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## Radiological comparison of acetabular anteversion on roentgenograms and computed tomograms & functional outcomes in total hip arthroplasty

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### Abstract

**Introduction:** Orientation and Alignment of prosthetic components are vitally important for the stability of total hip arthroplasty. Poor acetabular positioning is one of the many issues implicated with persistent pain due to impingement, dislocation, edge loading and liner fracture, which may lead to patient dissatisfaction after total hip arthroplasty.

**Material and methods:** Post-operative radiological analysis of the version of acetabulum through X-ray images and CT images was performed. Pre & post-operative scoring according to Modified Harris Hip Score (HHS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Oxford Hip Score (OHS) was documented.

**Results:** A total of 55 patients were included in the study. The mean anteversion angle calculated on anteroposterior (AP) radiographs by Lewinnek's method was 23.48° (Range 11 – 39°) and on cross-table lateral radiograph by Woo and Morrey's method was 22.41° (Range 16 – 56°), compared to CT Scans measured was 28.64° (Range 11.10 – 50.10°).

**Conclusion:** Majority 69.09% of patients had excellent functional outcomes in a range of 11.1 – 36° of anteversion compared to Lewinnek's safe zone. It suggests that there is flexibility in positioning the acetabular component than previously believed. If one has to err, it should be towards more anteversion. In fact to avoid dislocation, more anteversion is required to guard against unwarranted activities on part of the patient.

**Keywords:** Roentgenograms, computed tomograms, total hip arthroplasty

### Introduction

Total hip arthroplasty (THA) is one of the most common procedures performed in Orthopaedic Surgery and is considered to be one of the best medical innovations of our generation [1]. Arthroplasty depends upon ideal placement of both acetabular and femoral components. Accurate biomechanical reconstruction of the joint is essential to achieve function and longevity with acetabular positioning being a key factor, the consequences of malposition include instability, increased wear, impaired muscle function, reduced range of motion (ROM), impingement, bearing-related noise generation, poor functional outcomes, limb length discrepancy, and loosening and cup failure [2,3,4]. Dislocation is one of the most frequent complications after THA with an incidence of 0.6% to 11% in the early postoperative period; between 13% and 30% of dislocations reportedly are caused by implant malpositioning [5]. It is found that even in normal subjects there is a great variation in acetabular morphology. However, the range of normal acetabular & femoral variation may differ between races [6]. At age 13 to 14, the mostly ossified bones of the ilium, ischium, and pubis unite at the acetabulum, forming Y-shaped triradiate cartilage that proceeds to fusion by age 15 to 16. The other secondary centers unite and fuse between the ages of 20 and 22. The acetabular surface is orientated approximately 45 degrees caudally and 15 degrees anteriorly. The average anteversion of the native acetabulum measures 16 to 21 degrees with an average inclination of 48 degrees. Men tend to have less anteversion than females. Angular position includes the anteversion and inclination (abduction angle) of the cup. The most commonly quoted study is by Lewinnek *et al.* He found an increased dislocation rate in cups placed outside anteversion angles of 5°–25° and 30°–50° of inclination.

Inclination and anteversion can thus be operative, radiologic, or anatomic [7]. Operative and radiographic angles are the most relevant surgically in the lateral position of the patient. During surgery in the lateral position, operative anteversion is assessed by looking down, to project the insertion angle onto the sagittal plane, and measuring against the longitudinal axis. The most commonly used method for radiographic analysis is the one proposed by Woo and Morrey [8] namely the “angle formed by a line drawn tangential to the face of the acetabulum and a line perpendicular to the horizontal plane, as seen on a lateral view of the pelvis”. In comparison, McCollum and Gray [9] suggested a position of  $40^{\circ} \pm 10^{\circ}$  abduction and  $30^{\circ} \pm 10^{\circ}$  flexion to prevent impingement and dislocation. Harris recommends a position of  $30^{\circ}$  abduction and  $20^{\circ}$  anteversion; however, the Harris angles are referenced using a mechanical guide and the trunk of the patient [10]. During the implantation process, surgeons use different techniques to judge the positioning of the acetabular component. The purpose of the present study was aimed at the morphometric evaluation of the acetabular version radiologically using well-defined parameters of acetabular positioning in primary total hip replacements on patient satisfaction and functional outcomes at a tertiary center which will further help in planning, execution, and evaluation of total hip arthroplasty (THA). However, most of the studies have been done on western populations with limited follow-up period & to the best of our knowledge, only limited studies have been done in the Indian populations. The present study was undertaken to study the effects of acetabular component position well as acetabular position relative to bony anatomy on patient-reported functional outcomes and further to compare results whether accurately positioned acetabular component in Lewinnek’s safe zone using freehand technique as wide variability has been reported in cup orientation, also how accurately operating surgeon can achieve desired anteversion using factors such as visual cues and side of the operating table. To determine whether acetabular component positioned assessed by cross table radiographs and anteroposterior radiographs and computed tomography could provide measure of acetabular version and compare their reliability and accuracy of methods.

