Trans-lateral Decubitus Radiograph of the Hip: A New View to Measure the Version of the Femoral Stem

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Research article

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Abstract

Background We developed a radiological method, trans-lateral decubitus view, to measure stem version and assessed its reliability as well as the validity.

Methods Trans-lateral decubitus view of the hip was a lateral radiograph, which was taken with the patient in lateral decubitus position, hip extension, 90° knee flexion and patella facing forward. In 40 patients, who underwent total hip replacement (THR), a trans-lateral decubitus view and CT scan of the hip were taken. Three observers measured stem neck-shaft angle (α) on hip AP view, and the stem anteversion (β), which was the angle between the axis of stem neck and axis of the femur, on the trans-lateral decubitus view. The stem version (θ) was calculated using the formula; θ = arc ((tan (180°-β) /tan (180°-α)). The intra and inter-observer reliabilities of each measurement were examined. The radiological measurements were compared with those on the CT scan to evaluate their validity.

Results The mean stem anteversion on radiological measurement was 23.72° (SD 8.17) and the mean CT measurement was 23.91° (SD 10.25) ($p = 0.929$). The intra- and interobserver reliabilities of the radiological measurements were 0.934 and 0.931, respectively. Those of CT measurements were 0.941 and 0.942, respectively. When the radiological anteversion was between -30° and 30°, the correlation coefficient between radiological measurements and CT measurements was 0.729 ($p = 0.001$).

Conclusion The trans-lateral decubitus method appears reliable and valid for the measurement of femoral stem version. Trial Registration: NCT02554149 (29 March 2016).

Introduction

Implant malposition is an important risk factor for dislocation after total hip replacement (THR) and accurate assessment of implant position is critical to determine whether to change the implant in dislocating THR. [1–12] Although computerized tomography (CT) scan is accurate in the measurement of the acetabular and femoral component position, it has definite limitation due to cost and risk of radiation hazard. [13–16] Several studies reported radiological methods to measure the abduction and version of the acetabular component using plain radiograph. However, measurement of the stem version on radiographs is still difficult and controversial. [17–22]

To date, only two protocols were introduced for the radiological measurement of stem version. In 1957, Budin and Chandler developed a radiological measurement of femoral neck anteversion in children. In 2012, Lee et al. suggested a modified Budin method to measure the stem version on radiograph. However, it requires a special radiological view and is not applicable in patients with high body mass index (BMI) and those who cannot abduct the hip joint. [23] Recently, Weber et al. reported measurement methods of the stem version on anteroposterior (AP) radiographs using a computer program and mathematical formulas. [24]- [25] However, this method required a true lateral radiograph with highly standardized technique for its precise measurement and it is difficult to differentiate between anteversion and retroversion.

Therefore, simple and reliable measurement method of stem version using radiograph has been warranted. The purpose of this study was to develop a radiological method (trans-lateral decubitus radiograph) to measure stem version and to assess its reliability as well as the validity.

Materials And Methods

This prospective study was approved by our institutional review board, and informed written consent was obtained from patients, who participated in the study. The study was registered in the ClinicalTrials.gov Protocol Registration System (NCT02554149).

A total of 49 consecutive patients, who underwent primary THR from October 2015 to January 2016, were recruited. Among them, four patients withdrew informed consent, 9 patients refused postoperative CT scan, and the remaining 36 patients participated in the study. Two surgeons performed surgeries using a posterolateral approach. A cementless acetabular component (Mirabo; Corentec, Seoul, South Korea), a cementless stem (Bencox M; Corentec), a ceramic liner (BIOLOX Delta; CeramTec AG, Plochingen, Germany), and 32 or 36-mm ceramic head (BIOLOX Delta; CeramTec AG) were used in all hips. Postoperative hip radiographs and CT scans were taken 5 days after THR.

