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Assessment of Acetabular Component Anteversion after Total Hip Arthroplasty: Comparison of Anteroposterior and Cross-Table Lateral Radiographs with Computed Tomography Scans

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Background: Several methods of measurement of anteversion of acetabular components after total hip arthroplasty (THA) have been described in the literature using plain radiographs or computed tomography (CT) scans. None of these have proved to be the gold standard. We aimed to study the correlation between the CT and radiographic methods of calculation of acetabulum anteversion.

Methods: CT scans of the pelvis, anteroposterior (AP) and cross-table lateral (CL) radiographs were obtained in 60 patients who underwent THA two weeks after surgery. Anteversion was measured using Widmer method and Liaw method on AP radiographs, and the ischiolateral method on CL radiographs. Anteversion measured on the CT scan was taken as the reference anteversion and the above measurements were analysed for correlation with the measurements on CT scan. Intraclass correlation coefficients (ICCs) were calculated for both intra- and interobserver reliability.

Results: Mean acetabular version on CL radiographs was 53.1 ± 10.7. Mean version on AP radiographs by Widmer method was 21.4 ± 3.6 and by Liaw method was 20.3 ± 4.8. Mean version on CT scans was 26.02 ± 6.8. There was a good correlation between the acetabular version on CT scans with the version on AP radiographs by Widmer method ($r = 0.78$, $p < 0.001$) and Liaw method ($r = 0.87$, $p < 0.001$). Good correlation was seen between the acetabular version on CL radiographs and CT scans ($r = 0.91$, $p < 0.001$). Also, a good correlation was observed between the acetabular version measurements on CL radiographs and AP radiographs by Widmer method ($r = 0.81$, $p < 0.001$) or Liaw method ($r = 0.70$, $p < 0.001$). Excellent inter- and intraobserver reliability were seen for all the measurements.

Conclusions: Calculation of acetabular component version on AP views as well as CL views of plain radiographs showed a strong correlation with the version measurements on CT scans. Good correlations were observed between different techniques of measurement on radiographs. Therefore, all these measurements can be valid methods for assessment of anteversion.

Keywords: *Hip arthroplasty, Computed tomography, Radiography, Hip prosthesis, Acetabulum*

Achieving correct versions of the femoral and acetabular components is very important in total hip arthroplasty (THA). Improper placement of these components can lead to impingement, dislocation, accelerated wear, and failure.[1-3] The orientation of acetabular components can be expressed in terms of inclination and anteversion. The inclination refers to movement in the coronal plane and can easily be measured on plain anteroposterior (AP) radiographs. Version refers to placement of the acetabular

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component in transverse plane and its estimation is more difficult. Computed tomography (CT) is considered to be the investigation of choice for calculation of acetabular version.[4] CT scans are neither routinely performed nor recommended for routine evaluation of patients undergoing THA. Reliable methods of measurement of acetabulum version on plain radiographs would thus be a more practical way of evaluating component position in THA.

Several methods of estimation of anteversion on plain AP radiographs have been described in the literature.[5,6] Cross-table lateral (CL) radiography of the hip joint has also been used for the estimation of acetabular version.[5,7] Use of AP views has an advantage that they are the standard views performed in routine follow-up of the patients and both the radiographers and the surgeons are more familiar with them. But the calculation of version is more complicated on AP radiographs.[6] It will need a digital platform where an ellipse can be drawn and suitable measurements can be taken. On the other hand, measurements on CL views are more straightforward. But the CL view is a special radiographic view that is not routinely obtained.

On CL views, the angle of acetabular cup anteversion can be calculated in reference to the horizontal plane of the radiographs.[7,8] This measurement can be faltered by the inclination of the native acetabulum in relation to the pelvis. It was later replaced by a method using fixed bony landmarks such as ischial tuberosity as the reference.[9] Only a few studies using CL radiographs have used the ischiolateral method of measurement.[10-14]

CT scans can be considered an acceptable standard for measurement of acetabulum version, and radiographic methods of calculation should strongly correlate with the measurements on CT scans. Only a few studies have compared the relation between these two measurements.[4,10,15,16] Among them, only the study by Pankaj et al.[10] correlated acetabular component anteversion measurements on CT scans with the ischiolateral method in CL radiographs, whereas rest of the studies only assessed the anteversion in reference to the horizontal plane of the radiographs. The aim of the present study was to find a correlation between measurement of anteversion on AP and CL radiographs with that on CT scan. The null hypothesis was that there is no correlation between these measurements.

