Effect of screw fixation on acetabular component alignment change in total hip arthroplasty

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Abstract

Purpose The use of screws can enhance immediate cup fixation, but the influence of screw insertion on cup position has not previously been measured. The purpose of this study was to quantitatively evaluate the effect of intra-operative screw fixation on acetabular component alignment that has been inserted with the use of a navigation system.

Methods We used a navigation system to measure cup alignment at the time of press-fit and after screw fixation in 144 hips undergoing total hip arthroplasty. We also compared those findings with factors measured from postoperative radiographs.

Results The mean intra-operative change of cup position was 1.78° for inclination and 1.81° for anteversion. The intra-operative change of anteversion correlated with the number of screws. The intra-operative change of inclination also correlated with medial hip centre.

Conclusion The insertion of screws can induce changes in cup alignment, especially when multiple screws are used or if a more medial hip centre is required for rigid acetabular fixation.

Keywords Total hip arthroplasty · Acetabular component · Alignment change · Screw fixation · Navigation

Introduction

Optimal acetabular cup position is important to minimize wear and avoid impingement and dislocation after total hip arthroplasty (THA) [1]. The use of one or more screws in the shell of a cementless acetabular component can help achieve good early fixation, especially in patients with marginal bone quality [2–5], but inserting screws could impart changes in final acetabular component alignment. Acetabular component positioning can be assessed using computer-assisted navigation systems with real-time adjustments for component position. The purpose of this study was to quantitatively evaluate the effect of intra-operative screw fixation on acetabular component alignment that has been inserted with the use of a navigation system.

Materials and methods

Patient demographics

As part of a prospective study intended to help determine the accuracy of THA components that have been inserted with the use of a navigation system (results reported separately) [6–8], 144 consecutive primary THAs were performed in 144 patients using a CT-based fluoroscopic matched navigation system (VectorVision HIP 3.5; BrainLAB, Feldkirchen, Germany), and implanted Pinnacle acetabular cups (DePuy, Warsaw, IN) in all patients. The patients were 121 women and 23 men with a mean age of 65.2 years (range, 30–87 years) at operation. The diagnoses for primary THA included osteoarthritis (103 hips), rapidly destructive coxopathy (13 hips), osteonecrosis (16 hips), dislocated hips (four hips), rheumatoid arthritis (three hips), and others (five hips).

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Registration of navigation THA

Registration of the pelvis was performed using fluoroscopic imaging with reference landmarks on the patient's anatomy relative to the tracked reference arrays. A pelvic tracker was percutaneously fixed to the iliac crest (Fig. 1a). The software provides the surgeon with real-time information on the location of surgical instruments relative to the patient's anatomy by associating the positions of the registered anatomical landmarks relative to the reference arrays with the 3D representations of the patient's bones calculated from segmentation of the patient's CT scans. For the registration procedures, fluoroscopic images of the acetabulum including the femoral head and the pubic symphysis were taken first, and the anterior superior iliac spine (ASIS) was then recorded with a pointer. Finally, verification was completed by denoting the surface of the iliac crest. Subsequently, fluoroscopic images were matched with pre-operative CT images. The registration accuracy was verified by touching the ASIS and iliac crest with a pointer, and registration was concluded prior to skin incision.

Intra-operative measurements

The cup verification function in the navigation system can provide the surgeon with real-time cup alignment by continuously tracking the cup inserter. Intra-operative acetabular component inclination and anteversion at the time of press-fit were recorded after final impaction and positioning of the acetabular component with the cup inserter still in place (Fig. 1a). The cup inserter was reattached to the acetabular component firmly after screw fixation, and measured cup alignment again using the cup verification function in the navigation system (Fig. 1b). The mean of the absolute difference in inclination and anteversion angles between initial press-fit and after screw fixation was expressed as the intra-operative change of acetabular component position. The number of screws was also investigated, and patients were

subdivided into two groups, namely, patients with one screw and those with two or more screws.

Radiographical findings

We measured the Sharp angle on the pre-operative radiograph [9]. The central-edge angle of the acetabular component, and the distance from the centre of the femoral head to the interteardrop line as a horizontal and vertical reference on the postoperative radiograph with the patients in supine position was measured. We defined horizontal distance as hip centre medialization, and vertical distance as hip centre height. We compared the change of acetabular component alignment, radiographic measurement and intra-operative measurement.

Statistical analysis

The Mann–Whitney test was used to compare the intra-operative change in acetabular component alignment at the time of press-fit and after screw fixation, and between patients with one screw and patients with two or more screws. The Kruskal–Wallis and post-hoc Scheffe statistical tests were used to compare the change of acetabular component alignment and each factor. The correlation between the change of acetabular component and each factor was evaluated using Pearson's correlation coefficient test. *P* values below 0.05 were regarded as statistically significant.