Trans-lateral decubitus view

We developed trans-lateral decubitus view, which shows a true lateral image of the proximal femur. The patient was placed in a lateral decubitus position on the affected side. The affected hip was extended and the ipsilateral knee was flexed about 90°. A foam-block was placed below the opposite leg to maintain the opposite hip at 100° flexion and 30° abduction (Fig.1A). In this position, the intercondylar axis was placed in the vertical plane and a true lateral image of the proximal femur could be obtained (Fig.1B-C). The source-to-film distance was 100 cm. All images were digitally acquired using the Picture Archiving and Communication System (PACS) (Infinitt: Infinitt Healthcare, Seoul, Korea), and all radiological measurements were made on a 19-inch LCD monitor using the PACS software.

Limitation of trans-lateral decubitus view

The real stem anteversion ($\theta(a)$) is defined as angle between the condylar axis (line) and axis of the stem trunnion (dot line) (Fig. 2). [23]

The radiographic stem anteversion (θ) can be calculated from the projected angle on the lateral image of the femur using a formula: stem anteversion = f (projected stem anteversion on lateral view).

To measure the radiographic stem anteversion, the full length of the femur including femoral condyles as well as stem should be seen in the radiograph. However, only the proximal half of the femur is seen and the femoral condyles are not seen on the decubitus lateral view. Therefore, it is hard to know the sagittal axis of the femur in the decubitus hip image (Fig.3).

Preliminary study to identify the sagittal axis of the femur in the trans-lateral decubitus view

In order to measure an anteversion on this lateral view, we should know the relationship between the axis of the entire femur (entire femoral axis) and that of the proximal femur (proximal femoral axis) in the sagittal plane. Thus, a preliminary study was conducted to reveal the relationship between the two axes. The entire femoral axis and the proximal femoral axis were drawn on lateral image of the femur of 40 patients, who underwent primary THR from June 2015 to August 2015, and the angle between the two axes were measured. The angle ranged from 13.8° to 16.5° with an average of 15.0°.

Radiographic measurement of the stem anteversion on the trans-lateral decubitus image

On the decubitus lateral view, the stem-neck axis was defined as the line between the centre of the modular head and the centre at the base of the trunion of the stem.

The radiologic anteversion on decubitus lateral view was defined as the angle between the axis of the stem trunnion (Line A) and the axis proximal shaft (Line B) (Fig. 4A).

The radiological anteversion of the stem on decubitus lateral view was obtained by subtraction of the mean difference angle of 15° from the angle between a short axis (black dot line) and a stem-neck axis (white line) (Fig. 4B).

Calculation of real stem anteversion from radiological stem anteversion

We measured stem neck-shaft angle on both hip anteroposterior radiograph. Then, we calculated the stem anteversion (θ) using the formula by Ogata and Goldsand. [26] In brief, α = 180°- neck-shaft angle on AP view. β = 180°- radiological anteversion of the stem on translateral decubtus view. Then, tan θ (stem version) = tan β /tan α, and θ = arctan [θ], where arctan is the inversion of the tangent. They described α (Equation 1) and β (Equation 2) as supplementary angles to what we calculated as neck-shaft angles, which we then corrected for in our equations. We used Microsoft Excel (Microsoft Inc, Redmond, WA, USA) to perform the calculations as follows:

- Equation 1: 180°- neck-shaft angle of the stem (132° or 135°) = α
- Equation 2: 180°- radiological anteversion of the stem (θ) = β
- Equation 3: “θ = TAN (RADIANS [β])/TAN (RADIANS [α])" “tan θ = tan β /tan α
- Equation 4: “Anteversion = DEGREES(ATAN [θ])

Measurement of true stem anteversion on CT scan

Stem anteversion was measured with use of three cross-sectional CT images. The angle between the axis of the stem neck and the posterior intercondylar line was defined as the CT anteversion of the stem. In previous study of Lee et al. [23], we have described a method for measuring stem anteversion using three cross-sectional CT images.

The standard acquisition protocol for CT scans was as follows: for cross-sectional CT a collimation of

0.625 mm was used; the field of view at acquisition was 30 cm, and slice thickness was 0.67 mm with

0.33 mm increments (50% section overlap). We could reduce CT radiation dose by one third by scanning only two sections from antero-inferior iliac spine (AIIS) to 10cm below of the lesser trochanter and range from the top to bottom of condyle on femur.

