Deviation of cup alignment from target angle during press-fit insertion

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ABSTRACT
Background: Several factors lead to cup malalignment including preoperative pelvic tilt, inaccurate pelvic position on the operating table, pelvic movement during the operation and alignment change after screw fixation of the cup. There are few studies about the deviation of cup alignment from target angle during press-fit insertion, which may be the other cause of cup malalignment. The purpose of this study was to evaluate the deviation of cup alignment from target angle during press-fit insertion by using imageless navigation and to define any influential factors, including gender, age and side of operation.

Methods: Between February 2016 and March 2017, patients undergoing total hip arthroplasty (THA) with imageless navigation were included in the present single-center study. Cup inclination angle was set at 40 degrees in all cases but the anteversion angle varied depending on the stem anteversion in each case using a combined anteversion technique. The final cup was aligned at target angles in both inclination and anteversion, the tracker was detached from the insertion handle and the surgeon inserted the cup until it was seated completely. The tracker was attached again to display both inclination and anteversion angles and these angles were recorded. Deviated Inclination Angles (DIA) and Deviated Anteversion Angles (DAA) in each case were calculated.

Results: There were 124 cases in the present study. The mean age of the patients was 60.2 years (25–93). There were equal numbers of right-sided and left-sided operations, 62 cases each. There were 114 cases (91.9%) with DIA. The mean DIA was 2.65° (0–8°, SD 1.66). The DIA increased in 7 cases (5.6%) with 2 cases (1.6%) showing an increase of 5° or more. There were 103 cases (83.1%) with DAA. The mean DAA was 2.3° (0–14°, SD 2.3). The DAA increased in 25 cases (20.2%) with 4 cases (3.2%) increasing by 5° or more. The DIA was significantly higher in males than in females (p = .012). There was significant correlation between DAA and patient’s age (p = .037). There was no significant difference between DIA or DAA and side of operation.

Conclusion: Changes in cup orientation were observed in most cases during cup insertion with hammer blows detected by imageless navigation. Deviation of cup alignment from target angle during press-fit insertion was a possible cause of cup malalignment, male gender and patient’s age were influential factors.

Introduction
Acetabular cup malalignment has been linked to increased dislocation, impingement, pelvic osteolysis, cup migration, polyethylene wear and decreased longevity of the prosthesis in patients undergoing total hip arthroplasty (THA) [1,2]. Several factors leading to cup malalignment including preoperative pelvic tilt [3], inaccurate pelvic position on the operating table [4], pelvic movement during the operation [5] and alignment change after screws fixation of the cup [6]. At present, there are few studies about deviation of cup alignment from target angle during press-fit insertion as it may be the other cause of cup malalignment. Using imageless navigation, the system will display the real-time change of cup alignment from target angle. After the cup is fully seated, the surgeon can correct the alignment to achieve the target angle if it deviates. The objective of this study was to evaluate the deviation of cup alignment from target angle during press-fit insertion, as a possible cause of cup malalignment and to define any influential factors including gender, age and side of operation.
Materials and methods

This study was approved by the Institutional review board in Maharat Nakhon Ratchasima Hospital, Thailand (100/2017). Between February 2016 and March 2017, patients undergoing THA with imageless navigation were included in the present single-center study.

All cases underwent THA (Plasmafit cup and Metha or Excia stems; B. Braun Aesculap, Tuttingen, Germany) with imageless navigation in semilateral decubitus position with OrthoPilot THA Pro software (Aesculap AG) that already had proven accuracy for angular measurement [7]. The Plasmafit is a cementless cup with microporous pure titanium coating with three holes for supplemental screws fixation. The standard reaming technique up to designed acetabular size was used to acquire a tight fit between the 1.5-mm-oversized cup rim and the reamed acetabular bone. Supplemental screws fixation was based on the surgeon’s impression of relatively inferior resistance during press fitting.

A right-handed surgeon (YS) with 20 years’ experience performing THA conducted all operations. Two small pins were inserted into the ipsilateral Anterior Superior Iliac Spine (ASIS) through a stab incision. The navigation tracker was attached to the pin adaptor and the bony landmarks (ASIS of both sides and pubic symphysis) were determined and digitalized with a metal pointer to define Anterior Pelvic Plane (APP) as the reference plane for the cup inclination and anteversion. We performed a modified Hardinge’s approach in all patients. After removal of the femoral head, the deepest point of the acetabular fossa was registered as an additional reference point. Then, by using the trial cup, the native inclination and anteversion angles of the acetabulum were determined. During reaming, the position of the reamer was acquired by the navigation system and the operating surgeon was provided with real-time information about the resulting position of the reamer (medialization, cranialization and antero-posterior direction) and its orientation (inclination and anteversion angles) in relation to APP as well as the native acetabulum. During reaching the design reaming size, the femoral stem was prepared and the stem anteversion angle was evaluated and recorded. The final cup was implanted and the operating surgeon was provided with real-time information about the cup position and orientation. Cup inclination angle was aimed at 40 degrees in all cases and the anteversion was aimed as individual native anteversion angle in each case, then we recorded the combined anteversion angle. The final cup was aligned at target angles in both inclination and anteversion, the tracker was detached from the insertion handle and the surgeon inserted the cup with hammer blows until it was seated completely. The tracker was attached again to display both inclination and anteversion angles and these angles were recorded. The surgeon was allowed to correct the cup orientation if there was any variation from target angle outside the Lewinnek’s safe zone [8] in each case, 40 ± 10 and 15 ± 10 for inclination and anteversion respectively. After finishing the cup, the femoral stem was inserted and the joint was reduced. Patients’ age, gender, diagnosis, side of operation, cup size, and number of supplemental screws were recorded as demographic data. Deviated Inclination Angles (DIA) and Deviated Anteversion Angles (DAA) in each case were calculated.