METHODS

This is a cross-sectional study conducted from January 2019 to December 2019. Institutional Review Board approval was obtained prior to the study (AIIMS Rishikesh/IEC/18/149). We included 60 patients undergoing primary total hip replacement. The same total hip prosthesis (Fibre metal taper stem and Pinnacle acetabular shell, Zimmer, Warsaw, USA) was used in all patients. We excluded patients with stiffness of the opposite hip (range of motion less than two-thirds of the normal) or stiffness or ankyloses of the spine, as this could interfere with measurements. Informed consent was obtained from all patients and a radiologic technician who performed the X-ray.

AP and CL radiographs and CT scans of the hips were obtained two weeks after the surgery. CL radiographs were obtained using the technique described by Danelius and Miller.[17] This projection is taken with the patient in supine position and limb internally rotated by 15°–20°. The contralateral hip is flexed to 60°. Direction of the beam is parallel to the table, through the groin, directed 45° cephalad (Fig. 1). The ischiolateral method was used for calculation of anteversion of the acetabular shell on CL radiographs.[9] A line was drawn tangential to the opening of the acetabular shell. This is the line connecting the two ends of the ellipse formed by the opening of the cup. Another straight line is drawn along the long axis of ischial tuberosity. The angle is measured between the perpendicular to a line along ischial tuberosity and the tangent to the acetabular shell. This is called the angle of anteversion in the ischiolateral method (Fig. 2).

CT scans were performed in a 128-slice machine. Anteversion was measured in axial cuts. A tangent was

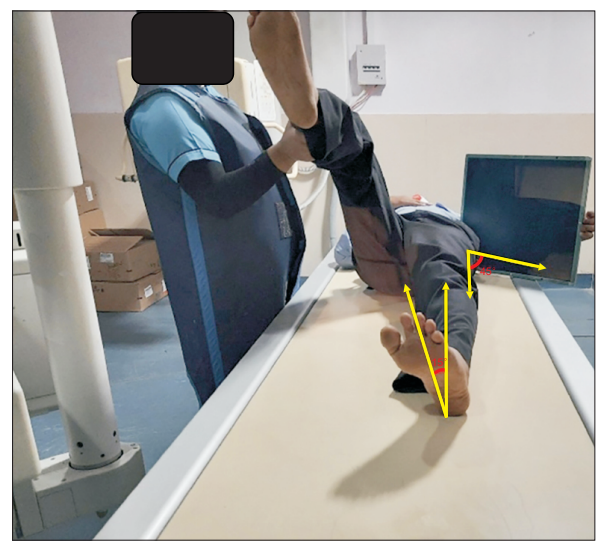

Fig. 1. Photograph showing the position of the patient and X-ray beam for cross-table lateral views. The projection is taken with the patient in supine position and limb internally rotated by 15°–20°. The contralateral hip is flexed to 60° and the direction of the X-ray beam is parallel to the table, through the groin, directed 45° cephalad.

drawn between the anterior and posterior edges of the acetabular cup. Another line joining the posterior pelvic margins was drawn. The angle between the perpendicular drawn to this line and the tangent drawn on the acetabulum shell was calculated (Fig. 3). Standard AP radiographs of the pelvis were taken with the X-ray beam centred on the symphysis pubis and legs in 10°–15° of internal rotation. Anteversion was measured on AP radiographs using two standard methods: the one by Widmer[18] and the other by Liaw et al.[19] The description of these methods is presented in Fig. 4.