Comparison between the radiological stem anteversion and CT stem anteversion

The stem anteversion was measured on radiographs and CT scans by three independent in a random order. The observers were unaware of any information with regard to the patient’s clinical data or the measurement results derived from other observers. The mean value of three measurements by each observer was regarded as the stem-neck anteversion. The CT anteversion was used as the reference standard.

Assessment of reliability and validity

To assess intra-observer reliability, all CT images and radiographs were re-evaluated by one observer 3 weeks after the first assessment. Interobserver reliability was assessed between the three independent observers. Convergent validity was defined as proximity of the radiological anteversion measurements to the reference standard of CT measurements. Correlations between radiological and CT measurements were, then, studied.

Statistical analysis

In this study, precision analysis was performed using intraclass correlation coefficients (ICCs) at a target value of 0.8 and a 95% confidence interval (CI) set at 0.2, and the minimum sample size was estimated to be 36 hips. [27] Intraclass correlation coefficients (ICCs) and their 95% CIs were used to summarise the interobserver reliabilities of single measurements. The intra- and interobserver reliabilities of the devised method were evaluated using the two-way random effects model assuming a single measurement and absolute agreement. An ICC of 1 means perfect reliability. To determine the convergent validity, anteversion from the proposed method on plain radiographs and anteversion from CT scans were compared using the paired *t*-test. In addition, Spearman's rho correlation coefficients were obtained and characterized as 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). Statistical analyses were conducted using SPSS v15.0 (SPSS Inc., Chicago, Illinois) and $p < 0.05$ was considered statistically significant.

Results

The thirty-six patients (19 men and 17 women) had a mean age of 59.8 years (SD 11.8; 27 to 84) and a mean BMI of 25.2 kg/m2 (SD 3.0; 18.8 to 30.9) at the time of operation. The primary diagnosis was osteonecrosis in 18 hips (50 %), and osteoarthritis in 18 hips (50 %) (Table 1).

There was no significant difference in mean anteversion between radiological and CT measurements (23.72°; SD 8.17) *vs* 23.91° (SD 10.25), respectively) (paired *t*-test, $p = 0.929$).

The intra- and interobserver reliabilities of the radiological measurements were 0.934 and 0.931, respectively. Those of CT measurements were 0.941 and 0.942, respectively (Table 2).

When the radiological anteversion was between –30° and 30°(Figs. 5A and B), the correlation coefficient between radiological measurements and CT measurements was 0.729 ($p = 0.001$). For practical use, we made a conversion table to obtain real stem version from radiological anteversion on translateral decubitus view (Table 3).

Discussion

Accurate assessment of implant position is important when evaluating a dislocating THA whether to change the implant position. This study demonstrate that modified stem version measurements using plain postoperative radiographs is more convenient and reproducible protocol comparing previously reported methods.

We developed more simple and convenient method for measuring stem version. The trans-lateral decubitus view in this study is obtained a true lateral image of the proximal femur that the patient was placed in a lateral decubitus position on the affected side. Comparing with previously reported methods such as modified "Budin views", they requires a special radiographic image causing additional exposure to radiation and is not applicable to patients who have a stiff hip or knee joint and overweight or obese patients. [23] In addition, recently reported new method using standard postoperative anteroposterior (AP) hip radiographs is calculated by the rotation-based change of the projected, prosthetic caput-collum-diaphyseal-angle (CCD*) using the mathematical formula Stem version = ARCOS [TAN (CCD*)/TAN (132)]. [28] However, this method is required for its precise and highly standardized measurement. Also, anteversion and retroversion cannot be differentiated. To distinguish between the 2 directions, a second radiographic plane such as true lateral x-ray is necessary.

Evaluation of stem version is also expected to be possible using a crosstable radiograph. In fact, some studies used crosstable radiographs for the measurement of stem version. [29,30] However, the angle between the prosthetic neck and the long axis of the body or femur on the crosstable lateral radiograph must be different from that of the stem version measured using CT, in which the angle of the prosthetic femoral neck relative to the posterior condylar line is measured. Kanazawa et al. [31] investigated the reliability of SV measurement on the cross table lateral radiograph. They reported Cross table-SV differed from true-SV in the measurement plane and did not correlate well with the true-SV, suggesting the unreliability of its measurements. Therefore, the cross table-SV is not recommended for clinical use.

