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Evaluation of the Accuracy of Computed Tomography–Based Navigation for Femoral Stem Orientation and Leg Length Discrepancy

Makoto Kitada, MD,* Nobuo Nakamura, MD, PhD,*
Daiki Iwana, MD,* Akihiro Kakimoto, MD, PhD,*
Takashi Nishii, MD, PhD,† and Nobuhiko Sugano, MD, PhD†

Abstract: Although there is a great deal in the literature about the clinical accuracy of computed tomography (CT)–based navigation systems for acetabular cup orientation and leg length discrepancy in total hip arthroplasty, there is little analysis of femoral stem orientation. Thirty total hip arthroplasties in which CT-based navigation system had been used had their anteversion, valgus angle of stem, and leg length discrepancy measured on postoperative CT data. Differences in postoperative measurements from intraoperative records were −0.6° ± 4.8° (range, −11° to 10°) for stem anteversion, −0.2° ± 1.8° (range, −4° to 3°) for valgus angle of stem, and 1.3 ± 4.1 mm (range, −6 to 10 mm) for leg length. Although this system may need further improvement for stem orientation, it was helpful for intraoperative leg length adjustment. **Keywords:** total hip arthroplasty, femoral stem, accuracy, leg length, CT-based navigation.

Component malpositioning and postoperative leg length discrepancy (LLD) are the most common technical problems associated with total hip arthroplasty (THA) [1]. To prevent cup malpositioning that might lead to dislocation of the hip joint and/or early wear of the polyethylene liner, the so-called safe zone was suggested by Lewinnek et al [2]. In the last decade, not only cup orientation, but stem alignment also came to be regarded as an essential factor to acquire the optimal range of motion and to reduce the rate of dislocation and mechanical problems related to impingement. [3-6].

As for the LLD, although it was common among the healthy population to have discrepancies as high as 2 cm and still be asymptomatic, discrepancy after THA may lead to more patient complaints [7], for example, back pain, gait disorders, and general dissatisfaction [8,9]. In some literature, it was reported that reduction of LLD contributed to a better functional outcome [10,11].

Because navigation systems were supposed to offer the potential to implant components in an optimal orientation, there have been many reports about the accuracy of implant orientation of navigated THAs [12-17]. Dorr et al [14] evaluated stem anteversion with an imageless navigation system; they reported 10.9° ± 9.0° of navigation measurement and 10.6° ± 8.0° of postoperative measurement. As for the evaluation of LLD with computed tomography (CT)–based navigation system, the difference between intraoperative and postoperative leg length was reported to be −0.5 ± 1.77 mm (−5 to 3.9 mm) by Ecker et al [1] and Murphy and Ecker [15]. Although most of the rest of the literature mentioned cup orientation and/or LLD [1,12-17], we could not find any clinical literature that examined the orientation of the cup and stem and leg length in the same study. Because LLD is a result of both cup and stem positioning, alignment of the stem is as important as that of the cup. So the purpose of this study was to examine the accuracy of the femoral stem orientation and the LLD under the precise use of CT-based navigation in clinical use.

Materials and Methods

From July 2007 to May 2008, 54 THAs with cementless stems (CentPillar, Stryker, Mahwah, NJ) were performed with the use of CT-based navigation system (Stryker CT-Hip System V1.0, Stryker-Leibinger, Freiberg, Germany) in our hospital. All preoperative planning and postoperative measurements were

*From the *Center of Arthroplasty, Kyowakai Hospital, Osaka, Japan; and †Department of Orthopaedic Medical Engineering, Osaka University Graduate School of Medicine, Osaka, Japan.*
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Reprint requests: Makoto Kitada, MD, Center of Arthroplasty, Kyowakai Hospital, 1-24-1, Kishibe-kita, Suita, Osaka, 564-0001, Japan.

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completed on this planning module. As preparation for planning, the CT was taken from pelvis to knee joint and transferred into the planning module. Twenty reference points (bilateral anterior superior iliac spines, bilateral pubic tubercles, the most distal point of bilateral ischium, mid pubic symphysis and sacral mid plane for pelvic frame and femoral head, piriformis fossa, the most posterior point of the proximal femur, bilateral posterior condyles, and knee center for femoral frame) were taken, and segmentation of pelvis and femur was performed semiautomatically. Size and orientation of the stem were decided. As the first step, stem anteversion and valgus angle were adjusted to match the anatomical neck anteversion and shaft axis; and then the size of femoral stem was decided to fit both medial canal and lateral flare and to fill the canal of the proximal femur as much as possible. Afterward, cup orientation was adjusted according to the stem anteversion angle to acquire the best range of motion. Leg length was planned to get minimum LLD by adjusting the stem size, head offset, and cup position.

