver measurements and intraclass correlations (ICCs) were calculated using JMP software (SAS Institute, Cary, NC). For accuracy determination, the differences in anteversion measurements from each method from the reference anteversion measurement were analyzed using paired t-tests with statistical significance set at $p < 0.05$.

To prevent bias from acquiring outlier data, subset analysis for accuracy of anteversion was performed for the anteversions within a safe inclination zone (30 to 50°).

Results

Interobserver and intraobserver correlations (ICC) were high in all measurements, ranging from 0.886 to 0.938 and 0.899 to 0.934, respectively (Table 1). The highest accuracy was observed for the Liaw method in hip-centered AP radiographs, which showed a difference of 1.37° ± 1.73 from the reference. Also, regardless of the radiograph type, the Pradhan, Lewinnek, and Liaw methods showed relatively high accuracies. However, substantial differences were observed for the Widmer, Hassan, and Ackland methods regardless of the radiograph type (Table 2). When the anteversions were measured in the inclination between 30 and 50°, Pradhan's method in pelvis AP showed the highest accuracy (1.23° ± 0.92°) (Table 3). We observed no significant differences in the measured anteversions between pelvis and hip-centered AP radiographs.

Discussion

Previous studies had limitations in their validations of anteversion measurement methods. First, many of the previous studies used computed tomography (CT) axial scans to validate the anteversion measured in plain anteroposterior radiograph (19-23). However, this may cause potential bias as the anteversion measured in CT scans reflects anatomical anteversion while the reference anteversion utilized in previous anteversion measurement methods using simple radiograph varied. Also, depending on how the simple AP radiograph is taken, the measured anteversion value may be significantly different. In simple pelvis AP radiographs, the radiation beam is projected toward the center of the triangle formed by the ASIS and the symphysis pubis. Thus, the radiation beam received by the hip joint in simple pelvis AP radiograph is deviated by about 6°. In contrast, the hip joint receives a perpendicular radiation beam in hip-centered AP radiographs.

The results of our study indicated that the anteversion measurement methods described by Pradhan, Lewinnek, and Liaw showed anteversion that differed by less than 4° from the real anteversion, while the methods proposed by Widmer, Hassan, and Ackland showed discrepancies of up to 29°. Moreover, measurement using hip-centered AP did not show superior accuracy compared to conventional AP; therefore, additional hip-centered AP radiographs are not recommended to improve the accuracy of anteversion measurement.

The correct positioning of the acetabular cup plays a significant role in minimizing wear and maintaining stability. The recommended inclination and version of the acetabular cup are controversial but the literature often refers to inclinations between 30 and 50° and anteversion between 5 and 30° as "safe zones" (24-27).

The inclination angle of the acetabular cup is defined as the angle formed by the tear drop line and the elliptical long axis of the entrance of the acetabular cup; thus, the inclination angle can be directly measured by simple radiography (15). However, anteversion of the acetabular component may be less accurate and difficult to obtain with two-dimensional simple radiographs (11, 13). Therefore, a number of studies have attempted to accurately measure the position of the acetabular components in plain AP radiographs using complex mathematics and trigonometric functions to describe the ellipses of the acetabular cup boundaries (1, 14-18). However, most of these studies did not specify where the center of the beam was directed or the reference plane that was utilized (Table 4). Several studies have tried to validate the accuracy and reliability of these methods but have reported inconsistent results (11-13). Marx et al compared five proposed formulas (Pradhan, McLaren, Hassan, Ackland, and Widmer) to measure anteversion in AP radiographs utilizing a CT-based navigation system as a reference (11). The study concluded that all five formulas had substantial differences in anteversion angles. Nho et al compared six formulas (Lewinnek, Widmer, Hassan, Ackland, Liaw, Woo, and Morrey) by CT axial scan, reporting that the Lewinnek, Hassan, Liaw, Woo, and Morrey methods provided satisfactory results (11). Nomura et al compared five formulas (Lewinnek, Widmer, Liaw, Pradhan, Woo, and Morrey), concluding that the values from Widmer's method were most similar to those measured using CT (12). It should be noted that study by Nomura et al is the only study to utilize the functional coronal plane as a reference while the other two studies used CT axial scans to measure anteversion (11). Compared to the previous studies, our results show that, while all measurements had high reliability, the accuracy was high only in the Pradhan, Lewinnek, and Liaw methods. We observed significant differences from the reference anteversion values for the Widmer, Hassan, and Ackland methods. We were unable to identify the reasons why the result of our study differed from those of the previous studies; however, we believe that we added precision to the reference anteversion values by adding a goniometer to the model.

We also found no significant difference in comparisons of anteversion measurements between conventional pelvis and hip-centered AP views. Depending on the measurement method, one radiograph measurement tended to be closer in value to the reference; however, the difference was minimal. We believe that this difference is based on which reference radiograph was used when the formula was first developed.