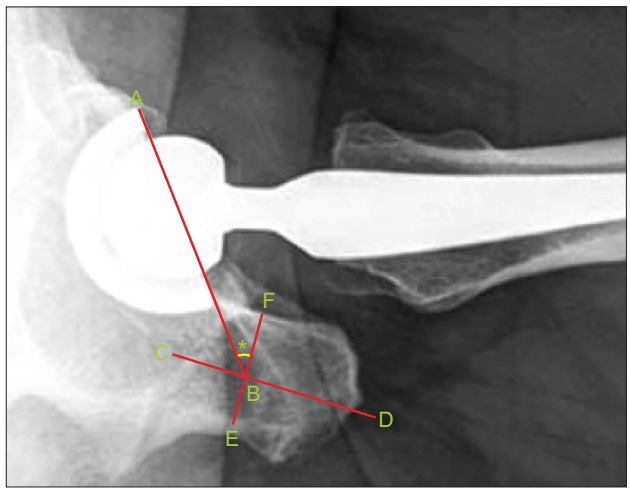

Fig. 2. Measurement of acetabular component anteversion by the ischiolateral method. A line is drawn tangential to the opening of the acetabular shell connecting the two endpoints of the ellipse (AB). Another straight line is drawn along the long axis of the ischial tuberosity (CD). The anteversion angle (*) is measured between the perpendicular (EF) to a line drawn along the ischial tuberosity and the tangent to the acetabular shell (AB).

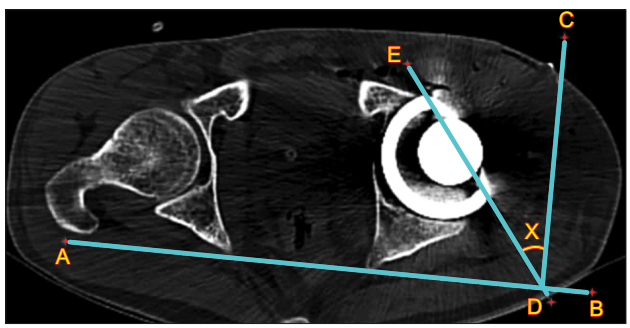

Fig. 3. Measurement of acetabular component anteversion on a computed tomography scan. A tangent is drawn between the anterior and posterior edges of the acetabular cup (DE). Another line joining the posterior pelvic margins (AB) is drawn. The angle (X) between the perpendicular to this line (CD) and the tangent drawn on the acetabulum shell (DE) is calculated.

All measurements were performed by two observers (SP, AKC), who were blinded to the patient details and to each other. Reliability of measurements was estimated by interobserver variability of the measurements on plain radiographs and CT scans. Validity of the radiographic method was calculated as the difference between the radiographic and CT measurements. Intraclass correlation coefficients (ICCs) were calculated for both intra- and interobserver reliability. Measurements were repeated by the observers after two weeks for intraobserver reliability. One-way random effect model was used to calculate ICC. An ICC value of 1 represented perfect reliability and 0 meant no reliability.[20] Pearson correlation coefficient was used to assess an association between different measurements of acetabular anteversion. A correlation coefficient greater than 0.8 was considered as strong agreement.

RESULTS

Details of patients including mean age, sex, and mean body mass index are summarized in Table 1. Mean version on CL radiographs was 53.1 ± 10.7, on AP radiographs by Widmer method[18] was 21.4 ± 3.6, and by Liaw et al.'s method[19] was 20.3 ± 4.8. Mean version on CT scans was 26.02 ± 6.8. Correlation coefficients between different calculations of acetabular version are summarised in Table 2.

There was a strong correlation between the acetabular version on CT scans with the version on AP radiographs by Widmer method ($r = 0.78$, $p < 0.001$) and Liaw method ($r = 0.87$, $p < 0.001$). Strong correlation was seen between the acetabular version on CL radiographs and CT scans ($r = 0.91$, $p < 0.001$) (Fig. 5). Also, a good cor-

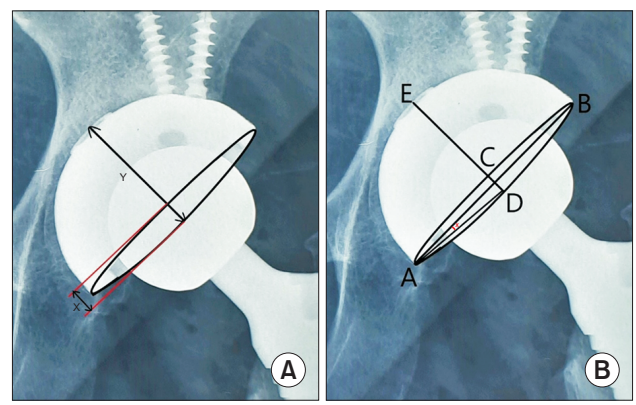

Fig. 4. Measurement of acetabular component anteversion on an anteroposterior radiograph. (A) Measurement by Widmer method:[18] arcsin (X/Y), X: short axis, Y: total length. (B) Measurement by Liaw method:[19] sin–1 tan X, AB: longitudinal axis of component, CD: transverse axis of component, X: angle between AB and AD.