### Material and methods

This present study was conducted in tertiary care institution between the periods of 2017 to 2019, a total of 55 patients were included in the study. In this study, males were 58.2% compared to 41.8% females. The mean age of study population was 49.65 years with range from 17-75 years. The most common indication for surgery in our study was idiopathic osteoarthritis in 43.64% patients followed by post-surgical osteonecrosis of femoral head in 21.82%. The mean follow-up was 19.83 months.

### Inclusion criteria

- All age group patients, who need THA for painful disabling hip were included in the study.

### Exclusion criteria

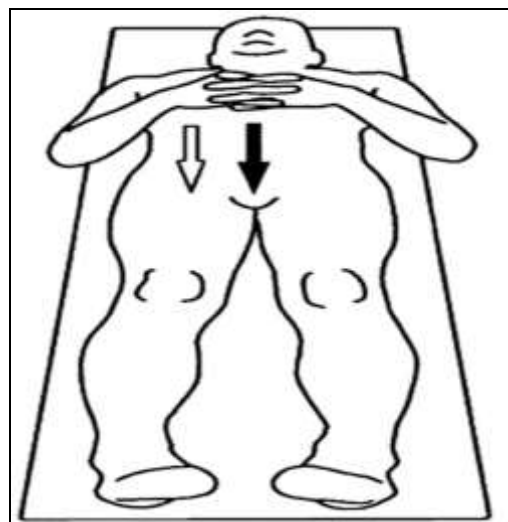
- Revision surgery
- Patients with bony pathology of pelvis and femur
- Patients with contralateral hip pathology as evident clinically with gait abnormality and pain or restriction of movements.
- Patients with current or previous metabolic bone disease.
- Bilateral Total Hip Arthroplasty,

- Medical illness or known case of malignancy predisposed by radiation.

Post-operative radiological analysis of the version of acetabulum through X-ray images and CT images was performed. Pre & post-operative scoring according to Modified Harris Hip Score (HHS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Oxford Hip Score (OHS) was documented.

**Radiographic Assessment:** Radiographs were taken with a tube-to-film distance of 120 cm by a computed digital radiographic system (Philips Bucky Primary Diagnost CS System 1000mA, November 2016 Hamburg, Germany).

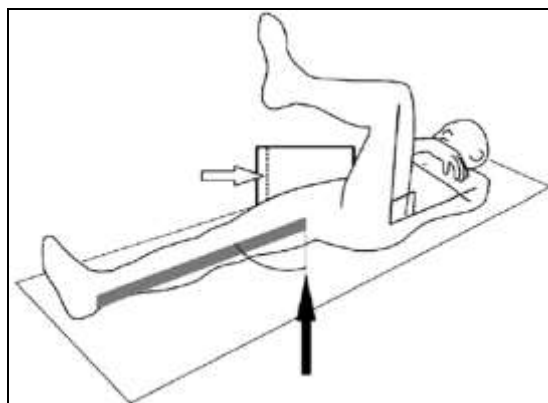
### Technique of taking AP Radiograph



**Fig 1:** Shows in supine position with the bilateral hip joint in a neutral position. The radiation beam was centered on the pubic symphysis (black arrow)

The patient was placed in the supine position with the bilateral hip joint in a neutral position. The radiation beam was centered on the pubic symphysis (black arrow) as shown in Figure 1 for an AP radiograph of the pelvis and was centered on the femoral head (white arrow) as shown in Figure 1 for the AP radiograph of the operated hip joint.

