abstract

The authors hypothesized that an image-free navigation system would be more accurate than postoperative 3-dimensional (3-D) reconstructed computed tomography (CT) for acetabular cup inclination and anteversion during total hip arthroplasty (THA) in an Asian population. Eighty-one THAs were performed in 72 patients using the OrthoPilot image-free navigation system (B. Braun Aesculap, Tuttingen, Germany). Cup placement position was measured by postoperative 3-D CT and compared with intraoperative navigation data. The discrepancies between the navigation data and the 3-D CT data were analyzed, as well as the correlation factors that affected the discrepancies. The discrepancies between the navigation data and the 3-D CT data were $2.1.5^\circ \pm 7.1^\circ (P=.04)$ for anteversion and $1.1^\circ \pm 7.6^\circ (P=.02)$ for inclination. The accuracy and precision of the anteversion discrepancies were $5.6^\circ \pm 4.4^\circ$ and $3.2^\circ$, respectively. The accuracy and precision of the inclination discrepancies were $4.5^\circ \pm 4.4^\circ$ and $2.8^\circ$, respectively. Five (6%) outliers existed in terms of the safe zones of anteversion and inclination. The main correlated factor among the pelvic geometry was tilt rather than rotation and obliquity of the bony anterior pelvic plane.

In an Asian population, the calculated accuracy and precision of acetabular cup inclination and anteversion during THA were more reliable and the outliers were reduced using the OrthoPilot navigation system. However, discrepancies existed between intraoperative navigation data and postoperative 3-D CT data. The pelvic geometry of biometrical factors influenced the discrepancies in the navigation data.
Optimal acetabular cup position is an important determinant of short- and long-term success of total hip arthroplasty (THA). Poor cup placement has been associated with impingement, dislocation, osteolysis, accelerated polyethylene wear, component loosening, and component migration. Historically, intraoperative methods of determining acetabular cup component position have consisted of freehand techniques and the use of mechanical guides. However, freehand (outliers, 25%-42%) and mechanically guided (outliers, 20%-78%) techniques have resulted in inaccurate cup component position, with numerous cups placed outside the safe zone. Acetabular cup positioning using these techniques, even in the hands of experienced surgeons, may result in considerable outliers. In the past decade, the accuracy and precision of acetabular cup positioning using these techniques has been debated.

Many studies have suggested that a navigation-assisted technique may be effective in obtaining optimal acetabular cup position and reducing cup positioning outliers. However, pelvic landmarks can be obscured by the overlying soft tissue, which can make direct referencing difficult. A considerable amount of tissue overlying the anterior superior iliac spine and symphysis pubis in an obese patient may also introduce errors in measurement. For surgeons to be confident in the inclination and anteversion values acquired by computer-assisted surgery, the accuracy and precision of these variables should be evaluated.

To the authors’ knowledge, no studies assess image-free navigation-assisted cup placement in THA in the Asian population. They hypothesized that an image-free navigation-assisted cup placement would be effective in obtaining optimal acetabular cup position and reducing cup positioning outliers.

Three independent orthopedic surgeons (T.H.K., S.H.L., J.H.Y.) measured each parameter 3 times at 2-week intervals. Means of the measured values were analyzed. Intrarobserver agreement averaged 93% (kappa coefficient, 0.86), and interobserver agreement averaged 91% (kappa coefficient, 0.89).

Statistical Analysis
Statistical analysis was performed using SPSS version 17.0 software (SPSS Inc, Chicago, Illinois). Results were considered statistically significant at the α = 0.05 level.
Mean and SD of all measurements were calculated. Paired t test was used to compare discrepancies between 3-D CT data and navigation data. Pearson’s correlation coefficient was used to analyze the correlation between the discrepancies and biometrical parameters. Logistic regression analysis was used for biometrical factors affecting the values of the discrepancies. P values less than .05 were considered statistically significant.

RESULTS

Mean lumbar lordosis angle was 30.5° (range, 13.2° to 54.7°). Mean tilt of the bony anterior pelvic plane and soft tissue anterior pelvic plane were −2.1° (range, −21.7° to 16.1°) and 11.1° (range, −7.5° to 33.4°), respectively. On axial 3-D CT scan, mean thickness of the soft tissue was 14.7 mm (range, 4.7 to 49.2 mm) for the anterior superior iliac spine and 36.2 mm (range, 11.2 to 52.9 mm) for the symphysis pubis.