Another finding of our study was that the anteversion measurements tended to be closer to the reference anteversion in the inclination between 30° to 50°. As most of the cup during total hip arthroplasty procedure is targeted in this range, the Liaw, Pradhan, and Lewinnek methods can be used with relatively high accuracy if the inclination is not excessively malpositioned.

Compared to the previous literature, our study showed a very high ICC. We believe this is because we did not utilize an in vivo model. As our model did not include soft tissue or a metal femoral head, we were able to more accurately identify the boundaries of the reference variables. Also, unlike taking X-rays in real humans, it can be hypothesized that the radiograph was taken with more accuracy. However, we also acknowledge that this may also be a potential limitation of the current study since the accuracy may be lower in real total hip arthroplasty scenarios due to the interference of the soft tissue of the metallic head, which may result in haziness in the radiograph. Another limitation of the current study was that we used only one type of cup. Thus, our results may only be applied to a cup which is perfectly hemispherical.

Conclusions

The results of the present study indicated that the Pradhan, Liaw, and Lewinnek methods may provide relatively accurate anteversion measurement regardless of radiograph type. Furthermore, it may be unnecessary to obtain hip-centered AP radiographs in addition to pelvis AP radiographs to measure anteversion.

Abbreviations

List of abbreviations:

AP: anteroposterior

ASIS: anterior superior iliac spine

CT: computed tomography

ICC: intraclass correlations

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

The datasets used and/or 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" in this section.

Funding

No funding was received for this study.

Authors’ contributions

Authors would like to thank the following individuals for their contributions to this study but not fulfilling the criteria for authorship : S. W. Jang, MD, H. B. Choi, MD, H. H. Park, for data acquisition

Acknowledgements

References

1. Lewinnek GE, Lewis J, Tarr R, Compere C, Zimmerman J. Dislocations after total hip-replacement arthroplasties. JBJS. 1978;60(2):217-20.
2. Dislocations after total hip arthroplasty., (1982).
3. McLaren RH. Prosthetic hip angulation. Radiology. 1973;107(3):705-6.
4. Ritter MA. Dislocation and subluxation of the total hip replacement. Clin Orthop Relat Res. 1976(121):92-4.
5. Wan Z, Dastane M, Dorr L, Malik A. Combined anteversion technique for total hip arthroplasty. 2008.
6. Nunley RM, Keeney JA, Zhu J, Clohisy JC, Barrack RLJTJoa. The reliability and variation of acetabular component anteversion measurements from cross-table lateral radiographs. 2011;26(6):84-7.
7. Eijer H, Leunig M, Mahomed M, Ganz RJHi. Cross-table lateral radiographs for screening of anterior femoral head-neck offset in patients with femoro-acetabular impingement. 2001;11(1):37-41.
8. The reliability and accuracy of measuring anteversion of the acetabular component on plain anteroposterior and lateral radiographs after total hip arthroplasty, (2015).
9. Arai N, Nakamura S, Matsushita T. Difference between 2 measurement methods of version angles of the acetabular component. J Arthroplasty. 2007;22(5):715-20.
10. Wiese M, Saxler G. Misinterpretation of cup anteversion in total hip arthroplasty using planar radiography. 2006.
11. Nho J, Lee Y, Kim H, Ha Y, Suh Y, Koo K. Reliability and validity of measuring version of the acetabular component. J Bone Joint Surg Br. 2012;94(1):32-6.
12. An analysis of the best method for evaluating anteversion of the acetabular component after total hip replacement on plain radiographs, (2014).
13. Marx A, von Knoch M, Pfortner J, Wiese M, Saxler G. Misinterpretation of cup anteversion in total hip arthroplasty using planar radiography. Arch Orthop Trauma Surg. 2006;126(7):487-92.
14. Planar anteversion of the acetabular cup as determined from plain anteroposterior radiographs., (1999).
15. Widmer K-H. A simplified method to determine acetabular cup anteversion from plain radiographs. The Journal of arthroplasty. 2004;19(3):387-90.
16. A new tool for measuring cup orientation in total hip arthroplasties from plain radiographs. - PubMed - NCBI, (2006).
17. Hassan DM, Johnston GH, Dust WN, Watson LG, Cassidy D. Radiographic calculation of anteversion in acetabular prostheses. J Arthroplasty. 1995;10(3):369-72.
18. Ackland M, Bourne W, Uhthoff H. Anteversion of the acetabular cup. Measurement of angle after total hip replacement. The Journal of bone and joint surgery British volume. 1986;68(3):409-13.