### Cross Table Lateral Radiographs



**Fig 2:** The direction of the radiation beam was parallel to the examination table and at  $45^{\circ}$  to the long axis of the body (black arrow), An X-ray film was held perpendicular to the floor using a cassette holder, and a gravity line is shown using a metal chain (white arrow)

The patient was placed in the supine position with the contralateral hip flexed to 90°. If the patient could not flex the contralateral hip to 90°, it was taken with the hip flexed as much as possible. The direction of the radiation beam was parallel to the examination table and at 45° to the long axis of the body (black arrow) as shown in Figure 2. An X-ray film was held perpendicular to the floor using a cassette holder, and a gravity line is shown using a metal chain (white arrow) as in Figure 2.

All CT scans included scanning by Antero-posterior tomogram as well as axial images of both acetabulum and femur. All angles were measured at CT work station (64 slice MDCT GE [General Electricals] Light Speed VCT XTE, April 2010, Wisconsin USA). The tomogram through the center of the acetabulum was selected for measurement of the acetabular anteversion angle, which is defined as the ventral orientation of the acetabulum related to the sagittal plane. A measuring point was assigned at the anterior edge of the acetabulum and a second at the posterior edge. The line connecting these points were drawn, and the angle formed by this line and the plane sagittal to the pelvis determined as the acetabular anteversion angle.

## Methods to calculate the version

### Lewinnek's method

Version = arc sin (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. Therefore, Lewinnek's method is more convenient for clinical practice and was used in the current study to calculate version angles.

Woo and Morrey's method.

This method uses cross-table lateral radiographs to measure the version of the component, 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.

The imaging data of CT scans for each case was anonymized prior to interpretation and stored in an online database where patient identification was removed, and the interpreting radiologists were blinded to prior measurements. The protocol was approved by our institution's ethics committee and written informed consent was obtained from each patient.

**Statistical Analysis:** Patient characteristics were summarized using means and standard deviations for continuous variables and frequencies and percentages for discrete variables. Pearson's coefficients were determined to quantify the correlations between radiographic assessments of acetabular version on AP, cross-table lateral views. The mean differences and standard deviations between AP and Cross Table Lateral radiographs anteversion measurements were calculated. The comparison of normally distributed continuous variables between the groups was performed using Student's t-test. Nominal categorical data between the groups were compared using the Chi-square test or Fisher's exact test whichever was found appropriate. Non-normal distribution continuous variables were compared using Mann Whitney U test, Odds ratio and 95% confidence interval was also calculated. For all statistical tests, a p-value less than 0.05 was taken to indicate a significant difference.

## Results

In this study, anteversion angles calculated on cross table lateral radiographs had mean anteversion angle of 22.41° (Range 16 – 56°), mean angle of anteversion calculated on AP

Radiographs was 23.48° (Range 11-39°), and as calculated on CT Scan had mean angle of 28.64° (Range 11.10 – 50.10°). At final post-op follow-up 63.63% patients had excellent HHS, 23.63% patients had good whereas 6 10.90% patients had fair HHS post-operatively. Improved post-operative WOMAC score in 98.1% patients to excellent score. 78.1% patients had excellent OHS (40-48) post-operatively whereas 20% patients had good OHS (30-39). This was found to be statistically significant (p value 0.038). The correlation between anteversion angles measured on CT Scan and cross table lateral radiographs using Woo & Morrey's method was found to be significant (p value 0.02). The correlation between anteversion angles measured on CT scan and anteroposterior radiographs using Lewinnek's method indicated significant results (p value 0.046). Patients with higher BMI in our study had trend towards decreased anteversion angles. However, there was no significant correlation between BMI of the patient and anteversion angle. In this study, 40% patients had excellent Harris Hip score with anteversion angle in range of 24.1-36° as measured on CT scan whereas 16.3% patients had excellent outcomes in range of 12.1-24° of anteversion; 58.18% patients reported excellent WOMAC Score in anteversion angle in range of 24.1-36°, whereas 27.2% patients reported excellent outcomes in range between 12.1-24° of anteversion; 50.9% patients reported excellent Oxford Hip Score with anteversion angle in range of 24.1-36°, whereas 16.3% of the patients reported excellent outcomes in range between 12.1-24°.

