Where is the best cup position for Crowe III hips with the presence of a false acetabulum in total hip arthroplasty?

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Abstract

Background

We aimed to evaluate the clinical and radiological results of three different cup positions for Crowe III hips with a false acetabulum.

Methods

From January 2008 to December 2018, we retrospectively evaluated 61 hips (57 patients) which were classified as Crowe type III and presented a false acetabulum. Based on the position of cup on postoperative radiographs, all hips were divided into three groups: anatomic group (A group), false acetabular group (F group) and middle group (M group).

Results

There were no significant differences in comparison of anteversion, inclination and leg length discrepancy among three groups. The cup size of A group was significantly smaller than other two groups. In the A group, autograft was utilized in 5 hips (33.3%) and a S-ROM stem was used more frequently. By the comparison of horizontal distance, the F group showed an overmuch lateralization of rotation center. At the last follow-up, the mean Harris hip scores were significantly improved in three groups. There were 2 patients from the M group with both a moderate limp and positive Trendelenburg sign. During the follow-up period, one hip of the M group performed an acetabular revision by the reason of acetabular fracture.

Conclusions

All three cup positions for Crowe III hips with a false acetabulum showed good clinical outcomes and no significant difference. However, compared with the anatomical position, the mid-position allows for larger acetabular cups and liners. Further, the mid-position allows for more mediazation compared with the false acetabular position.

Background

Developmental dysplasia of the hip (DDH) is one of the most common cause of secondary hip osteoarthritis and encompasses a wide spectrum of anatomic abnormality, ranging from a shallow acetabulum to a completely dislocated “high-riding” hip(1). Based on the ratio of proximal displacement distance of the femoral head in relation to the height of the pelvis, Crowe et al.(2) proposed a simple and available classification with four different degrees of dysplasia. Subsequently, a three-type classification according to the morphological relationship between acetabulum and femoral head was presented by Hartofilakidis in 1996(3). Although the Crowe classification is more prevalent today, it is still lack of description to the morphology of acetabulum compared to the Hartofilakidis classification. Particularly, Crowe III DDH remains variations in acetabular morphology according to the absence or presence of a false acetabulum (Fig. 1). That may influence the placement of the cup and make the reconstruction problematic during total hip arthroplasty (THA).

As is known, there are various of alternative reconstruction strategies for Crowe III hips, mainly including anatomical reconstruction and high hip center (HHC), sometimes combining with structural bone graft or metal augmentations(4–7). In general, the vital important factor for acetabular reconstruction is the residual host bone mass. Different from the hip without false acetabulum which is always accompanied by more extensive segmental deficiency in the superior and posterosuperior directions(8), a hip with the presence of a false acetabulum tends to keep more native host bone, especially in the middle of the true and false acetabulum. Therefore, except anatomical position and false acetabular position, another alterative reconstruction option is putting the cup in the intermediate position between the true and false acetabulum.
As yet, research on the selection of cup position for Crowe III hips with a false acetabulum has not been carried out. In the present study, we aimed to evaluate the clinical and radiological results of three different cup positions for Crowe III hips with a false acetabulum and figured out where the optimal position is.

**Materials And Methods**

This retrospective study was approval by our institutional review board. From January 2008 to December 2018, a total of 528 patients with dysplastic hip who were admitted to our institution and underwent primary cementless THA was reviewed. All operations were performed by one senior orthopedic surgeon. According to the Crowe classification, 138 patients were categorized as type III DDH. However, we only included the Crowe III hip presenting a false acetabulum in this study. Those with histories of neuromuscular disease were excluded. A total of 61 hips (57 patients) met the study criteria and were finally included in the present study.

All patients were successfully followed up, and the mean follow-up time was 6.1 years (range, 1.1–11.3 years). The mean age at the time of THA was 41.9 years (range, 21–71 years) and the mean body mass index (BMI) was 23.4 kg/m² (range, 17.2–32.2 kg/m²). In this study, 51 (89.5%) of the 57 patients were female. Five hips had a history of previous surgeries: femoral derotational osteotomy in 3 hips, pelvic osteotomy in 1 hip and hip shelf procedure in 1 hip.

