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Utility of Preoperative Femoral Neck Geometry in Predicting Femoral Stem Anteversion

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ABSTRACT

This study investigated the relationships between the preoperative femoral anteversions and the femoral stem anteversion using CT scans and CT-based 3D models to determine whether any preoperative anteversion measurement correlates with the postoperative stem anteversion. Pre-operative and post-operative CT scans of 19 hips with THAs were evaluated. Five preoperative anatomical femoral anteversion measurements (CT-Head, CT-Below Head, CT-Neck, 3D-Head, and 3D-Neck) were compared with the postoperative femoral stem anteversion. The preoperative CT-Neck anteversion measurement was most correlated with the postoperative stem anteversion ($r = 0.761$, $P = 0.002$) with the narrowest ranges of the differences (−10.2° to 11.0°). The preoperative anteversions using the femoral neck geometry from CT scans can be used for the estimation of the postoperative femoral stem anteversion in THA.

Femoral stem anteversion in total hip arthroplasty (THA) is an important parameter in minimizing dislocation and impingement [1]. Recently, combined anteversion technique has been advocated in THAs. Dorr et al suggested insertion of femoral stem and adjusting acetabular cup anteversion accordingly to achieve combined anteversion within a "safe zone" of 25°–50° [2]. Cemented stems can be rotated, however there is limited adjustability for geometry of most cementless femoral stem designs. [2]. Among the various types of cementless stems, metaphyseal filling stems have been the subjects of more published reports than any other design [3]. This widely used stem design geometry tends to follow proximal femoral anatomy [2,4,5]. Since native anatomy of proximal femur varies within the population, the resultant stem version varies accordingly [6–10], rendering intraoperative decision for cup positioning challenging [11,12]. Hence, it is important to identify preoperative native anatomical anteversion landmark measurements that would reliably correlate with postoperative stem version. Such pre-operative information would be helpful for surgeons in accurately planning cup versions during THA in order to optimize combined version.

Conflict of interest statement: None.

Ethical review committee statement: This study was approved by the Institutional Review Board of our institute, and all patients provided informed consent

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Several previous studies investigated the preoperative femoral anteversion and the postoperative stem version. However these studies used different measurement method or evaluation tool [13–17]. Each study used different reference lines such as the epicondyle axis [15] or the posterior condylar axis [13,17], or different femoral anteversion lines such as the line using head geometry [13,14] or the line using neck geometry [15,17] which contributed to significantly different results [14,18]. Furthermore, although CT scans have achieved widespread popularity owing to their easy interpretation, accuracy and precision [18], CT scans accuracy was debated recently when it was compared to 3D modeling technique, the virtual equivalent of the gold standard (the direct anteversion measurement of dried femur in vitro) [18,19].

The aim of the current study was therefore to investigate, using the CT scans and CT-based 3D models, the relationships between the preoperative native anteversion and the postoperative femoral stem anteversion. We hypothesized that the pre-operative anteversion measurement based on the femoral neck geometry would correlate with the post-operative femoral stem anteversion.

Materials and Methods

Patients and Radiologic Evaluations

Nineteen hips in 17 patients with primary osteoarthritis who underwent robot assisted cementless THA between January 2012 and April 2013 were included in this study. Approval of Institutional Review Board was obtained and each subject provided written informed consent for this study. Demographic data are summarized in Table 1. Prior to the scheduled operation, CT scans of the each patient from the

Table 1
Demographics of Subjects.

Age (years)	63.6 ± 4.0 (47–73)
Height (cm)	162.2 ± 10.1 (137–180)
Weight (kg)	70.4 ± 17.3 (49–111)
BMI	27.1 ± 7.8 (18.5 – 43.4)
Gender (Male : Female)	2 male : 14 female
Side (Left : Right)	7 left : 12 right

BMI, body mass index; HSS, hip Society Scores.

fifth lumbar vertebra to the distal femur were obtained (Sensation 64, Siemens, Germany) with an image resolution of 512 × 512 pixels and a voxel size of 0.97 × 0.97 × 0.60 mm using 140 kVp. Posterior approach was used in all cases and a tapered stem (Linear stem, DJO Global, Vista, CA, USA) was inserted using MAKO haptic robotic hip system (MAKOplasty total hip application; MAKO Surgical Corporation, Ft. Lauderdale, FL, USA) which uses the RIO (Robotic Arm Interactive Orthopedic System) for the implant placement.

Although the utility of robot-assisted THA was outside the scope of the current study, the study was limited to those patients who underwent robot-assisted THAs as CT is routinely performed for surgical planning purposes in these patients. Thus, inclusion of these THA patients avoided exposing additional radiation to the potential study patients. Postoperative hip CT scan of the each patient was also obtained mean 10.0 ± 2.3 (range, 6–14) months after surgeries. The mean follow up was mean 19.6 ± 4.8 months (range, 12–24 months) and there was no case of infection or dislocation during follow up period.