19. Lazennec J-Y, Boyer P, Gorin M, Catonné Y, Rousseau MAJCO, Research® R. Acetabular anteversion with CT in supine, simulated standing, and sitting positions in a THA patient population. 2011;469(4):1103-9.
20. Stem ES, O'Connor MI, Kransdorf MJ, Crook JJSr. Computed tomography analysis of acetabular anteversion and abduction. 2006;35(6):385-9.
21. Dorr LD, Wan Z, Malik A, Zhu J, Dastane M, Deshmane PJJ. A comparison of surgeon estimation and computed tomographic measurement of femoral component anteversion in cementless total hip arthroplasty. 2009;91(11):2598-604.
22. Sugano N, Noble PC, Kamaric EJJocat. A comparison of alternative methods of measuring femoral anteversion. 1998;22(4):610-4.
23. Ghelman B, Kepler CK, Lyman S, Della Valle AGJCO, Research® R. CT outperforms radiography for determination of acetabular cup version after THA. 2009;467(9):2362-70.
24. Dislocations after total hip-replacement arthroplasties., (1978).
25. Coventry MB. Late dislocations in patients with Charnley total hip arthroplasty. J Bone Joint Surg Am. 1985;67(6):832-41.
26. Harris WH. Advances in surgical technique for total hip replacement: without and with osteotomy of the greater trochanter. Clin Orthop Relat Res. 1980(146):188-204.
27. 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(4):513-7.

Tables

Table 1. Interobserver and intraobserver reliabilities of measurement on plain radiographs.

Measurement method	Interobserver correlation	Intraobserver correlation
Pradhan	0.938	0.934
Lewinnek	0.937	0.916
Widmer	0.928	0.933
Liaw	0.887	0.908
Hassan	0.902	0.899
Ackland	0.886	0.913

Table 2. Differences between measured and reference anteversions in pelvis and hip-centered anteroposterior (AP) radiographs.

Measurement method		Mean ± SD difference from reference anteversion	Maximum difference from reference anteversion
Pradhan	Pelvis AP	1.62 ± 1.54	5.43
	Hip-centered AP	-3.11 ± 1.14	-4.83
Lewinnek	Pelvis AP	2.84± 1.59	6.61
	Hip-centered AP	-2.91 ± 1.56	-5.34
Widmer	Pelvis AP	-7.10 ± 3.96	-14.46
	Hip-centered AP	-15.66 ± 3.80	-21.13
Liaw	Pelvis AP	2.52 ± 1.59	6.42
	Hip-centered AP	1.37 ± 1.73	4.31
Hassan	Pelvis AP	-12.95 ± 9.71	-33.97
	Hip-centered AP	-18.11 ± 7.59	-30.9
Ackland	Pelvis AP	-10.15 ± 6.73	-24.24
	Hip-centered AP	-13.87 ± 5.48	-28.89

SD standard deviation

Table 3. Differences between measured and reference anteversions in pelvis and hip-centered anteroposterior (AP) radiographs within a safe inclination zone (30

Measurement method		Mean ± SD difference from reference anteversion	Maximum difference from reference anteversion
Pradhan	Pelvis AP	1.23 ± 0.92	2.90
	Hip-centered AP	-2.66 ± 1.14	-4.83
Lewinnek	Pelvis AP	2.46 ± 0.98	3.92
	Hip-centered AP	-2.65 ± 1.12	-4.69
Widmer	Pelvis AP	-7.61 ± 3.74	-14.46
	Hip-centered AP	-14.99 ± 4.12	-20.64
Liaw	Pelvis AP	2.13 ± 0.96	3.35
	Hip-centered AP	1.76 ± 1.55	4.31
Hassan	Pelvis AP	-11.65 ± 8.92	-29.35
	Hip-centered AP	-17.61 ± 8.04	-29.42
Ackland	Pelvis AP	-10.84 ± 6.98	-24.22
	Hip-centered AP	-13.56 ± 5.30	-28.89

Table 4. Reference radiographs and planes in previous literature measuring anteversion in plain anteroposterior (AP) radiographs.

Measurement method	Type of radiograph	Reference plane
Pradhan	Hip-centered AP	Planar
Lewinnek	Not specified	Not specified
Widmer	Pelvis AP	Planar
Liaw	Hip-centered AP	Planar, True
Hassan	Hip-centered AP	Planar
Ackland	Hip-centered AP	Planar, True

Figures

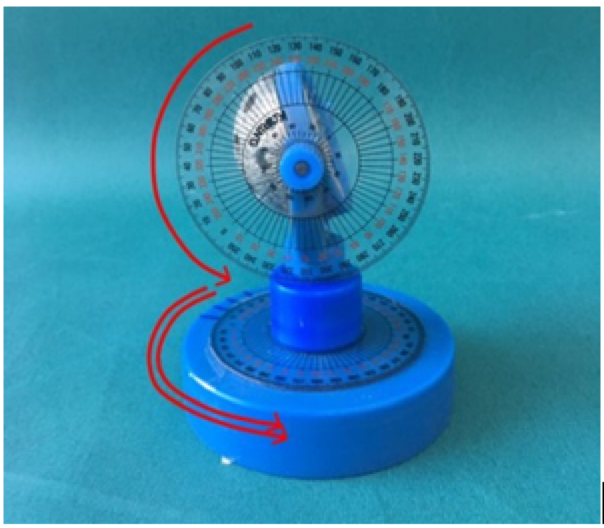

Figure 1

Custom-made device allowing inclination and anteversion of the mounted cup with protractors in two axes. The solid arrow indicates the change in anteversion, while the hollow arrow indicates the change in inclination.