Statistical analyses

DIA and DAA were compared between male and female, between right and left-sided operations using Mann-Whitney U test. Spearman rank correlation coefficient was used to define the correlation between DIA, DAA and age of the patient. A p-value less than .05 was considered statistically significant.

Results

There were 124 cases in the present study. Fifty-eight cases (48.8%) were male and 66 cases (53.2%) were female. The mean age of the patients was 60.2 years (25–93). There were 65 cases (52.4%) of femoral neck fracture, 47 cases (38%) of osteonecrosis of the femoral head (ONFH), 6 cases (4.8%) of developmental dysplasia of the hip (DDH) and 6 cases (4.8%) of post-traumatic arthritis. There were an equal number of right-sided and left-sided operations, 62 cases each. The mean cup size was 52 (48–64). One supplemental screw was used in 64 cases (51.6%), 2 screws in 26 cases (21%), 3 screws in 2 cases (1.6%) and no screw for the other 32 cases (25.8%) (Table 1).

There were 114 cases (91.9%) with Deviated Inclination Angles (DIA). The mean DIA was 2.65° (0–8°, SD 1.66). The DIA decreased in 107 cases (86.3%) with 12 cases (9.7%) decreased by 5° or more. The DIA increased in 7 cases (5.6%) with 2 cases (1.6%) increased by 5° or more (Table 2).

There were 103 cases (83.1%) with Deviated Anteversion Angles (DAA). The mean DAA was 2.3° (0–14°, SD 2.3). The DAA increased in 78 cases (62.9%) with 11 cases (8.9%) increased 5° or more.
Table 1. Demographics data of the patients.

| Parameters                      | Values |
|---------------------------------|--------|
| No. of hips                     | 124    |
| Gender (male/female)            | 58/66  |
| Mean age (years) (range)        | 60.2 (25–93) |
| Right-side/left-side operations (cases) | 62/62 |
| Etiology (cases) (%)            | 55 (%) |
| Femoral neck fracture           | 65 (52.4%) |
| Osteonecrosis of the femoral head (ONFH) | 47 (38%) |
| Developmental dysplasia of the hip (DDH) | 6 (4.8%) |
| Posttraumatic                   | 6 (4.8%) |
| Mean cup size (mm)              | 52 (48–64) |
| Supplemental screw (cases) (%)  | 32 (25.8%) |
| No screw                        | 64 (51.6%) |
| One screw                       | 26 (21%) |
| Two screws                      | 2 (1.6%) |

Table 2. Details of Deviated Inclination Angles (DIA).

| Deviated Inclination Angles (DIA) | Values |
|-----------------------------------|--------|
| No. (cases) (%)                   | 114 (91.9%) |
| Mean DIA (degrees) (range, SD)    | 2.65 (0–8, 1.66) |
| Decreased DIA (cases) (%)         | 107 (86.3%) |
| Decreased 5° or more (cases) (%)  | 12 (9.7%) |
| Increased DIA (cases) (%)         | 7 (5.6%) |
| Increased 5° or more (cases) (%)  | 2 (1.6%) |

The DAA decreased in 25 cases (20.2%) with 4 cases (3.2%) decreased 5° or more (Table 3).

The mean DIA was 3° (0°–8°) in males and 2° (0°–8°) in females with a statistically significant difference (p = .012). The mean DIA was 3° (0°–7°) in right-sided operations and 3° (0°–8°) in left-sided operations, there was no significant difference (p = .987). The mean DAA was 2° (0°–10°) in males and 2° (0°–14°) in females, there was no significant difference (p = .41). The mean DAA was 1.5° (0°–6°) in right-sided operations and 2° (0°–14°) in left-sided operations, there was no significant difference (p = .373) (Table 4). There was no significant correlation between DIA and patient’s age (p = .069), however there was significant correlation between DAA and patient’s age (p = .037). DAA values decreased when patients’ age increased.