relation was observed between the acetabular version on CL radiographs and that measured with Widmer method ($r = 0.8$, $p < 0.001$) and Liaw method ($r = 0.70$, $p < 0.001$). Inter- and intraobserver reliability were good for all the measurements (Table 3). Postoperative power analysis with means and standard deviations of measurements obtained from CT and ischiolateral views showed adequate power.

DISCUSSION

Findings from the present study suggest that anteversion on AP radiographs is as valid as the measurements using the ischiolateral method. Both methods had comparable correlation with the measurements on CT scans. Anteversion of the acetabulum is a complex concept as the position of the acetabular shell is three-dimensional. Therefore, uniplanar measurement of the angle of version is an oversimplification. Different methods of calculation of acetabular version have been described in the literature.[21]

The position of the acetabulum and its version can be affected by the position of the pelvis. Version increases with the reclination of the pelvis.[12] Reliance on the position of the pelvis may not be accurate as used in the method by Woo and Morrey.[8] The ischiolateral method of measurement uses the ischial tuberosity as the fixed bony landmark for measurement and it has shown to be quick, low cost, consistent, and reliable for measuring anteversion of acetabular components.[12] Pankaj et al.[10] observed an excellent correlation between the ischiolateral method and CT measurements ($r = 0.925$). They compared these two methods of measurements on CL radiographs with CT scans. The mean anteversion was 18.35° (range, 3°–38°) using Woo and Morrey's method,[8] 51.45° (range, 30°–85°) using the ischiolateral method, and 21.22° (range, 2°–48°) using CT scans. The mean anteversion measured by the ischiolateral method (mean ± standard deviation [SD], 53.1±10.7) and CT scans (mean ± SD, 26.02 ± 6.8) in this study is quite comparable to their study.

Nunley et al.[22] compared acetabular versions on CL radiographs and CT scans. Mean anteversion was 26.1° (range, −2° to 48.3°) on CL imaging and 28.8° (range, −7° to 54°) on CT scans. A strong correlation ($r = 0.82$, $p =$

Table 1. Demographic Characteristics of Patients

Variable	Value
Mean age (yr)	41.1 ± 15.6
Sex (male : female)	24 : 36
Body mass index (kg/m^2)	21.9 ± 2.1
Diagnosis	
Advanced arthritis secondary to avascular necrosis of femoral head	21
Rheumatoid arthritis	17
Posttraumatic arthritis	11
Advanced arthritis secondary to femoroacetabular impingement	8
Advanced arthritis secondary to dysplasia of hip	3

Values are presented as mean ± standard deviation.

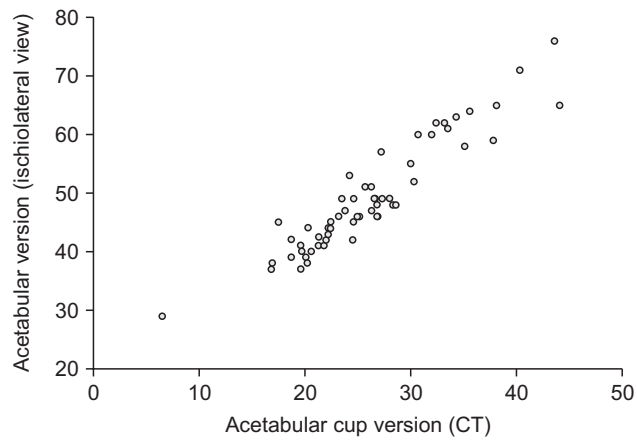

Fig. 5. Scatterplot showing the correlation between measurements of anteversion in acetabular computed tomography (CT) scans and cross-table lateral radiographs (ischiolateral method).

