

## Femoral Anteversion in THA and its Lack of Correlation with Native Acetabular Anteversion

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**Abstract** Several studies support the concept that, for optimum range of motion in THA, the combined femoral and acetabular anteversion should be some constant or fall within some “safe zone.” When using a cementless femoral component, the surgeon has little control of the anteversion of the component since it is dictated by native femoral anteversion. Given this constraint, we asked whether the surgeon should use the native anteversion of the acetabulum as a target for implant position in THA. Forty-six patients scheduled for primary THA underwent CT scanning and preoperative planning using a computer workstation. The native acetabular anteversion and the native femoral anteversion were measured. Prosthetic femoral anteversion was measured on the workstation by three-dimensional templating of a straight-stemmed tapered implant. The mean of the sum of the native acetabular anteversion and native

femoral anteversion was 28.9°; however, 17% varied by 10° to 15° and 11% by more than 15°. The mean of native femoral anteversion and prosthetic femoral anteversion was 13.8° (range, -6.1°–32.7°) and 22.5° (range, 1°–39°), respectively. Based on our data, we believe the surgeon should not use the native acetabular anteversion as a target for positioning the acetabular component.

### Introduction

There is considerable debate in the literature about the best target position for the acetabular component when performing THA. Most surgeons use bony landmarks that are visible or palpable, as well as some target value of inclination and anteversion. That target is usually 40° to 45° of inclination and 15° to 20° of anteversion as estimated visually by the surgeon, unless computer navigation is used to measure the values. Ranawat [5] popularized the concept that the combined anteversion of the femoral and acetabular components should be some constant (approximately 45°) and described a maneuver to allow the surgeon to visually determine if this condition is met. Others, such as Widmer and Zurfluh [12], Yoshimine [13], and Malik et al. [6], have developed so-called “safe zones” for the combined anteversion of the cup and stem.

In cementless THA performed manually, the surgeon has little control of the anteversion of the femoral component, since it tends to be dictated by the shape of the proximal femur. A so-called “best fitting” straight-stemmed femoral component must negotiate the twist and bow of the proximal femur. Therefore, there may be a difference between the anteversion of the final position of the femoral prosthesis and the native anteversion of the femoral neck.

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Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at The Sutter Institute for Medical Research and at UC Davis.

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We asked two questions: (1) Is there a difference between the anteversion of a “best-fit” cementless femoral stem (“prosthetic femoral anteversion”) and the native femoral anteversion, and if so, how well do they correlate? And (2) is there a relationship between the anteversion of the native acetabulum and native or prosthetic femoral anteversion? The clinical corollary to the second question is: Should the surgeon use the native anteversion of the acetabulum as a target for implant position in THA?

## Patients and Methods

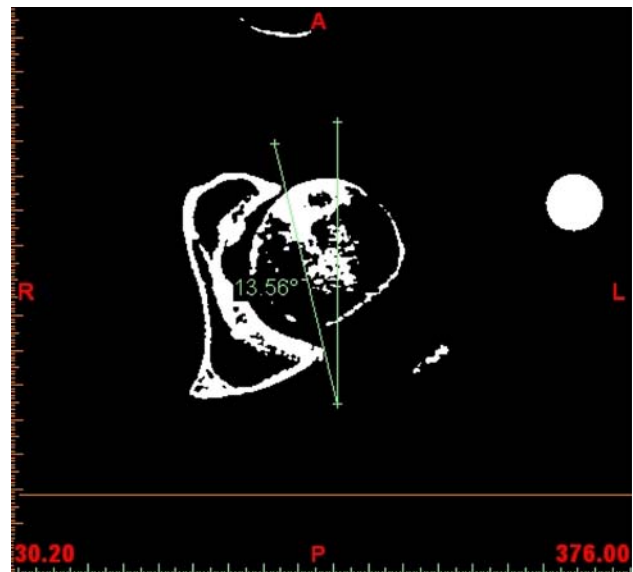
This study analyzed CT images obtained during a randomized clinical trial. From February 2001 through July 2004, we enrolled 46 patients in a US Food and Drug Administration (FDA) randomized controlled study to compare patients whose cementless THAs were performed using the ROBODOC® Surgical Assist Device (Curexo Technology Co, Sacramento, CA) with those performed manually [1]. Those in the ROBODOC® arm of the study underwent preoperative computed tomography (CT) scanning and preoperative planning using the ORTHODOC® computer workstation (Curexo Technology Co). The CT scans of these 46 patients form the basis of the present study. Criteria to participate in this study were patients with primary osteoarthritis or avascular necrosis who were candidates for THA using a cementless femoral component. We excluded patients if they had rheumatoid arthritis, prior infection, severe dysplasia, or prior surgery on the affected hip. During the same study time period, the senior author (WLB) performed 422 primary THAs. There were 31 men and 15 women with a mean age of 61 years (range, 42–77 years). Thirty-nine patients had a diagnosis of primary osteoarthritis, three had mild dysplasia and severe degenerative joint disease, one traumatic arthritis, one ankylosing spondylitis and one avascular necrosis.