**Table 1:** Shows in intra class coefficient, reliability ( $\alpha$ ) and p value

	Infra class Coefficient	Reliability ( $\alpha$ )	p value
CT vs. X-ray lateral	0.658	0.794	<0.0001***
CT vs. X-ray AP	0.604	0.301	<0.0001***

Precision analysis was performed using intraclass correlation coefficients (ICCs) and spearman's rho. There was excellent intra-observer reliability for both Woo and Morrey's cross table lateral radiographs (ICC = 0.658, p <0.0001) and Lewinnek's method on anteroposterior radiographs (ICC = 0.604, p <0.0001). On CT scan measurement spearman's rho coefficient was 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). CT had a high intra- and interobserver reliability, supporting this as the ideal method for measuring acetabular anteversion.

## Discussion

Measuring the acetabular component position after total hip arthroplasty (THA) is commonly performed as part of the routine postoperative follow-up and as part of the assessment of the malfunctioning THA. The assessment of the acetabular component position is based on a combination of the inclination and anteversion angles. Pelvic computed tomography (CT) scans have been shown to be the most accurate assessment of the component position [11]. However, there still exists a dearth of literature regarding the effects of acetabular component positioning on hip functional outcome scores and till date patient satisfaction as a primary outcome in relation to acetabular version has not been done. Reikeras *et al.* [12] concluded that cross-table radiography provides acceptable information for clinical use. Reikeras *et al.* [13] studied that the range of acetabular component anteversion actually achieved by the use of a cup positioner by the freehand technique in many cases was not within the intended range of 10 to 30°. In our study, we used Lewinnek's method [14] which was found to be consistent with CT scans values of measured anteversion angles. Nishino *et al.* [15] postulated that

AP radiographs are better than cross-table lateral radiographs. Nho *et al.* [16] recommended the use of Lewinnek's, Woo and Morrey's method, for measuring the anteversion of acetabular component. Arai *et al.* [17] compared Lewinnek's method with Woo Morrey's method and concluded that there was a difference of an average of 5.80 between angles measured on cross-table lateral radiographs and those measured on AP radiographs of the hip joint. Maheshwari *et al.* [18] in their study on Indian population measured mean acetabular anteversion of normal hips to be 19° (Range 8-35°) which was comparable to measured angle on normal non operated hips in our study. The best functional outcomes as reported by the patients on the basis of functional scores in our study was in the wider range of 12.1-36° of anteversion, which is similar to studies done in recent past. Therefore, our study supports the notion that Lewinnek's safe zone is not a reliable predictor of stability and there is no absolute specific safe zone for acetabular component positioning. We also found that in the freehand placement of acetabular cups only a minority of the cups could be placed in Lewinnek's safe zone as seen in 30.90% of the patients.

**Table 1:** Shows in Study and Ideal Anteversion

Study	Ideal Anteversion
Lewinnek <i>et al.</i>	15° ± 10°
Dorr <i>et al.</i>	15° ± 15°
McCollum and Gray	30° ± 10°
Biedermann <i>et al.</i>	15° ± 10°
Barrack <i>et al.</i>	20° ± 10°
Widmer and Zurfluh	20°-28°
Present study	30 ± 6°

Goyal *et al.* [19] demonstrated significant improvement in HHS total score. The absolute position of the cup showed a very weak yet significant positive correlation in between cup anteversion and HHS pain (p=0.01), HHS function (p=0.001) and HHS total score (p=0.001). The mean anteversion was 21.8 ± 11.80 in their study compared to mean of 28.64° (Range 11.10-50.10°) in our study. The ideal position of the acetabular component is still debated in the literature. Previous studies have not examined patient satisfaction as a primary outcome. Our study shows significant improvement in post-operative HHS in terms range of motion, pain relief as reported by patients. Our study also shows that the Lewinnek's "safe zone" does not have any direct effect on patient outcome score. Quintana *et al.* [20] have shown that the minimal clinically important difference (MCID) for WOMAC is between 25.91 and 29.26 points for patients with primary total hip arthroplasty. In our study, anteversion angles in the range of 24.1-36° which is well outside the Lewinnek's safe zone reported excellent WOMAC scores which is comparable to a study done by Goyal *et al.* In our study, anteversion angles in range 30±6° had excellent outcomes which are fairly comparable to the study done by Sculco *et al.* and Grammatopoulos *et al.* [21, 22] In our study, the anteversion was measured in relation to the horizontal plane, and we assumed that the patient positioning was in parallel plane. Pelvic tilting and rotation of pelvis possibly while performing cross table lateral where contralateral hip is flexed can lead to tilting of pelvis during imaging can possibly lead to a change in radiographic projection and distort the measurement. Moreover, measurement done on radiographs was manual using a goniometer which theoretically can contribute to error if any in measurement when compared to more precise measurements done in CT console. In our study, possible reason for difference in measurements of anteversion angles could possibly be due to pelvic tilt (PT) although every possible precaution was taken to eliminate it. It has been

found that there is a linear relationship between changes in PT and functional anteversion, anterior PT reduces functional component anteversion by approximately 0.74° per degree of PT, while posterior PT increases it by the same amount [23].

