Feasibility And Availability of Standard-Sized Cup At The True Acetabulum In Acetabular Reconstruction of Crowe Type IV Hip Dysplasia

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Abstract

Background:

This study aimed to investigate the morphological features and 2D/3D coverage parameters of the true acetabulum of Crowe type IV hips and to identify the optimal component center of standard-sized cup implantation.

Methods:

A total of 42 Crowe IV hips in 37 patients and 36 normal hips were included in the present study. Based on 3D reconstruction, anatomy and volume of the true acetabulum were measured quantitatively. Through simulated implantation, the feasibility of standard-sized cup implantation was evaluated by cup-based morphological assessments and coverage parameters. Eventually, bony landmarks for optimal component center location were determined. Mean follow-up was 4.7 years (1.2 to 6.3 years).

Results:

All the dysplastic hips were placed with standard-size acetabular implant (44.67mm, 44 to 48mm) successfully, with no acetabular implant loosening during the follow-up period. Compared with control group, the dysplastic acetabulum was more anteverted and abductive, with a thicker medial wall. According to the true acetabulum, bone stock is relatively sufficient in the posterior direction and prominently deficient in the anterosuperior and superior direction. Average 3D component coverage can reach 79.89% by standard-sized cup implantation at the true acetabulum. Regarding the component opening plane, the optimal component center located at the midpoint between the superolateral and posteroinferior point of the true acetabulum.

Conclusion:

Standard cup implantation is feasible and available in Crowe IV hip at the true acetabulum. The optimal component center was determined to be relatively constant based on the useful bony landmarks.

Level of evidence: Therapeutic Level 3b.

Introduction

Total hip arthroplasty (THA) in patients with high-riding Crowe type IV developmental dysplasia of the hip (DDH) is a challenging procedure for surgeons. It is crucial regarding the restoration of an anatomical joint biomechanics and the reconstruction of the center of rotation[1–3]. For acetabular reconstruction, challenges associated with managing the true acetabulum include distinctively triangular socket, remarkable increased anteversion, hypoplastic anterosuperior wall, and decreased bone stock[4–6].

In terms of the severe dysplasia of the hip, the use of small acetabular prosthesis was recommended to achieve satisfactory bony coverage[7, 8]. However, polyethylene wear and risk of postoperative dislocation have been proved to be associated with small prosthesis size[9–11]. Follow-up studies of high-riding DDH also showed that acetabular revision risk was significantly higher than femoral revision[9, 11]. During prior surgeries, we noted that standard size cup (> 44mm) can also achieve acceptable implant coverage by accurate 3D preoperative planning and cautious acetabular reaming. Accordingly, Zhou et al[12] claimed that standard cup was feasible by implanting the cup posteriorly and inferiorly, resulting in promising bony coverage and clinical survival. Hartofilakidis et al[7] and Xu et al[13] recommended a superior and posterior standard-sized reaming regarding relatively sufficient bone stock, which was similar with our previous study[4]. Relative researches involved quantitative coverage status and ideal reaming location were still limited for standard-sized cup implantation.

Few studies have addressed the morphological evaluation of true acetabulum reconstruction and optimal bony landmarks for standard-sized cup implantation in Crowe IV hips. By using a 3D implantation simulation method, the aim of this study was: (1) To investigate the morphological features and 2D/3D coverage parameters of the true acetabulum in Crowe IV hip, and (2) To evaluate the feasibility of standard cup (> 44 mm) implantation at the true acetabulum in Crowe IV hips, and (3) To identify the optimal position and useful bony landmarks of acetabular reaming center in Crowe IV hips.

Materials And Methods

Study Design and Setting

The study was approved by the institutional review board of Guangdong Provincial People's Hospital (IRB: 2019528HR1). From January 2014 to January 2020, 58 consecutive primary THAs were performed in 46 patients with type IV DDH at our institution. Of the 46 subjects, 7 (12 hips) with substandard scans and 2 (4 hips) with surgery history were excluded. Thus, 42 dysplastic hips in 37 patients met the inclusion criteria and performed morphological evaluation and 3D simulative planning preoperatively. Eighteen patients (36 hips) without acetabular fracture or deformities who had undergone computed tomography (CT) angiography to diagnose proximal femoral fractures were chosen as controls. Demographic data for the subjects are shown in **Table 1**. None of the patients was lost to follow up. The mean follow-up duration was 4.7 years (1.2 to 6.3 years).