All CT scans were performed such that every patient was supine and symmetrically positioned in the scanner as shown by the scout views. The images were imported into a previously validated three-dimensional rendering software (Mimics®; Materialise, Ann Arbor, MI) in generic DICOM (Digital Imaging and Communications in Medicine) format [2]. The scans included the affected hemipelvis, the proximal femur, and the knee. The femora were then converted to three-dimensional models such that the three-dimensional femoral neck axis could be defined according to the methods of Sugano et al. [10].

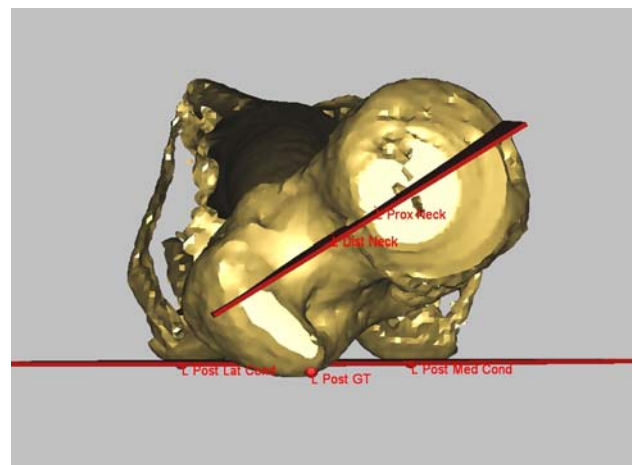
The anatomic acetabular anteversion as defined by Murray [7] was measured on the axial CT images for each hemipelvis and was defined as the native acetabular anteversion (Fig. 1). Osteophytes were excluded and only the native walls of the acetabulum were used for the

measurements. Since the entire pelvis was not available on the scans, the anteversion was measured relative to the anteroposterior sagittal axis of the patient within the scanner.

To measure the native femoral anteversion we established points and planes on the femur using the anthropometric analysis module of the software. These included the inferior and superior points of the femoral neck axis, the posterior tip of the greater trochanter, and the posteromedial and posterolateral femoral condyle tips (Fig. 2). From these values, a coronal femoral plane was established that would simulate placing the femur on a flat



**Fig. 1** An image shows the measurement of the native acetabular anteversion.



**Fig. 2** An image shows the measurement of the native femoral anteversion. Abbreviations are as follows: L = left; Prox = proximal; Dist = distal; Post = posterior; Lat = lateral; Cond = condyle; GT = greater trochanter; Med = medial.

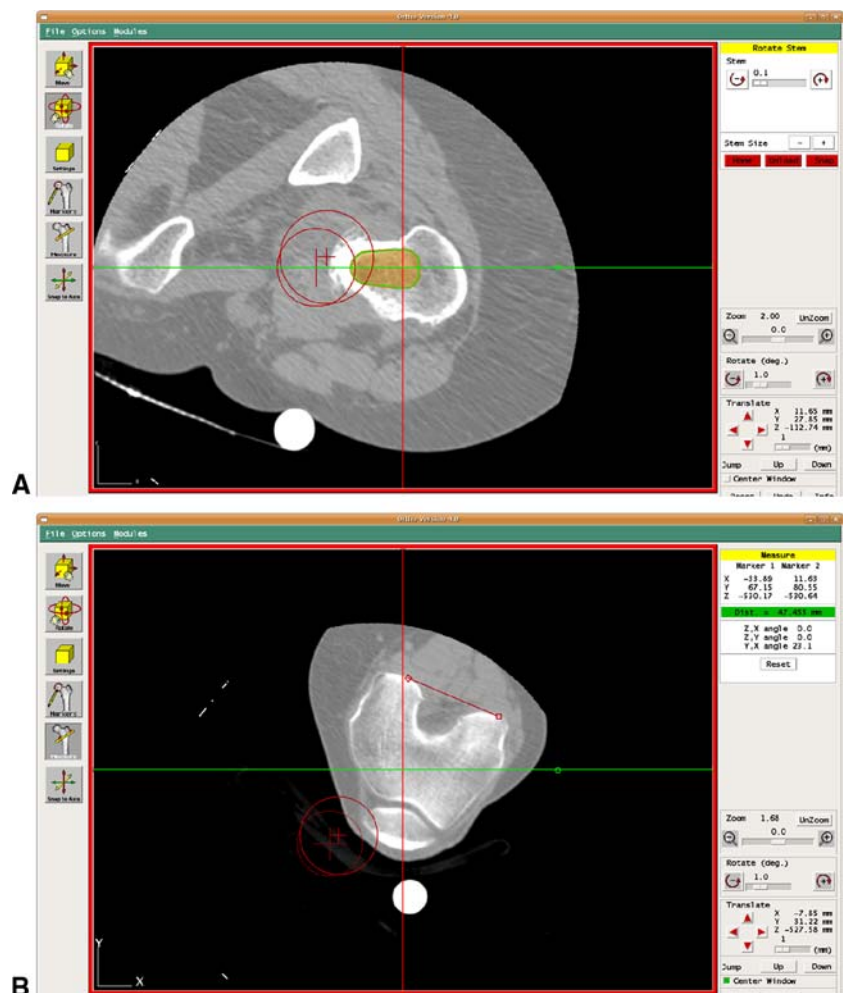
surface with three-point contact of the posteromedial and posterolateral condyles and the posterior greater trochanter. A femoral axial plane was established perpendicular to the coronal plane. A femoral neck anteversion axis was established that included the femoral neck axis points and was perpendicular to the femoral axial plane. In this way, the femoral neck anteversion plane varied from the coronal plane in only one degree of freedom. The angle between the femoral coronal plane and the femoral neck anteversion plane was defined as the native femoral anteversion.