Thus, all of these problems eventually need a well-controlled lateral x-ray film with reliability and validity. We devised new trans-lateral decubitus measuring method and compared the stem version measured on this lateral film with the stem version measured on CT.

There are several limitations in this study. First, large errors can be occurred when the deformation of the femur is severe in long axis and short axis angles that we defined. Second, our study was obtained in stem with a neck-shaft angle of 132 degree. Our method is not applicable in stems other than 132 degree. Third, beam is not entered into the hip joint vertically, therefore, errors may occur when applying the formula in a true lateral image. However, our method is easily performed and associated with less radiation than a CT scan.

Conclusion

In summary, the trans-lateral decubitus method may provide orthopedic surgeons with are liable and valid measurement of stem anteversion after THR. In addition, the translateral decubitus view seems to be helpful to determine whether a surgery is indicated or not in patients with recurrent hip dislocation after THR,

Abbreviations

THR: total hip replacement, CT: computerized tomography, BMI: body mass index, AP: anteroposterior, AIIS: antero-inferior iliac spine, ICCs: intraclass correlation coefficients, CI: confidence interval, CCD: caput-collum-diaphyseal-angle, SV: stem version

Declarations

Ethics approval and consent to participate

This prospective study was approved by our institutional review board, and informed written consent was obtained from patients, who participated in the study. The study was registered in the ClinicalTrials.gov Protocol Registration System (trial number NCT02554149).

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

All authors declare that they have no conflict of interest. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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Author's contributions

Study concept and design: YJI, HYC

Acquisition of data: AJM, LYK, KYS, KKH

Analysis and interpretation: YJI, HYC, LYK

Study supervision: HYC, KKH

All authors have read and approved the manuscript.

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Tables

Table 1. Demographics of patients

Number of patients (hips)	36
Age (years) (mean ± SD)	59.8 ± 11.8
Body mass index (kg/m^2) (mean ± SD)	25.2 ± 3.0
Primry diagnosis (number of hips)	
Osteonecrosis	18
Osteoarthritis	18

SD; standard deviation

Table 2. Intra- and interobserver reliability of measurement on CT scans and plain radiographs

	Intra-observer reliability (ICC, 95% CI)	Interobserver reliability (ICC, 95% CI)
CT scan	0.941(0.894 to 0.962)	0.942 (0.882 to 0.968)
Radiograph	0.934 (0.892 to 0.963)	0.931(0.884 to 0.962)

ICC, Intraclass correlation coefficient; CI, confidence interval

Table 3. Calculation table for stem anteversion using translateral decubitus view

	NSA : 132°	NSA : 135°		NSA : 132°	NSA : 135°
α (°)	ß (°)	ß (°)	α (°)	ß (°)	ß (°)
-48	-90.0		0	0.0	0.0
-45	-64.2	-90.0	2	1.8	2.0
`-44	-60.4	-74.9	4	3.6	4.0
`-42	-54.2	-64.2	6	5.4	6.0
-40	-49.1	-57.0	8	7.3	8.1
-38	-44.7	-51.4	10	9.1	10.2
-36	-40.9	-46.6	12	11.0	12.3
-34	-37.4	-42.4	14	13.0	14.4
-32	-34.2	-38.7	16	15.0	16.7
-30	-31.3	-35.3	18	17.0	19.0
-28	-28.6	-32.1	20	19.1	21.3
-26	-26.1	-29.2	22	21.3	23.8
-24	-23.6	-26.4	24	23.6	26.4
-22	-21.3	-23.8	26	26.1	29.2
-20	-19.1	-21.3	28	28.6	32.1
-18	-17.0	-19.0	30	31.3	35.3
-16	-15.0	-16.7	32	34.2	38.7
-14	-13.0	-14.4	34	37.4	42.4
-12	-11.0	-12.3	36	40.9	46.6
-10	-9.1	-10.2	38	44.7	51.4
-8	-7.3	-8.1	40	49.1	57.0
-6	-5.4	-6.0	42	54.2	64.2
-4	-3.6	-4.0	44	60.4	74.9
-2	-1.8	-2.0	45	64.2	90
0	0.0	0.0	48	90.0	