Table 2. Correlation between Different Calculations of Acetabular Version

Variable	Widmer method	Liaw method	Ischiolateral method	CT
Widmer method	1	0.79 ($p < 0.001$)	0.81 ($p < 0.001$)	0.87 ($p < 0.001$)
Liaw method	0.79 ($p < 0.001$)	1	0.70 ($p < 0.001$)	0.78 ($p < 0.001$)
Ischiolateral method	0.81 ($p < 0.001$)	0.70 ($p < 0.001$)	1	0.91 ($p < 0.001$)
CT	0.87 ($p < 0.001$)	0.78 ($p < 0.001$)	0.91 ($p < 0.001$)	1

CT: computed tomography.

Table 3. Descriptive Data of Different Calculations of Acetabular Version and ICCs

Variable	Ischiolateral method	Widmer method	Liaw method	CT measurement
Anteversion of acetabular shell, mean ± SD (range)	53.1 ± 10.7 (28–76)	21.4 ± 3.6 (6.7–28.6)	20.3 ± 4.8 (4.5–33.4)	26.02 ± 6.8 (6.5–44.1)
ICC for intraobserver reliability (95% CI)	0.84 (0.74–0.93)	0.82 (0.73–0.88)	0.78 (0.7–0.83)	0.88 (0.81–0.93)
ICC for interobserver reliability (95% CI)	0.81 (0.73–0.9)	0.86 (0.77–0.9)	0.85 (0.74–0.93)	0.91 (0.86–0.97)

ICC: intraclass correlation coefficient, CT: computed tomography, SD: standard deviation, CI: confidence interval.

0.001) was seen between version measurements on CL radiographs and CT scans. A high variability (average, 6.1° ± 3.8°) was seen in the anteversion measurements on CL radiographs. They used the method described by Woo and Morrey[8] for calculation of version. High variability in measurement of acetabular version using this method has also been reported by other authors.[7]

Many different techniques for estimation of version using plain AP radiographs have been described in the literature, but it is not clear which one of them is more accurate. Studies comparing these techniques have found variable results on the validity of these different techniques. Lu et al.[23] compared anteversion on plain AP radiographs using the method by Lewinnek et al.[24] with the measurements on CT scans. No significant difference was seen in these measurements ($p = 0.19$). Ghelman et al.[4] noted good correlation between anteversion of acetabular components on CT scans and the methods by Widmer[18] ($r = 0.86$), Lewinnek et al.[24] ($r = 0.93$), Liaw et al.[19] ($r = 0.919$), Hassan et al.[25] ($r = 0.86$), and Pradhan[26] ($r = 0.844$). Widmer's method was found to be best by Nomura et al.[27] and Marx et al.,[28] whereas the method described by Liaw et al.[19] was found to be more suitable in studies by Nho et al.[29] and Park et al.[5]. We used methods of Liaw et al.[19] and Widmer[18] for calculation of anteversion on AP radiographs.

Correlations between the AP and CL radiographic measurements have not been reported in the literature. Shin et al.[30] compared anteversion on the AP views as measured by Liaw et al.[19] with anteversion measurement on CL views using Woo and Morrey.[8] The two measurements were significantly different ($p < 0.001$). They did not study the correlation between the two. In the present study, an excellent correlation was observed between the measurements on AP and CL radiographs.

Anteversion represents a complex spatial orientation of the acetabulum and has been described as anatomical anteversion as measured on CT scans, operative anteversion as assessed intraoperatively, and radiographic anteversion as measured on plain radiographs.[21] These are based on measurements on different references and their values are expected to be different. Lu et al.[23] pointed out that measurements of version measured on radiographs and CT scans have different definitions and thus their values cannot be equated. Hence anteversion measured by different methods cannot have similar values, but a good correlation between methods is an indicator of validity of the measurements. There is no gold standard for the calculation of acetabular anteversion, but measurements on CT scans can be considered to be more accurate than radiographic measurements. The ischiolateral method on CL radiographs showed the strongest correlation with the measurements on CT scans.

The strengths of this study are the large sample size and comparison of several different methods of measurement of version. The limitation of this study is that although all X-rays were obtained in a standardized manner, unavoidable errors in positioning of patients for AP radiographs might have affected the data.

Calculation of acetabular component version on AP views as well as CL views of plain radiographs showed a strong correlation with the version measurements on CT scans. Good correlations were observed between different techniques of measurement on radiographs. Therefore, all these measurements can be valid methods for assessment of anteversion.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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