In this study, all hips were divided into three groups based on the position of cup on their postoperative radiographs (Fig. 2). The anatomic group (A group) comprised 15 hip joints of which the cup was put at the position of true acetabulum. The false acetabular group (F group) consisted of 14 hips of which the cup completely covered the false acetabulum. The rest of 32 hips were in the middle group (M group) which was defined that the cup covered the false acetabulum in part (Table.1).

**Surgical Technique And Implant Feature**

All operations were performed using a modified Kocher-Langenbeck posterolateral approach without trochanteric osteotomy. In the process of preparing the acetabulum, all the osteophytes were completely removed. During the anatomical reconstruction, structural autograft with the resected femoral head was performed on condition that the cup coverage was insufficient to provide initial stability. The adjustment of cup orientation and intentional medial placement were adopted, aiming to achieve a bone-cup surface contact not inferior to 70%. When excellent initial stability was observed, the bareness of superolateral rim was acceptable, not necessary to perform additional bone graft or spongioplasty. A ceramic on ceramic (COC) bearing surface was used in all cases of our study. Other components and technical considerations were shown in Table 2.
| Demographic                                      | A group | F group | M group |
|-------------------------------------------------|---------|---------|---------|
| Hips (patients)                                 | 15 (15) | 14 (13) | 32 (29) |
| Females/Males                                   | 14/1    | 11/2    | 26/3    |
| Age (years) *                                   | 34.8 ± 9.4 (21-50) | 42.2 ± 10.2 (22-71) | 45.0 ± 11.5 (25-59) |
| BMI (kg/m²) *                                   | 22.0 ± 2.7 (17.2-27.1) | 24.7 ± 3.0 (21.5-32.2) | 23.5 ± 3.2 (17.3-30.8) |
| Mean follow-up (years) *                        | 8.2 ± 2.5 (3.8-11.3) | 5.9 ± 3.1 (1.1-11.3) | 5.1 ± 2.7 (1.3-9.0) |
| The percentage of dislocation height (%) *      | 16.1 ± 0.9 (15.0-18.0) | 16.3 ± 1.8 (15.0-19.9) | 16.7 ± 1.5 (15.1-19.8) |
| Contralateral hip                               |         |         |         |
| Normal                                          | 10 (66.7%) | 7 (50%) | 19 (59.4%) |
| Crowe IV                                        | 5 (33.3) | 1 (7.1%) | 3 (9.4%) |
| Crowe II/III                                    | -       | 6 (42.9%) | 10 (31.2%) |

* Values given as mean ± standard deviation (range); BMI, body mass index.
## Table 2
Surgical characteristics and acetabular and femoral components.

| Variable                      | A group (n = 15) | F group (n = 14) | M group (n = 32) |
|-------------------------------|------------------|------------------|------------------|
| Structural bone graft (hips)  | 5 (33.3%)        | -                | -                |
| Acetabular component          |                  |                  |                  |
| Duroloc (DePuy, Warsaw, IN, USA) | 7 (46.7%)        | 2 (14.3%)        | 2 (6.3%)         |
| Pinnacle (DePuy, Warsaw, IN, USA) | 8 (53.3%)        | 9 (64.3%)        | 24 (75.0%)       |
| Betacup (Link, Hamburg, Germany) | -                | 3 (21.4%)        | 6 (18.7%)        |
| Femoral stem                  |                  |                  |                  |
| S-ROM (DePuy, Warsaw, IN, USA) | 12 (80%)         | 7 (50.0%)        | 9 (28.1%)        |
| sleeve                        | 8                | 7                | 9                |
| cone                          | 4                | -                | -                |
| Corail (DePuy, Warsaw, IN, USA) | 3 (20%)          | 7 (50.0%)        | 19 (59.4%)       |
| LCU (Link, Hamburg, Germany)  | -                | -                | 3 (9.4%)         |
| Accolade (Stryker, Mahwah, NJ, USA) | -              | -                | 1 (3.1%)         |

All patients received antithrombotic prophylaxis using low-molecular-weight heparin postoperatively. We advised the patient to load the surgically treated leg using two crutches for 6 weeks.