Using commercially available program (Rhinoceros, Robert McNeel and Associates, Seattle, WA, USA), surface models of preoperative pelvis and femur, and those of postoperative pelvis, femur, acetabular cup and femoral stem were created from CT scans. In accordance with previously published study protocol [20], preoperative and postoperative models were combined based on the pelvis and femur models and the deviation of the distances in between was 0.98 ± 0.24 mm for the pelvis and 0.69 ± 0.26 mm for the femur. All created models were imported to MATLAB program (The Mathworks Inc., Natick, MA) for analyses.

Femoral Anteversion Measurements

Three preoperative anteversions from CT scans, and 2 preoperative anteversions from 3D models were measured. Postoperative stem anteversion was also measured from 3D models as CT scan's accuracy was debated recently when it was compared to 3D modeling technique, the virtual equivalent of the gold standard (the direct anteversion measurement of dried femur in vitro) [18,19].

For the 3 preoperative anteversions from CT scans, 3 slice levels on scout film were chosen based on the study by Sugano et al [18] (Fig. 1ⓐ–ⓒ):

1. *CT-Head* level is an initial slide where the neck saddle merges with the great trochanter (Fig. 1ⓐ).
2. *CT-Below Head* level is the most proximal portion of the inferior neck that has no head portion (Fig. 1ⓑ).
3. *CT-Neck* level is midpoint level between CT-Below Head level and a slice just above the lesser trochanter (Fig. 1ⓒ).

Anteversion of the CT-Head (CT-Head anteversion) level was defined as the angle between the line connecting the midpoint of the neck isthmus and the center of the femoral head and the posterior condylar line. Anteversions of the CT-Below Head level (CT-Below Head anteversion) and CT-Neck level (CT-Neck anteversion) were defined as the angles between the line bisecting the anterior and posterior cortex of femur neck and the posterior condylar line [17] (Fig. 1ⓐ–ⓒ).

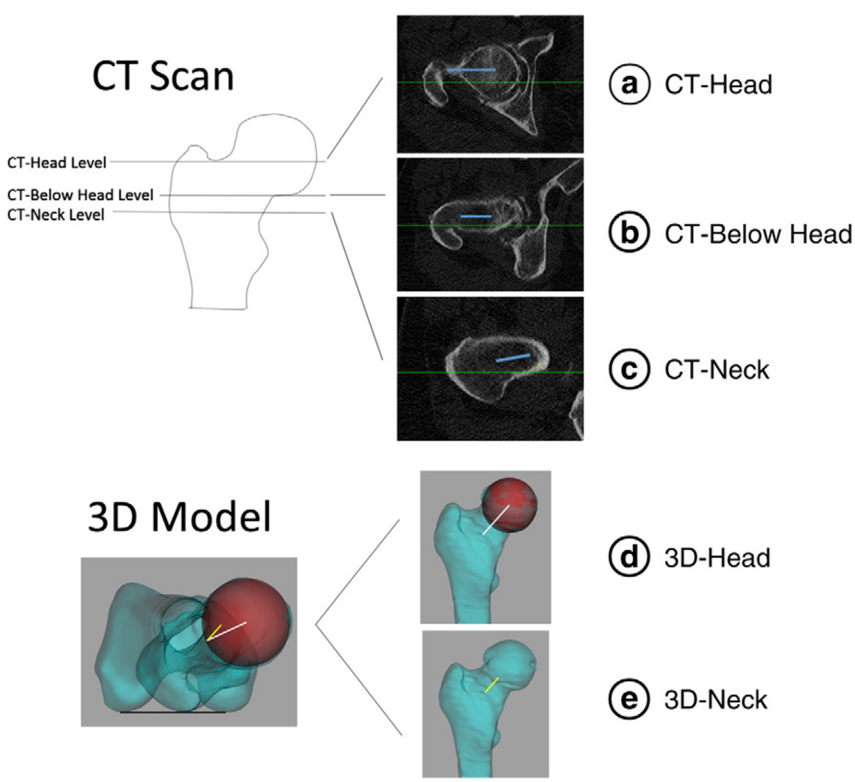

Fig. 1. A schematic figure of the measurement of the anteversion by each method. Three preoperative anteversions were measured from CT scans based on the study by Sugano et al [18] (ⓐ CT-Head, ⓑ CT-Below Head, and ⓒ CT-Neck), and 2 preoperative anteversions were measured from 3D models (ⓓ 3D-Head and ⓔ 3D-Neck). 3D-Head anteversion line (white line in ⓓ) was obtained by connecting the centroid of the best fitted sphere (red sphere) and the centroid of the best fitted circle of most distal part of femur neck [21]. 3D-Neck line (yellow line in ⓔ) was obtained by connecting the centroids of the best fitted circles of most distal and the most proximal part of femur neck.