Table 1
Demographic Data.

	Normal	IV DDH
Hips/patients (no.)	36/18	42/37
Males/females (no.)	6/30	5/32
Age (y)	39.00 ± 10.13 (20 to 54)	42.73 ± 13.62 (21 to 70)
Height (cm)	163.17 ± 7.40 (155 to 185)	157.50 ± 10.22 (141 to 175) *
Weight (kg)	64.72 ± 7.82 (49 to 87)	56.19 ± 11.12 (33 to 84) **
BMI (kg/m ²)	24.34 ± 2.72 (18.00 to 29.14)	18.75 ± 9.97 (21.66 to 35.42) **
Values are expressed as the mean and the standard deviation, with range in parentheses; *p < 0.05, ** p < 0.01, when compared with control group.		

3D Reconstruction and Acetabular Size Analysis

Pelvic CT was performed with a Toshiba brand Aquilion CT scanner (120 kVp, 320 mA, 512x512 matrix; slice thickness 0.5mm). The patients were placed in a neutral supine position with the patellae facing the ceiling. Scanning was performed from the iliac crest to the distal third of the femur. All standard CT slices were saved in Digital Imaging and Communications in Medicine (DICOM) format and imported into Mimics 19.0 software (Materialise, Leuven, Belgium) for 3D reconstruction. Before simulation and measurement, the pelvic position was standardized with reference to the anterior pelvic plane (APP) coordinate system[14, 4], determined by the anterior superior iliac spines and the pubic tubercles bilaterally (Fig. 1A). According to resliced CT image, the 3D, coronal, sagittal, and transverse views were presented simultaneously in Mimics software. Morphology and bone stock distribution of the true acetabulum were compared between Crowe IV hips and normal hips. According to the true acetabulum, the distal part of the cotyloid notch (DPCN)[15, 4, 16], the most superolateral point and the midpoint between them were digitized (Fig. 1B). In the coronal and axial plane passing through the midpoint, the acetabular length, height, width and depth were measured to determine the acetabular size in the control and Crowe IV DDH group. According to the acetabular rim, the acetabular volume was also evaluated with reference to the acetabular opening plane[17, 18] (Fig. 1C-E).

Simulating Implantation of the Acetabular Component

A set of hemispherical virtual acetabular component with negligible thickness was created by using 3-matic 9.0 software (Materialise, Leuven, Belgium), whose component center was marked in advance. According to the standard size of on-shelf acetabular implants, the outer diameters of these egg-shell cups ranged from 44 to 60 mm in 2-mm intervals. These 3D models were imported into Mimics software in STL (stereolithography) format.

Based on the method described by Sariali et al. and Yang et al.[4, 15], the simulated acetabular replacement was performed by placing the component in the true acetabulum, oriented at 40 abduction

and 20 anteversion. For attaining optimal bony coverage, the cup size was chosen to best accommodate the anteroposterior diameter of the true acetabulum, which tended to utilize the osseous peak of the anterior bone columns in case of the deficient bone stock. The inferior edge of the virtual cup was placed at the level of the DPCN, considered as the position of transverse acetabular ligament[15, 16]. In IV DDH group, the outer wall of the component was tangent to but did not penetrate the inner cortex of the medial acetabular wall to achieve the theoretical maximum coverage. In the control group, the outer wall of the component was tangent to the cortical bone edge of the cotyloid notch.

Morphological Evaluations and Measurements

On the basis of the implantation simulation, the morphological evaluations and coverage parameters included: (1) Measurement of the cup-CE angle and cup-Sharp angle (Fig. 2A), (2) Measurement of the acetabular anteversion (AceAV) angle and minimum thickness of medial acetabular wall (Fig. 2B), (3) Acetabular sector angles (ASAs): Basing on the contact point between native bone and the component, we measured the anterior and posterior ASAs in the axial plane (Fig. 2B). Further, the ASAs in the 45° anterosuperior direction, superior direction, and 45° posterosuperior direction were also measured on the corresponding planes. Angles were respectively named as A-ASA, P-ASA, AS-ASA, S-ASA and PS-ASA (Fig. 2C). (4) 3D Component coverage ratio: Utilizing the simulation and Boolean function of Mimics, segmentations were performed according to the border between the covered and uncovered parts of virtual cup (Fig. 2D). Accordingly, the coverage was calculated as the ratio between the covered and total surface area.