### Radiographic Evaluation

The preoperative, immediate postoperative and most recent anteroposterior (AP) radiographs of the pelvis centered on the pubic symphysis and including the iliac wings were obtained for all patients in our study. The cup position was defined by the vertical and horizontal distance of the center of rotation in relation to the inferior margin of teardrop. The inclination angle of the cup was defined as the angle formed by the inter-teardrop line and the connecting line to the edges of the rim of the component. The anteversion angle of the cup was calculated using the measured dimensions of the ellipse’s axis as described by Ackland et al.(9). The leg length discrepancy (LLD) was measured as the difference in distance between the tip of the lesser trochanter and the inter-teardrop line. Osteolysis was defined as a circular or oval area of distinct bone loss. Radiolucent lines were
classified as described by DeLee and Charnley(10). The acetabular component was considered loosened in presence of a change in alignment of > 4° or migration of > 3 mm(11).

**Clinical Assessment**

We clinically evaluated each patient with the Harris Hip Score (HHS), Trendelenburg sign and limp. The Harris hip score was calculated preoperatively and at last follow-up. Limp was categorized as none, slight, moderate, severe or unable to walk(12).

**Statistical Assessment**

Statistical analysis was conducted with SPSS for Windows Version 24.0 (SPSS Inc, Chicago, IL, USA). The Student’s t-test was used to compare the pre- and postoperative HHS, cup size and radiographic parameters between three groups. The use of S-ROM stem was assessed by chi-squared test. Significance was set at $p < 0.05$.

**Results**

**Radiographic evaluation**

The size of acetabular component and other radiographical evaluations are shown in Table 3. The results of the statistical analyses of these parameters between three groups are illustrated in Fig. 3. There were no significant differences in comparison of anteversion, inclination and leg length discrepancy among three groups. The cup size of the A group was significantly smaller than other two groups. By the comparison of horizontal distance, the acetabular component was located more lateral in the F group and more medial in the A group. Compared to the M group, S-ROM stem was used more frequently in the A group($p = 0.003$). At the final follow-up, all structural bone grafts of the A group have been integrated and no bone resorption happened. Of all cases, no loosening or progressive radiolucency or osteolysis adjacent to the acetabular and femoral component was observed.

| Evaluation parameter            | A group * | F group * | M group * |
|---------------------------------|-----------|-----------|-----------|
| Anteversion (°)                 | 17.2 ± 9.6 (3.7–32.9) | 12.8 ± 8.0 (0.0-27.6) | 13.3 ± 9.1 (0.0-36.2) |
| Inclination (°)                 | 43.8 ± 6.4 (30.8–55.6) | 40.6 ± 7.1 (26.2-49.8) | 41.4 ± 7.3 (29.0-59.6) |
| Size (mm)                       | 46.7 ± 3.7 (44-56)     | 49.1 ± 2.6 (46-56)     | 48.6 ± 2.5 (44-54)    |
| Vertical distance (mm)          | 11.5 ± 5.2 (5.9–25.0)  | 31.6 ± 5.9 (17.4-40.3) | 31.3 ± 6.7 (19.6-45.2) |
| Horizontal distance (mm)        | 24.1 ± 3.2 (20.5–31.3) | 34.8 ± 7.7 (27.3-54.6) | 30.9 ± 5.2 (22.0-41.3) |
| Leg length discrepancy (mm)     | 4.9 ± 3.0 (1.5–12.1)   | 8.3 ± 6.8 (0.2-21.4)   | 5.5 ± 4.3 (0.1–14.3)  |

* Values given as mean ± standard deviation (range).