The prosthetic femoral anteversion was determined by three-dimensional templating on ORTHODOC<sup>®</sup> [4] using templates of a single cementless femoral component (Fiber Metal Taper; Zimmer Inc, Warsaw, IN). This is a straight, tapered cementless stem that fills the metaphysis and proximal diaphysis in the mediolateral plane. The senior author performed the templating, selecting the “best” size and position of the component to address optimum fit and fill, as well as leg length, offset, and anteversion. Before the templating for this study, the senior author had participated in an earlier FDA study using the same criteria;

therefore we do not believe there is any effect of a learning curve in this study. Since this stem fills the metaphysis from medial to lateral, the position of the stem is dictated in part by the native femoral neck anteversion, but the final position of the “best-fit” stem is a compromise of fitting a straight stem down the canal of the femur, addressing the twist and bow of the proximal femur. The anteversion of the final position of the femoral component was measured on the ORTHODOC<sup>®</sup> workstation by adjusting the view to be looking down the longitudinal axis of the implant and measuring the angle of the prosthetic femoral neck relative to the posterior condyles of the knee (Fig. 3).

Scatterplots and Pearson’s correlation coefficients were used to evaluate the association between native acetabular anteversion and prosthetic femoral anteversion, between native acetabular anteversion and native femoral anteversion, and between native and prosthetic femoral anteversion. Frequency distributions were calculated for the above groups as to the number of values placing less than 5°, between 5° and 10°, between 10° and 15°, and greater than 15°. The coefficient of determination,  $r^2$ , and

**Fig. 3A–B** (A) An ORTHODOC<sup>®</sup> screen shot axial view shows a template of the “best-fit” femoral component. (B) An ORTHODOC<sup>®</sup> screen shot axial view of the knee indicates the plane of the posterior condyles.



the sample correlation coefficient,  $r$ , were determined. All analyses were performed with a standard statistical software package (StatView®; SAS Institute Inc, Cary, NC).