All THAs were performed using the navigation system through the posterolateral approach, with patients in the lateral decubitus position. Before skin incision, a pelvic tracker was percutaneously fixed on an ipsilateral ilium by an external fixation device (Hoffman II, Stryker-Leibinger) through two 4-mm Apex pins (Fig. 1A). Following the dislocation of the hip joint, a femoral tracker was rigidly fixed on the greater trochanter by a triangular plate with three 2.0-mm screws (Fig. 1B).

Registration of the femur was completed by surface matching, digitizing 30 points on the femur with a pointer, and confirmed by touching femoral surface and characteristic points, that is, the tip of greater trochanter, smaller trochanter, and lateral epicondyle of the femur. A verification point of the femur, which was used to check intraoperative loosening of the femoral tracker fixation, was set on the greater trochanter (Fig. 2A). The femoral neck was then cut along the preoperative planned line that was shown on the navigation monitor. Registration of the pelvis was also done by surface matching, and a verification point of the pelvis was set on the posterosuperior portion of acetabular rim (Fig. 2B).

After reaming, implantation of the acetabular cup was done under the navigation system; final anteversion and inclination were recorded; and fixation of the pelvic tracker was checked by touching its verification point. Subsequently, femoral preparation was performed. At the end of rasping and implantation of the stem, anteversion, valgus angle, and leg lengthening were recorded. Afterward, the femoral tracker was checked for stability by touching its verification point. Leg length was finally adjusted by changing the neck length of the femoral head.

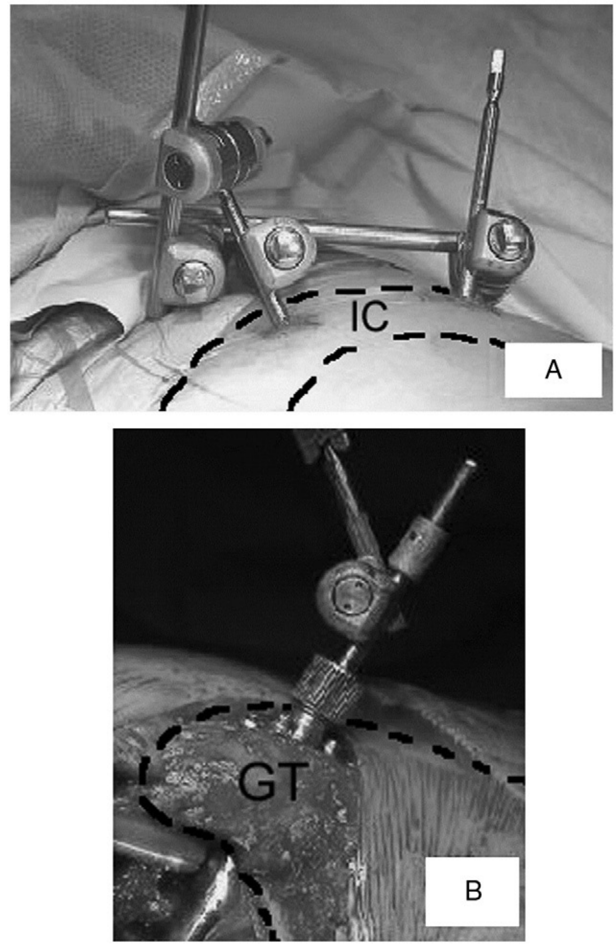

Fig. 1. A pelvic tracker was percutaneously fixed on an ipsilateral ilium (iliac crest, IC) by external fixation device through two 4-mm Apex pins (A). A femoral tracker was fixed at the lateral phase of the greater trochanter (GT) through the triangular plate (B).

Of all these patients, 24 hips in which stability of either the pelvic or femoral trackers could not be verified were excluded, even if the tracker seemed to be securely fixed and not displaced. Finally, 30 hips of 25 patients remained (Table 1).

Preoperative diagnoses were osteoarthritis (28 hips), osteonecrosis (1 hip), and rheumatoid arthritis (1 hip). For evaluation of LLD, 14 hips were excluded. Simultaneous bilateral THA (6 patients, 11 hips) could not be evaluated. The other 3 hips were not planned with getting equal leg length in mind to avoid nerve palsy because preoperative LLD was too large (40, 32, and 32 mm). As a result, LLD was evaluated for the remaining 16 hips.

Stem orientation (anteversion and valgus angle), cup orientation (Murray anatomical anteversion and inclination angle [18]), and LLD were measured preoperatively, intraoperatively, and postoperatively. Preoperative parameters were acquired from preoperative planning. Intraoperative parameters were extracted from navigation records that were measured after each component