**Clinical Results**

The mean HHS at the last follow-up showed a significant improvement in three groups. In the A group, the mean
HHS improved from $57.0 \pm 11.0$ (range, 37.0–70.0) to $92.7 \pm 4.3$ (range, 81.5–98.5) at the final follow-up ($p < 0.001$). Similarly, it improved from $54.6 \pm 9.2$ (range, 39.0–69.0) to $92.8 \pm 3.5$ (range, 85.0–99.5) in the F group ($p < 0.001$) while it improved from $52.3 \pm 13.8$ (range, 32.0–75.0) to $93.2 \pm 2.8$ (range, 87.6–99.5) in the M group ($p < 0.001$). There were only 2 patients from the M group with both a moderate limp and positive Trendelenburg sign. During the follow-up period, only one hip of the M group performed an acetabular revision by the reason of acetabular fracture at three years postoperatively.

**Discussion**

Reconstructing dysplastic acetabulum presents considerable technical challenges for orthopedic surgeons, especially for a patient with Crowe III DDH. The placement of acetabular cup for Crowe III hips has several alternative positions in the presence of a false acetabulum, including the position of true acetabulum, false acetabulum and the middle of them. This study aimed to evaluate the outcomes of three different cup positions.

In our clinical opinion, an appropriate cup position depends primarily on three elements: (1) Lower limitation on selection and orientation of the acetabular component; (2) Be beneficial to intraoperatively correct leg length discrepancy; (3) Low incidence rate of postoperative complications.

**Selection And Placement Of The Cup**

Compared with the F group and M group, the diameter of acetabular component was significantly smaller when performing anatomical reconstruction. That could be explained by dysplastic deficiency of the true acetabulum, making it insufficient to accommodate a large sized acetabular cup. In fact, a larger cup and femoral head tended to be a preference which were reported decreasing postoperative dislocation rate among DDH patients(13). Moreover, Murray et al.(14) have demonstrated that a small sized cup and femoral head were associated with polyethylene wear and periprosthetic osteolysis in patients with hip dysplasia. Thus, polyethylene liner was not suggested when putting the cup at the anatomic position. In short, the position of true acetabulum restricted the choice of acetabular cup and liner.

Our results showed that anteversion in the A group was comparatively larger than that in other two groups even there was no statistically difference in inclination and anteversion among three groups. The main explanation was relatively more bone mass of posterior wall of true acetabulum. Because the cup was intraoperatively adjusted to attain adequate coverage, the orientation of the cup was partly determined by surrounding bone mass, especially the bone stock of superolateral rim and anterior and posterior wall which were always deficient in false acetabular position and middle position. However, Zheng et al.(8) have reported that medial wall thickness in Crowe III hips increased with the distance from teardrop and the bone-cup coverage could achieve at least 70% by medialization when the vertical height of the cup center ranged from 21 mm to 36 mm. In this study, the vertical height of the cup in the F group and the M group were respectively $31.6 \pm 5.9$ mm and $31.3 \pm 6.7$ mm. Accordingly, medialization could meet the requirements of bone-cup coverage with no need for excessively abducting the cup. But for anatomical reconstruction, due to a relatively thin medial wall, augmentation by structural autograft to supplement superolateral insufficiency was commonly required. Of the 15 hips in the A group, 5 hips utilized the femoral head autograft during cementless THA. In spite of the complex and time-consuming procedure of autograft, it’s notable that a cementless socket rather than a cement socket used in conjunction with a femoral head autograft have been demonstrated could provide good long-term results by Spangehl et al.(15) and Abdel et al.(16). Therefore, with the assistance of structural autograft and medialization, different cup positions wouldn’t strongly influence the orientation of acetabular cup.

**Leg Length Discrepancy**

Correcting leg length discrepancy was an important issue of THA for Crowe III hips. Our postoperative measurement showed a favorable result in each group and no difference was shown among three groups. However, a modular S-ROM femoral stem was utilized in the A group more frequently to restore the leg length. Sometimes, a cone instead of sleeve was applied to deepen the position of the stem in the femoral canal. By contrast, a common femoral prothesis such as Corail stem utilized in 19 hips (59.4%) of the M group and 7 hips
(50%) of the F group, approving that it was more convenient to correct LLD when fixing the cup in the high rotation center. In brief, the elevation of the stem could be easily achieved by a larger size common femoral stem while the subsidence of the stem always needed a modular S-ROM femoral stem.