## Results

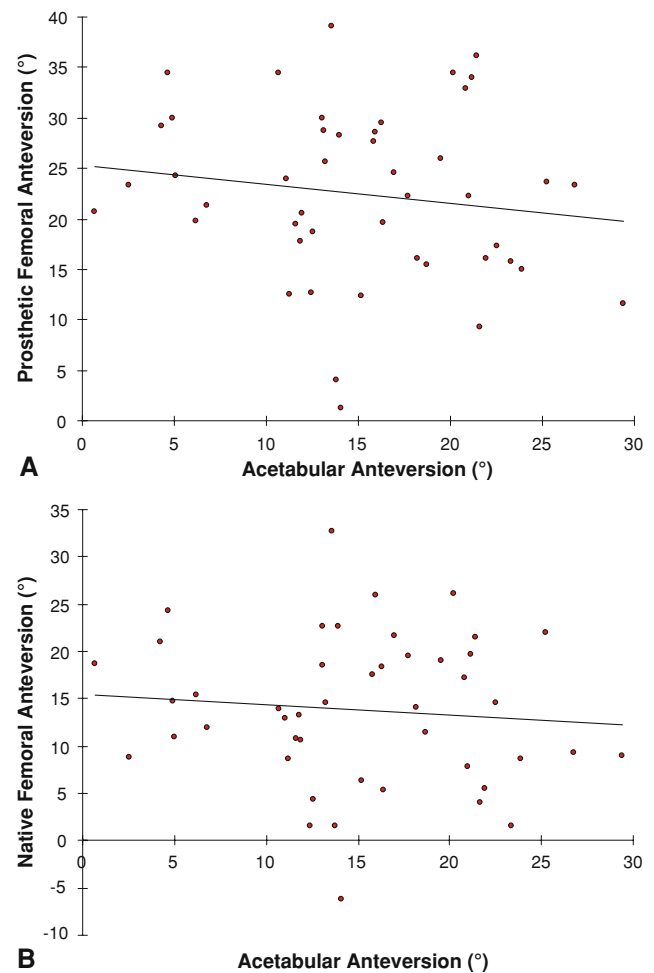
The mean of the measured native acetabular anteversion was  $15.1^\circ$  (range,  $0.71^\circ$ – $29.4^\circ$ ; standard deviation (SD),  $6.7^\circ$ ). The mean of the native femoral anteversion was  $13.8^\circ$  (range,  $-6.1^\circ$ – $32.7^\circ$ ; SD,  $7.9^\circ$ ), whereas the mean of the prosthetic femoral anteversion was  $22.5^\circ$  (range,  $1.0^\circ$ – $39.0^\circ$ ; SD,  $8.5^\circ$ ). The mean of the sum of the native acetabular anteversion and native femoral anteversion was  $28.9^\circ \pm 9.8^\circ$  (Table 1); however, there was wide variation, with 33% differing from the mean by less than  $5^\circ$ , 39% by  $5^\circ$  to  $10^\circ$ , 17% by  $10^\circ$  to  $15^\circ$ , and 11% by greater than  $15^\circ$ . The mean of the sum of the native acetabular anteversion and the prosthetic femoral anteversion was  $37.5^\circ \pm 10.0^\circ$ .

The correlation between native acetabular anteversion and native and prosthetic femoral anteversion was  $r = 0.094$  ( $p = 0.54$ ) and  $r = 0.148$  ( $p = 0.33$ ), respectively (Fig. 4). The correlation of 0.148 between acetabular anteversion and prosthetic femoral anteversion has 17% power with our sample size of 46 patients.

The native femoral neck anteversion correlated ( $r = 0.831$ ,  $p < 0.0001$ ) with the prosthetic neck anteversion (Fig. 5). The difference between native and prosthetic femoral anteversion was less than  $5^\circ$  in 28%,  $5^\circ$  to  $10^\circ$  in 28%,  $10^\circ$  to  $15^\circ$  in 37%, and greater than  $15^\circ$  in 7%.

## Discussion

The typical surgical technique used by many surgeons is to place a best-fitting implant into the femoral canal and then place the acetabular component in line with the native acetabular anteversion. For this technique to result in optimum range of motion, the combined native acetabular and prosthetic femoral anteversion should have some relationship such that their sum is a constant or falls into a “safe zone” as described by several authors [5, 6, 12, 13].

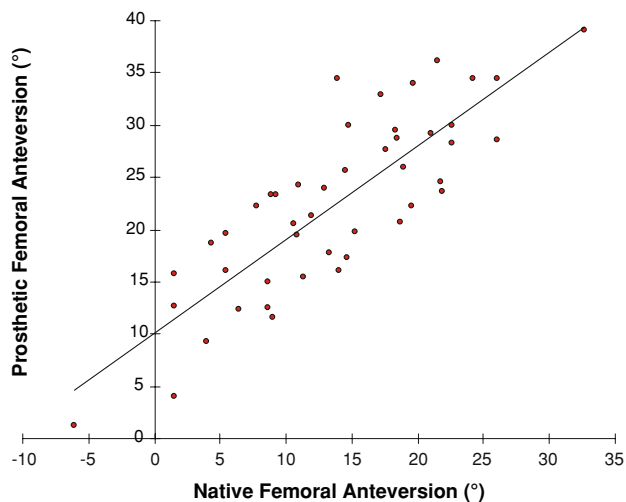


**Fig. 4A–B** (A) A scatterplot shows the correlation of prosthetic femoral anteversion to acetabular anteversion ( $p = 0.33$ ,  $r^2 = 0.022$ ,  $\alpha = 0.01$ ). (B) A scatterplot shows the correlation of native femoral anteversion to acetabular anteversion ( $p = 0.54$ ,  $r^2 = 0.009$ ,  $\alpha = 0.01$ ).