NSA : neck-shaft angle of the stem, α : Stem anteversion on translateral decubitus view

= (The angle between the axis of the stem trunnion and the axis proximal shaft) – 15 º

, ß : real anteversion of the stem

Figures

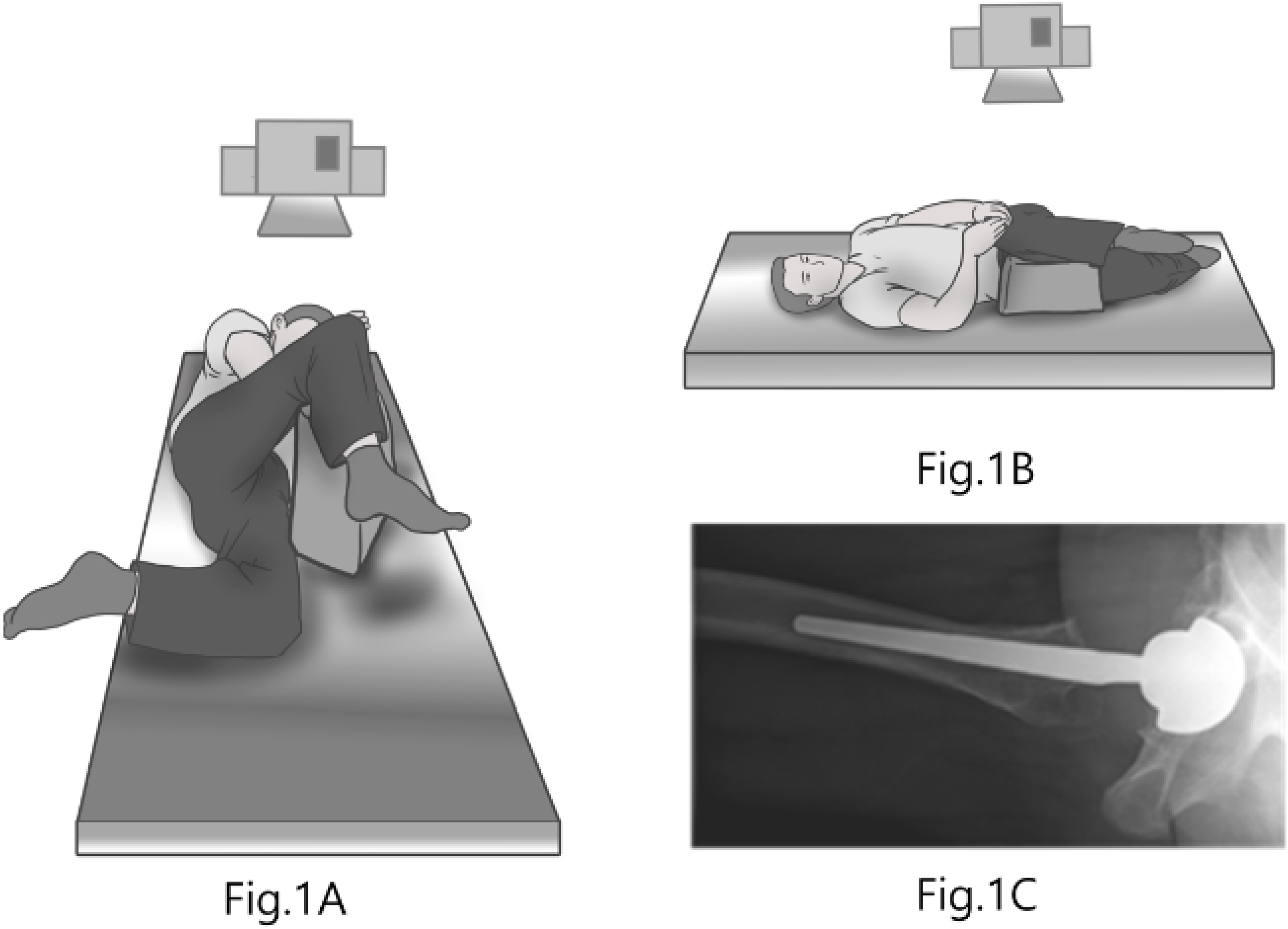

Figure 1

(A) Lateral decubitus position is taken to the affected side. (B) Both condyles