### Optimal Range of Anteversion

In our study, anteversion angles ranged from 11.10– 50.10° with 30.90% patients in Lewinnek safe zone. Saxler *et al.* [24] concluded that safe position as defined by Lewinnek *et al.* was only achieved in a minority of the cups that were implanted freehand. Danoff *et al.* [25] advocated a sweet spot safe zone of 17.10° of anteversion. Abdel *et al.* [26] concluded that the historical target values for cup inclination and anteversion may be useful but should not be considered a safe zone given that the majority of these contemporary THAs that dislocated were within those target values. Cotong *et al.* [27] did a survey and concluded that strict usage of the Lewinnek "safe zone" cannot be justified. We too believe that ideal cup position varies from patient to patient. Our study is the first to calculate acetabular anteversion in patients operated by posterolateral approach with freehand technique. Also we have assessed functional outcomes by HHS, WOMAC and OHS and correlated this with version angles calculated on cross table lateral radiographs using Woo & Morrey's method, AP radiographs using Lewinnek's method and CT scan. There are limitations of this study. The first limitation was that we used goniometer to measure angles on radiographs instead of more precise computer softwares. We used free hand techniques on the basis of visual cues instead navigation controlled implantation of acetabular cup or mechanical alignment guides. There is a bias in the measurements of anteversion using radiographs which is inevitable when measuring a 3D object with a 2D projection. In our study, AP radiographs have also been used for measurement of acetabular component anteversion. However, this use of AP radiographs also has some disadvantages. It is difficult to identify the apex of the ellipse on AP radiographs, depending on the articulation type or the extent of the anteversion. If we had used the template software, we might have been able to more accurately measure anteversion on AP radiographs. The patient's position during radiography influences the measurements. We largely eliminated the patient positioning variables (pelvic tilt and rotation) which produce error in clinical practice. These limitations must be taken into consideration when our results are applied in clinical practice. The study design was reviewed by our institutional review board, which restricted the case number because of the radiation hazard and cost of CT scans, further we did not perform multiple CT scans on the same patients because of concern for radiation exposure; thus, we have no repeatability data for the CT scans. Our study is one of the few studies done in the past which measures patient reported functional outcomes as a function of anteversion angle. In present study, we used both AP and Cross table lateral radiographs to validate the version angles measured thereby decreasing the observer bias. Defining the optimal cup position is challenging. A good understanding of anatomic, patient and implant related factors that affect the "optimal" cup position is mandatory. Creating a stable THA remains a balancing act among appropriate component positioning taking into account individual patient bony and muscular anatomy in both the static and dynamic state, soft tissue balance and tensioning, and appropriate aftercare and rehabilitative efforts. Considering the advantages of plain radiography, including low cost, low radiation level, and convenience for clinical follow-up and assessment of prosthesis position we recommend the use of Lewinnek's method and Woo & Morrey's method as they provide

reproducible and accurate data compared with CT. We believe that the safe zone should be tailored to the surgical approach used. It has been observed that 20-25% of patients subject their hip to deep seating and even go for squatting against advice. To avoid dislocation, the anteversion was kept about 10 degrees above the normal. If we had to err, it was towards more anteversion. This was coupled with myocapsuloplasty, as a result we had no dislocation in our patients. Further research is encouraged to investigate the ability of emerging technologies to assist surgeons in optimally positioning the acetabular components. Functional outcome measurements with improved resolution may be of great importance for clinical research in the future.

### Conclusion

There should be flexibility in positioning the acetabular component than previously believed. If one has to err, it should be towards more anteversion. In fact to avoid dislocation, more anteversion is required to guard against unwarranted activities on part of the patient. The anteroposterior as well cross-table lateral radiographs can be used as a surrogate method for measuring the anteversion angle compared to CT Scan as it avoids radiation exposure and lessens the cost.

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