Results

The mean Sharp angle $43.4^{\circ} \pm 6.3^{\circ}$. The mean horizontal distance was 32.3 ± 12.1 mm, and mean vertical distance was 21.8 ± 6.8 mm. The number of screws used was an average of 1.31 ± 0.57 (range, one to four). Mean inclination and anteversion at the time of press-fit were $40.3^{\circ} \pm 4.2^{\circ}$ and $15.6^{\circ} \pm 9.0^{\circ}$, respectively. Mean inclination and anteversion

Fig. 1 **a** A pelvic tracker on the iliac crest and a cup inserter. **b** Intraoperative navigation screen displaying actual anteversion and inclination for the acetabular component

after screw fixation were $40.4^\circ \pm 4.5^\circ$ for inclination and $15.6^\circ \pm 9.2^\circ$ for anteversion. There was no significant difference between press-fit and screwing. Mean intra-operative change of acetabular component was $1.78^\circ \pm 1.6^\circ$ (0° to 5°) for inclination and $1.81^\circ \pm 1.6^\circ$ (0° to 8°) for anteversion (Table 1). There was no correlation between the change of either inclination or anteversion and age, or number of screws. The intra-operative change of acetabular component anteversion correlated with the number of screws ($r=0.212$, $p=0.011$). The intra-operative change of acetabular component inclination also correlated with the horizontal distance ($r=-0.217$, $p=0.010$).

There was no significant difference between patients with one screw and patients with two or more screws in intra-operative change of inclination ($1.76^\circ \pm 1.60^\circ$, $1.87^\circ \pm 1.46^\circ$, respectively) ($p=0.70$). Intra-operative change of anteversion in patients with two or more screws ($2.37^\circ \pm 2.45^\circ$) was significantly greater than in patients with one screw ($1.61^\circ \pm 1.38^\circ$) ($p=0.022$) (Fig. 2).

Discussion

Several screws are commonly used to aid fixation of the acetabular component during cementless THA [2–5], but as far as we know, few clinical studies have quantified the influence of screw insertion on acetabular component alignment.

Screws achieve fixation based on their initial bony purchase, and these screws rely on contact pressure and the resultant friction between the screw head and the cup to control translation and angulation of the prosthesis [10]. Spears et al. [11] used finite element simulations to study the effect of interfacial parameters on relative micromotion between the cup and pelvis. They reported that the use of multiple screws for fixation has only a minor effect on micromotion and press-fit fixation is more important. Our study showed mean intra-operative changes of 1.78° for inclination and 1.81° for anteversion. The changes should be small; however, maximum change of the acetabular component was 5° for inclination and 8° for anteversion. These findings suggest that the alignment of the acetabular

Table 1 Mean inclination and anteversion after screw fixation were $40.4 \pm 4.5^\circ$ for inclination and $15.6 \pm 9.2^\circ$ for anteversion. There was no significant difference between press-fit and screwing. Mean intraoperative change of acetabular component was $1.78 \pm 1.6^\circ$ for inclination and $1.81 \pm 1.6^\circ$ for anteversion

Measure	Inclination	Anteversion
Press-fit	$40.3 \pm 4.2^\circ$	$15.6 \pm 9.0^\circ$
After screwing	$40.4 \pm 4.5^\circ$	$15.6 \pm 9.2^\circ$
Intraoperative change	$1.78 \pm 1.6^\circ$	$1.81 \pm 1.6^\circ$

Fig. 2 There was no significant difference between patients with one screw and patients with two or more screws in intraoperative change of inclination ($1.76 \pm 1.60^\circ$, $1.87 \pm 1.46^\circ$, respectively) ($p=0.70$). While intraoperative change of anteversion in patients with two or more screws ($2.37 \pm 2.45^\circ$) was significantly greater than in patients with one screw ($1.61 \pm 1.38^\circ$) ($p=0.022$)

component can be changed during screw fixation and the changes could be clinically important.

Hsu et al. [12, 13] showed the number of screws applied does not appear to have a significant effect on peak micromotion or the patterns of micromotion distribution from finite element analyses. Kwong et al. [14] experimentally investigated the use of one to four screws to fix the acetabular cup, and concluded that addition of supplemental screws did not significantly enhance stability of the implant under press-fit conditions. Our study showed significantly greater intra-operative change of anteversion in patients with two or more screws compared to those with one screw. These findings suggest that surgeons should be especially attentive to a possible change of acetabular component alignment when multiple-screws are required for rigid acetabular fixation.

The stability of the acetabular component also could be affected by bone quality and bone stock [5, 15]. Multiple-screw fixation could also affect micromotion of the acetabular component in situations where the host bone quality is poor or acetabular deficiency is severe. We tried to better define the associations between change of acetabular component alignment and bone quality as reflected by patient age or acetabular deficiency. Our results showed the horizontal distance correlated with the intra-operative change of acetabular component alignment, so medialization of the hip centre could affect the change of acetabular component alignment. The finding suggests that we should pay attention to change of acetabular component alignment when we need to place the acetabular component at medial hip centre for sufficient acetabular coverage.

There are several limitations to the present study. First, the acetabular component alignment could be influenced by the location, direction, and length of screws. However, we investigated only the numbers of screws, so further study about association between acetabular alignment change and other factors would be helpful. Second, bone quality and bone stock

could influence acetabular component stability. We tried to assess bone quality as a result of age, acetabular deficiency (by looking at Sharp angle and CE angle), and initial stability of acetabular component (by centre-tear drop distance), but we did not analyse bone mineral density.

In summary, although the actual clinical significance of these changes are unknown, surgeons should recognize that the acetabular component could undergo changes in anteversion and inclination during screw fixation, especially when multiple screw fixations and a medial hip centre are required for rigid acetabular fixation.

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