automatically become parallel intercondylar plane and then the decubitus lateral view was taken. (C) Decubitus lateral radiograph was taken on the intercondylar plane.

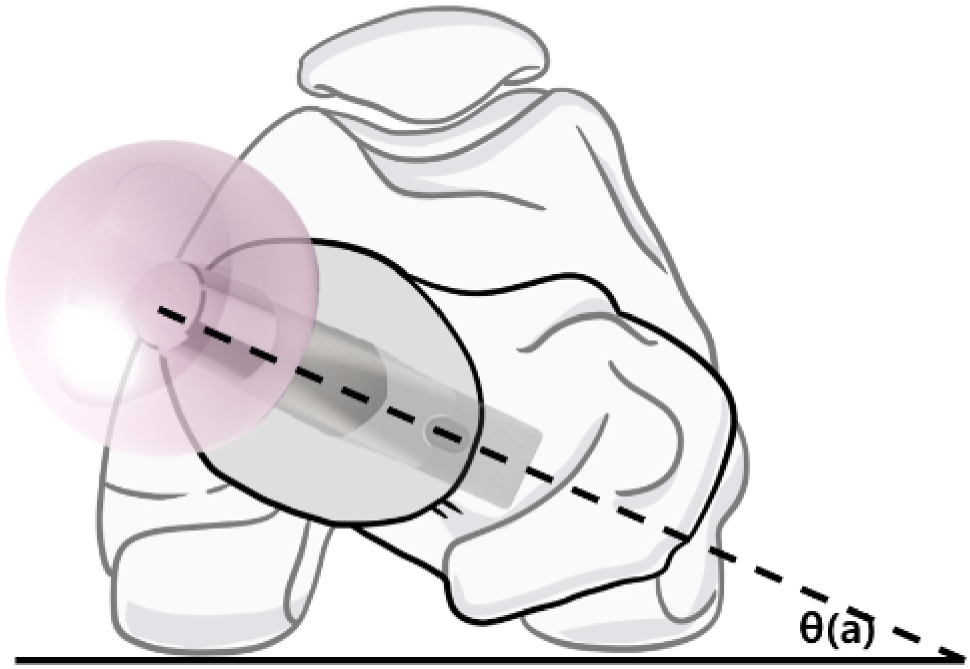

Figure 2

The real stem anteversion (θ(s)) was defined as the angle between the condylar axis (Line) and the axis of the stem trunnion (dot line).