Complications

As is known, the complication rate is higher in patients with hip dysplasia than it is in patients who have osteoarthritis(17). Especially, a high hip center which was utilized in all cases of the F group and the M group was always associated with polyethylene liner wear, cup loosening, dislocation and limp(18–20). Nawabi et al. (20) reported a higher polyethylene liner wear rate of lateralized high hip centers. While different, we used a COC interface in all cases, as we hypothesized that the favorable wear characteristics of COC bearing surfaces may counteract to the excessive joint reaction forces. In addition, because it was thought that the risk of dislocation which is greater with a high hip center might result from the impingement, some measures were taken to avoid that, including completely removing of osteophytes, a larger size head, an increased femoral offset and sometimes a modular femoral stem to adjust appropriate anteversion. As a result, no dislocation occurred in our study. Furthermore, limp after a high hip center THA was also a major concern. However, recent studies on HHC technique have reported numerous favorable results of postoperative gait(21, 22). In this study, there were only 2 patients (4.8%) with limp. But it’s worth noting that the cup position of the F group was significantly more lateral than that of the M group. Though no limp and positive Trendelenburg sign was observed in the F group, lateralization would biomechanically increase the burden of the gluteus medius and potentially raise the risk of limp.

For an anatomical reconstruction, the main advantage was restoration of near-normal biomechanics. In this study, anatomic placement was only performed when contralateral hip was normal (10 hips) or Crowe IV (5 hips). It’s helpful for an equilibrium with a normal or anatomical reconstructed Crowe IV contralateral hip. Moreover, a potential particular complication in the A group was the bone absorption of autograft. But in fact, autograft in the cementless THA have been demonstrated to be a reliable method(16). All autografts integrated and no bone absorption occurred in our study also proved it.

Our study has several limitations. First, this was a retrospective study and all operations were performed in single center. Second, this study included a relatively small sample size, maybe because the series of patients with this deformity were not common. Third, the follow-up time varied greatly, from 1.1 to 11.3 years. All of the above reasons may have affected the objectiveness of this study. However, as the first study focusing on the Crowe III hips with a false acetabulum, we think this study is of great value.

Conclusion

In this study, all three cup positions for Crowe III hips with a false acetabulum showed good clinical outcomes and no significant difference. However, compared with the anatomical position, the mid-position allows for larger acetabular cups and liners and refrains from using time-consuming autograft. Further, the mid-position allows for more mediazation compared with the false acetabular position.

Abbreviations

DDH: Developmental dysplasia of the hip; THA: Total hip arthroplasty; HHC: High hip center; BMI: body mass index; COC: ceramic on ceramic; AP: anteroposterior; LLD: leg length discrepancy; HHS: Harris hip score.

Declarations

Ethics approval and consent to participate
The Ethics Committee of our hospital, General Hospital of Chinese People’s Liberation Army, approved the study protocol. A certificate of approval has been provided. The requirement of informed consent was exempted due to the retrospective nature of the study.

**Consent for publication**

Not applicable.

**Availability of date and materials**

The data will be made available from the authors upon reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

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**Authors’ contributions**

JMS: Designing the study, Analyzing the data, Writing the manuscript; YGZ: Designing the study, Editing the manuscript; JYS, HYM and YQD: Collecting the data, Analyzing the data, Reviewing the manuscript; BHZ: Reviewing the literature. All authors have read and approved the final version of this manuscript.

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Figure 1

The two different acetabulum morphology of Crowe III DDH. (a). with a false acetabulum; (b). without a false acetabulum. The triangle indicates true acetabulum and the star indicates false acetabulum.
Figure 2

Preoperative (a) and postoperative (b) radiograph of anatomical reconstruction; Preoperative (c) and postoperative (d) radiograph showed the cup was placed at the position of false acetabulum; Preoperative (e) and postoperative (f) radiograph showed the cup was put at the middle position, and a part of false acetabulum as indicated by the arrow wasn’t covered by the cup.
Figure 3

The acetabular anteversion (°), inclination (°), size (mm), vertical distance (mm), horizontal distance (mm), and leg length discrepancy (mm) in the three groups. * p0.05 for the comparison between two groups. The error bars represent the standard deviation.