Figure 2

Two custom-made anteversion-measuring models fixed to plexiglass. It represents the distance from the center of the triangle formed by both anterior superior iliac spine (ASIS) and symphysis pubis and the hip joint

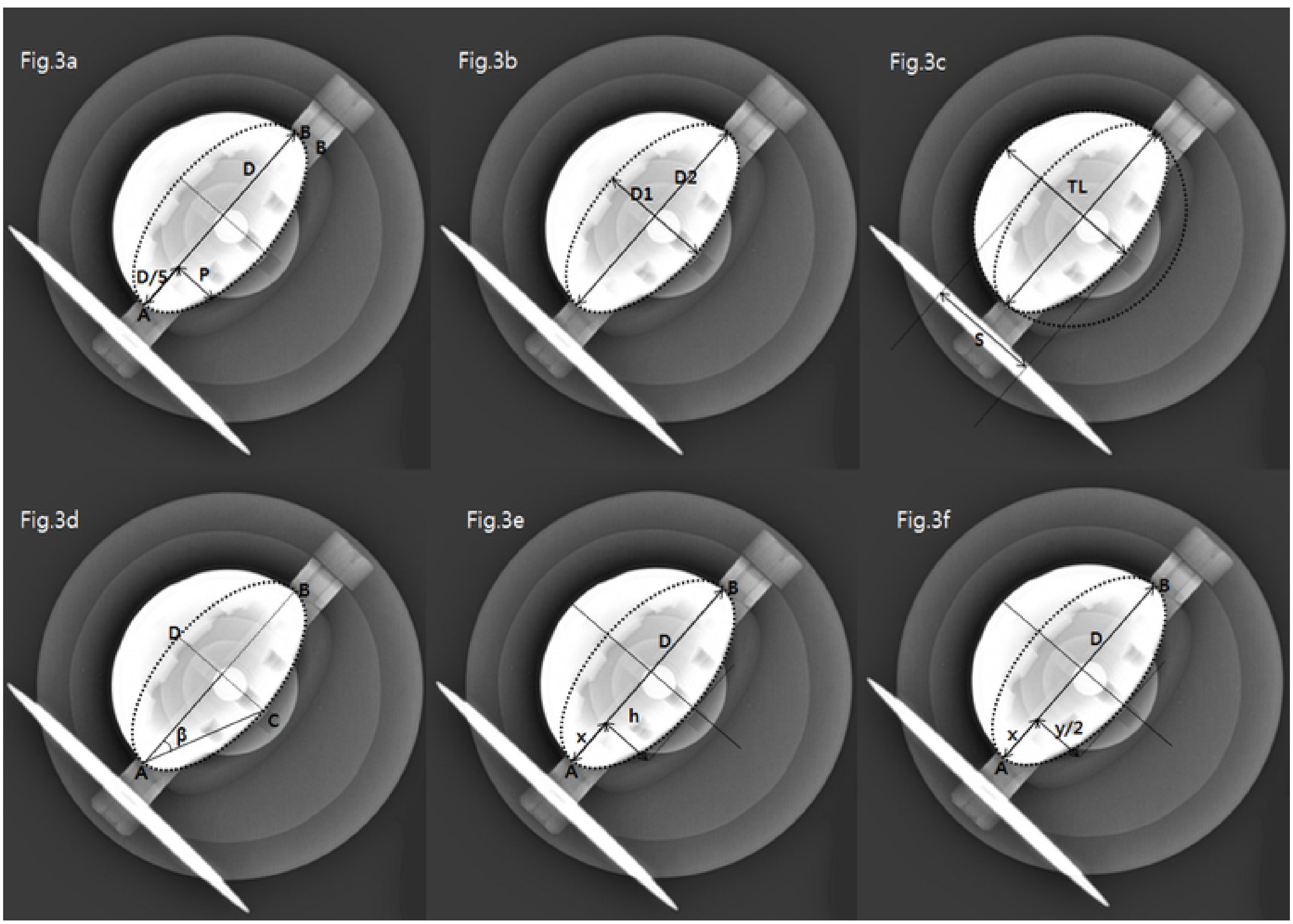

Figure 3

Methods for measuring anteversion on plane anteroposterior radiographs. A) Pradhan, B) Lewinnek, C) Widmer, D) Liaw, E) Hassan, F) Ackland