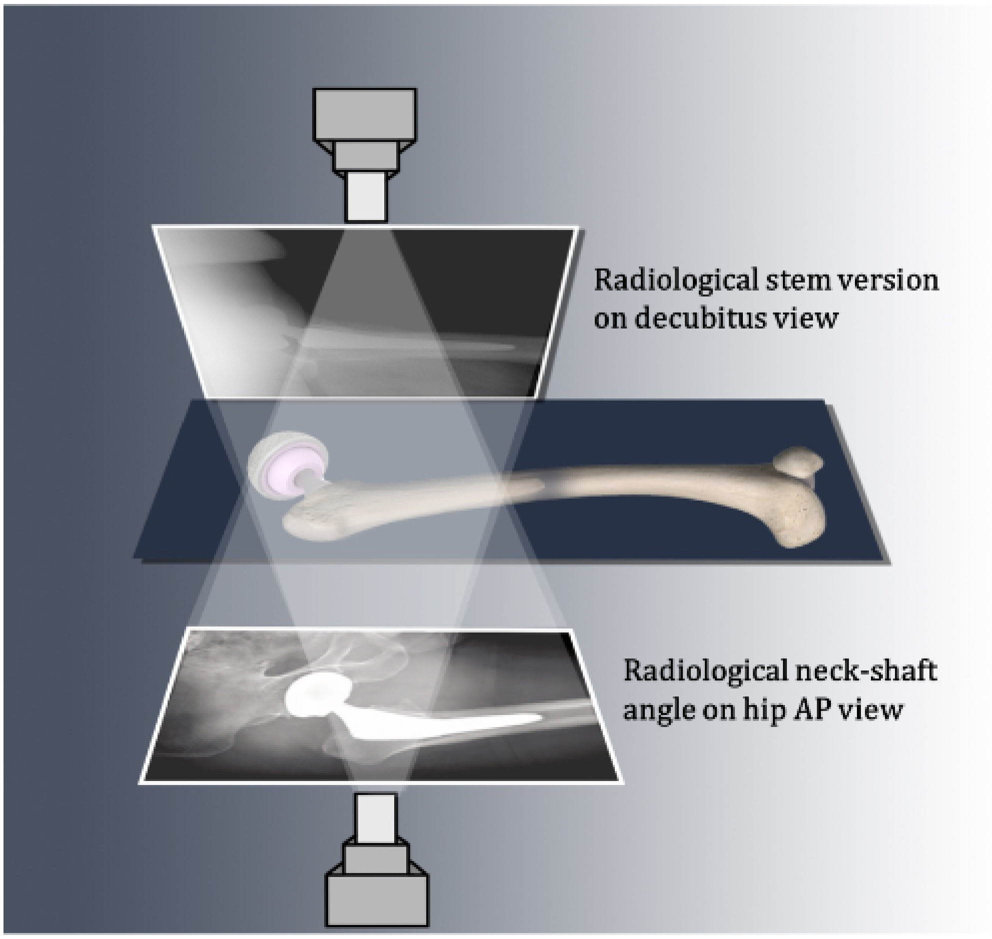

Figure 3

Only the proximal half of the femur is seen and the femoral condyles are not seen in this view.