We therefore asked two questions: (1) Is there a difference between the anteversion of a “best-fit” cementless femoral stem (“prosthetic femoral anteversion”) and the native femoral anteversion, and if so, how well do they correlate? And (2) is there a relationship between the anteversion of the native acetabulum and native or prosthetic femoral

**Table 1.** Descriptive statistics ( $n = 46$ )

Measurement (°)	Mean	Minimum	Maximum	Standard deviation
Acetabular anteversion	15.1	0.71	29.4	6.7
Native femoral anteversion	13.8	-6.1	32.7	7.9
Prosthetic femoral anteversion	22.5	1.0	39.0	8.5
Difference between native femoral anteversion and prosthetic femoral anteversion	8.7	1.8	20.5	4.8
Acetabular anteversion + native femoral anteversion	28.9	8.0	47.2	9.8
Acetabular anteversion + prosthetic femoral anteversion	37.5	15.3	57.5	10.0



**Fig. 5** A scatterplot shows the correlation of prosthetic femoral anteversion to native femoral anteversion ( $p = 0.0001$ ,  $r^2 = 0.69$ ,  $\alpha = 0.01$ ).

anteversion? The clinical corollary to the second question is: Should the surgeon use the native anteversion of the acetabulum as a target for implant position in THA?

There are several limitations to this study. First, we included only the hemipelvis and affected femur on the scans. We therefore assumed the patient's position in the CT scanner was such that the pelvis was not tilted and the anterior pelvic plane was parallel to the floor of the gantry. It would have been best if the entire pelvis was scanned, but this was not the protocol for the ROBODOC<sup>®</sup> study at the time the CT scans were obtained. Second, the three-dimensional templating performed on the ORTHODOC<sup>®</sup> workstation was performed by a single surgeon and the "best-fit" position of the femoral component was determined by his judgment. Third, the data may also be limited to the specific femoral component used in this study, but its design is not dissimilar to many other straight-stemmed tapered implants currently on the market. Fourth, we made no repeatability or intraobserver variability data for the CT measurements on the acetabulum or the femur. Fifth, our sample size is small. The statistical power for the correlation of the femoral and acetabular anteversion is only 17%. To achieve 80% power, we would have needed 350 patients, which was not feasible to obtain. Despite the low power of the study, we do not consider a correlation of 0.148 clinically meaningful. Finally and most importantly, the clinical relevance of this study is dependent on the assumption that the various papers proposing the use of combined femoral and acetabular anteversion for optimal position of the implants are correct.

Our measurements of native femoral and acetabular anteversion are similar to those measured by others. Sugano et al. [10] cite "true" femoral anteversion to be

$19.8^\circ \pm 9.3^\circ$ . Tönnis and Heinecke [11] cite normal femoral and acetabular anteversion to be  $15^\circ$  to  $20^\circ$ . Stem et al. [9] report mean acetabular anteversion to be  $23^\circ$  (range,  $12^\circ$ – $39^\circ$ ; SD,  $5^\circ$ ). Murtha et al. [8] measured normal full rim anteversion of the acetabulum to be  $18.1^\circ \pm 5.8^\circ$ . Jamali et al. [3] in a study of cadaveric specimens reported the anatomic anteversion of the central acetabulum to be  $20.1^\circ \pm 6.4^\circ$ . No other published study, however, has attempted to correlate native acetabular with femoral anteversion.

In answer to the first question posed by this study, the mean prosthetic femoral anteversion was greater than the mean native femoral neck anteversion by  $8.7^\circ$ , but it is important to recognize this is not always the case. The correlation coefficient was high, but there is substantial variation between the two, as indicated by the result showing 37% of cases had a difference of  $10^\circ$  to  $15^\circ$ . Therefore, the surgeon, when using a straight-stem femoral component that fills the metaphysis in the medial-lateral plane, should not use the native femoral anteversion to predict the anteversion of the femoral component.

The answer to the second question is that there was no correlation between the native or prosthetic femoral anteversion and the native acetabular anteversion. This means, if the surgeon aligns the acetabular component with the anterior and posterior walls of the native acetabulum, the combined anteversion will frequently be outside the safe zones as described by Ranawat in Lucas and Scott [5], Widmer and Zurfluh [12], Yoshimine [13], and Malik et al. [6] [1–4]. Therefore, assuming these authors are correct, the answer to the corollary question is: No, the surgeon should not use the native acetabular anteversion as a target for positioning the acetabular component. Instead, this study would support using the prosthetic femoral anteversion as a guide for the best target position of the acetabulum.

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