Mean anatomic, radiographic, and operative anteversion on 3-D CT were 29.9° (range, 1.6° to 49.4°), 27.8° (range, 1.6° to 40.2°), and 21.9° (range, 1.4° to 40.2°), respectively. Mean inclination on 3-D CT was 42.1° (range, 30.4° to 56.6°). Mean final cup anteversion on 3-D CT using the mathematical formula was 21.2° (range, 1.1° to 36.7°). Mean rotation of the bony anterior pelvic plane was −0.4°±2.8°, and mean obliquity of the bony anterior pelvic plane was −0.2°±3.3°.

Discrepancies existed between the intraoperative navigation data and the postoperative 3-D CT data. Mean anteversion discrepancy between the navigation data and the 3-D CT data was −1.5°±7.1°, which was statistically significant (P=.04) (Figure 3). Mean inclination discrepancy between navigation data and 3-D CT data was −1.1°±7.6°, which was also statistically significant (P=.02) (Figure 4). The accuracy and precision of the anteversion discrepancies were 5.6°±4.4° and 3.2°, respectively. The accuracy and precision of the inclination discrepancies were 4.5°±4.4° and 2.8°, respectively (Table). Regarding outliers, 24 (29%) hips had more than 10° anteversion and 12 (14%) hips had more than 10° inclination. Five (6%) outliers existed in terms of the safe zones of anteversion and inclination (Figure 5).

The main correlated factor among the pelvic geometry was tilt rather than rotation and obliquity of the bony anterior pelvic plane. The tilt of the bony anterior pelvic plane (γ=−.57; P=.001) and the soft tissue anterior pelvic plane (γ=−.31; P=.01) showed a statistically significant correlation with the discrepancies between navigation anteversion and 3-D CT anteversion. However, the tilt of the bony anterior pelvic plane (γ=−.32; P=.007) alone showed a statistically significant correlation with the discrepancies between navigation inclination and 3-D CT inclination. Inclination discrepancies of more than 5° showed no correlation with any biometrical factor, whereas inclination discrepancies of more than 10° showed significant correlation with lumbar lordosis (P=.02). However,
anteversion discrepancies of more than 5° showed significant correlation with the tilt of the bony anterior pelvic plane (P=.001) and the soft tissue anterior pelvic plane (P=.04), whereas anteversion discrepancies of more than 10° showed significant correlation with the tilt of the bony anterior pelvic plane alone (P=.01).

**DISCUSSION**

In this study, the accuracy of inclination and anteversion were $4.5°\pm4.4°$ and $5.6°\pm4.4°$, respectively, and the precision of inclination and anteversion were $2.8°$ and $3.2°$, respectively. Recently published studies using the OrthoPilot navigation system reported considerably different results: discrepancies of $-2°$ to $1.9°$ for inclination and $-4°$ to $2.6°$ for anteversion, and inclination and anteversion precision of $4.4°$ and $4.1°$, respectively.

The concept of using the anterior pelvic plane was introduced to computer-assisted cup placement in 1998 by Jaramaz et al. Lembeck et al. reported that the tilt of the bony anterior pelvic plane at rest was $-4°$ in the lying position and $-8°$ in the standing position and ranged from $-27°$ to $3°$. Babisch et al. reported that the mean preoperative tilt of the bony anterior pelvic plane was $-8.9°$ and the mean postoperative tilt was $-10.9°$ when measured using CT scan.

Regarding correlation factors, Parratte and Argenson reported the discrepancies correlated with body mass index, and Ybinger et al. reported the discrepancies correlated with the thickness of the soft tissue underlying the pelvis. In the current study, the tilt of the bony anterior pelvic plane alone showed a statistically significant correlation with the discrepancies between navigation inclination and 3-D CT inclination. Also, anteversion discrepancies more than 10° had significant correlation with the tilt of the bony anterior pelvic plane. Therefore, the main correlated factor among the pelvic geometry was tilt rather than rotation and obliquity of the bony anterior pelvic plane.

This study evaluated only an Asian population. Because differences may exist in pelvic parameters among different populations, potential pelvic geometry differences may influence correlated biometrical factors affecting discrepancies.

Outliers of more than 10°, which were described by Lewinnek et al., were 24 (29%) hips for anteversion and 12 (14%) hips for inclination.
hips for inclination, respectively. Five (6%) outliers existed in terms of the safe zones of anteverision and inclination. When compared with previous freehand techniques, the current study showed a significantly lower proportion of outliers.

**CONCLUSION**

In an Asian population, the calculated accuracy and precision of acetabular cup inclination and anteverision during THA were more reliable and the outliers were reduced using the OrthoPilot navigation system. However, discrepancies existed between intraoperative navigation data and postoperative 3-D CT data. The pelvic geometry of biometrical factors influenced the discrepancies in the navigation data.

**REFERENCES**