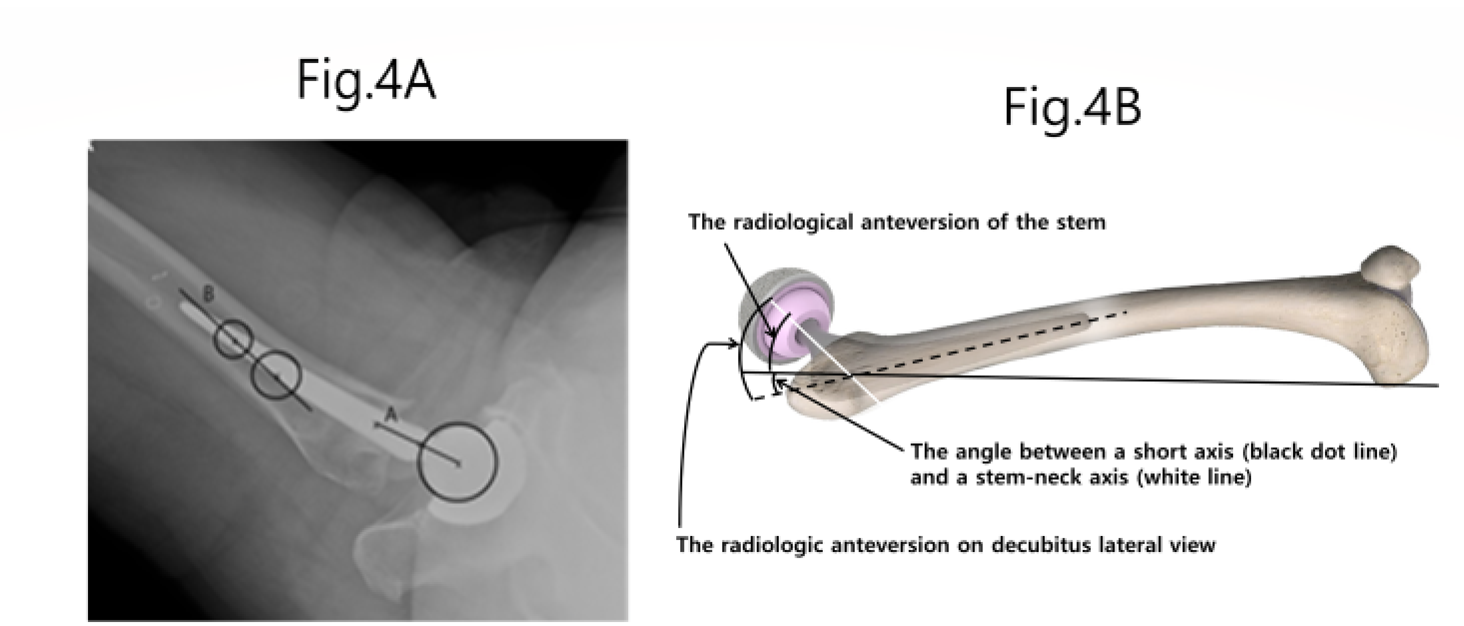

Figure 4

(A) The radiologic anteversion on decubitus lateral view (B) The relationship between the axis of the entire femur (black line) and that of the proximal femur (black dot line) in the sagittal plane.

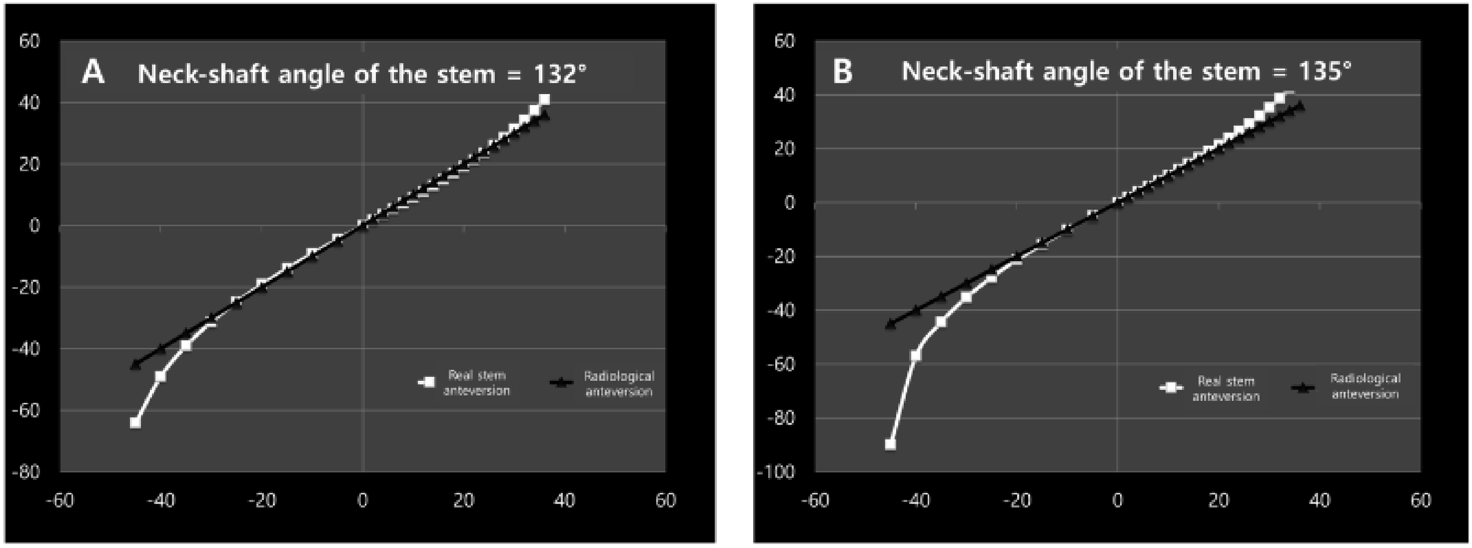

Figure 5

In the neck-shaft angle of the stem (A: 132°, B: 135°), the radiological anteversion was almost similar with the real stem anteversion, when the radiological anteversion was between -30° and 30°.