Discussion

Acetabular cup position influences the longevity of a prosthesis [2]. The causes for cup placement malposition have been reported as due to many factors such as preoperative pelvic tilt. Maratt et al. [3] reported mean preoperative pelvic tilt was 0.6° ± 7.3° (−19 to 17.9) with 17% having greater than 10° of pelvic tilt on preoperative radiographs. The mean change in functional anteversion was a 0.74° increase in anteversion per degree of posterior tilt (range: −0.75° to −0.72°) while the mean change in inclination was 0.29° per degree of posterior tilt. Inaccurate pelvic position and pelvic movement during the operation were another cause of cup malalignment. Nishikubo et al. [4] evaluated the preoperative errors of pelvic position in 249 hips in lateral decubitus position. They found that mean absolute errors were 2.94° (SD 2.92°), 2.49° (SD 2.68°) and 5.92° (SD 5.20°) in coronal, transverse and sagittal planes respectively. Grammatopoulos et al. [5] studied pelvic movement during hip replacement and found that the mean angular movement was 9° (SD 6°), factors influencing pelvic movement included surgeon, approach (posterior > lateral), procedure (hip resurfacing > THA) and type of support.

The other cause of cup malalignment was a change of alignment after screw fixation of the cup. Fujishiro et al. [6] studied the effect of screw fixation on acetabular component alignment change. They reported that the mean intraoperative change of cup position was 1.78° ± 1.6° (0°–5°) for inclination and 1.81° ± 1.6° (0°–8°) for anteversion.

One of the possible causes of cup malalignment was misdirection from the target angle during cup insertion caused by hammer blows while seating the cup. Nishii et al. [9] studied fluctuation of cup orientation during press-fit insertion. They reported that the mean Maximum Deviated Inclination (MDI) and Maximum Deviated Anteversion (MDA) were −3.7° ± 4.0° (−12° to 10°) and 0.67° ± 4.0° (−8° to 10°) respectively. They found 1 (1%) and 29 (41%) hips with increases and decreases in MDI of 5° or more, and 13 (19%) and 6 (8%) hips with increases and decreases in MDA of 5° or more. The MDI in men was significantly lower and the MDA for left-sided surgery was significantly higher.

Consistent with the present study, we found that the mean deviated angle was higher for inclination when compared with anteversion angles, 2.65° (0°–8°, SD 1.66) and 2.3° (0°–14°, SD 2.3) respectively. Most DIA in our present study were decreased with 12 cases showing a decrease of 5° or more, it might be due to the heavy weight of insertion handle and the direction of surgeon’s impaction, which might have resulted in increasing impingement after THA if it’s not been
corrected. On the other hand, most DAA were increased with 11 cases increasing by 5° or more. This may result in an increased the incidence of anterior dislocation with modified Hardinge’s approach if not corrected.

The authors found that DIA was significantly higher in males than in females ($p = .012$) and there was a significant correlation between DAA and patients’ age ($p = .037$), DAA values were lower in older patients. The mean age in males was lower than females, 56.2 years (28–90) and 62.5 years (25–93) respectively and females were mostly diagnosed with femoral neck fracture (46 in 65 cases) in the present study. Therefore, the bone quality in male patients might be better than females because of younger age, and we might have needed to use heavier hammer blows to overcome greater resistance in male patients until the cup was fully seated, perhaps resulting in more handle misdirection. The authors found no significant difference between right-sided and left-sided operations in both DIA and DAA.

There were some limitations in the present study. First, the number of patients was relatively small. Furthermore, the main diagnosis of the patient in this present study was femoral neck fracture (52.4%) and the mean age was relatively old, which may mean decreased bone quality. Different outcomes might be obtained in different etiologies and surgeons, because it depended on the strength of hammer impact and ability to stabilize the handle during press-fit insertion.

**Conclusion**

In conclusion, changes in cup orientation were observed in most cases during cup insertion with hammer blows detected by imageless navigation. Deviation of cup alignment from target angle during press-fit insertion was a possible cause of cup malalignment, male gender and patients’ age were influential factors. It would be detected and corrected during the operation to prevent the cup malalignment and to avoid the complications of THA, especially impingement and dislocation.

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**Disclosure statement**

The authors have no conflict of interests to disclose.

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**Table 4. Comparison between male and female, right-sided and left-sided operations.**

| Parameters | Male degree (range) | Female degree (range) | p-Value | Right-side degree (range) | Left-side degree (range) | p-Value |
|-----------|---------------------|-----------------------|---------|---------------------------|--------------------------|---------|
| Mean DIA | 3 (0–8)             | 2 (0–8)               | .012    | 3 (0–7)                   | 3 (0–8)                  | .987    |
| Mean DAA | 2 (0–10)            | 2 (0–14)              | .41     | 1.5 (0–6)                 | 2 (0–14)                 | .373    |