Location Analysis of the Acetabular Component Center

On the basis of the implantation at the true acetabulum, the component opening plane was defined as the coordinate system (oriented at 40 abduction and 20 anteversion), with the origin positioned at the center of the acetabular component. Representative bone landmarks included the ipsilateral anterior superior iliac spines (ASIS), the DPCN, as well as the most superolateral point, the most anteroinferior point and the most posteroinferior point of the true acetabulum rim were digitized (Fig. 3A). Subsequently, the 3D pelvis model and acetabular component were imported into 3-Matic software. Based on the coordinate system, bony landmarks were projected to the component opening plane to characterize the distributed regularity of bone stock in the true acetabulum and the location of the component center (Fig. 3B).

Surgical Performance

All THAs were performed by the same surgeon team using a posterolateral approach. After true acetabulum exposure, the anatomic bony landmarks including anterior, posterior walls, inferior wall and transverse ligament were adequately identified. Based on preoperative planning, the reaming center was determined according to the bony landmarks and implanted height towards the transverse acetabular ligament. All the implants were placed at 30–50 abduction and 10–30 anteversion and reamed to the inner cortex of the pelvis to maximize bony coverage. In practice, the implant size and autogenous bone augmentation were determined in combination with preoperative simulation and fixation condition intraoperatively. Additional screws were applied to reinforce the initial stability of the cup. The

uncemented femoral component selected to best matched the intramedullary canal was carefully controlled for a combined anteversion of 30–50°. The patients were allowed partial weight-bearing from 3 days to 1 week after the surgery and then full weight-bearing at 6–8 weeks with crutches.

Statistical Analysis

For assessing inter-observer reliability, two experienced surgeons (YHY and YCM) performed simulating implantation, point selection and corresponding measurements independently. For assessing intra-observer reliability, implantation, points selection and measurements were removed and repeated twice at monthly intervals by BHY. Intraclass correlation coefficient (ICC) was used to calculate inter-observer and intra-observer effects.

All statistical analyses were performed using SPSS version 21.0 (SPSS, Chicago, IL, USA). A post hoc power calculation was determined by the statistical power analyses G Power 3.1 to eliminate type II error[19]. Group comparisons for quantitative data were performed using unpaired Student's t-tests, and categorical data were compared using the chi-squared test. Paired t test was used to compare difference of two selected landmarks distances towards component center. $P < 0.05$ was considered to be statistically significant.

Results

Clinical Outcomes

A total of 37 patients (42 hips) with Crowe IV DDH were followed up for a mean of 4.7 years (1.2 to 6.3 years) and all the dysplastic hips were placed with standard-size acetabular implant (44.67mm, 44 to 48mm). The postoperative acetabular abduction and anteversion angles were 43.75 (41.03 to 46.46°) and 24.19 (16.05 to 31.33°), respectively. Autogenous bone augmentation was used in 9 hips (21.43%) whose 3D coverage ratio was less than 75% in simulated implantation or cannot achieve absolute primary stabilization intraoperatively. There was no acetabular implant loosening during the follow-up period and one revision was performed due to periprosthetic joint infection. Two patients suffered postoperative dislocation and successfully managed with closed reduction.

Acetabular Anatomy and Morphology Analysis

Compared with the hemispherical shape of the normal acetabulum, the true acetabulum in Crowe IV hip tended to be markedly triangular and shallow. As detailed in **Table 2**, all aspects of the anatomic parameter in Crowe IV hip were significantly smaller than normal hip, especially the acetabular width (25.41 ± 5.37 vs 50.14 ± 2.48). Herein, the accurate volume of the dysplastic socket was approximately one fifth of normal acetabulum. Accordingly, both the size and vertical implanted height of the component were significantly greater in normal hips. At the level of acetabular component center, the dysplastic acetabulum was found to be more anteverted and abductive, with smaller Cup-CE and larger Cup-Sharp angle. Medially, the acetabular wall was significantly thicker in Crowe IV hips than in normal hips (6.30 ± 2.77 mm vs 3.58 ± 1.22 mm).

Table 2
Acetabular Anatomy and Morphological Parameters after Implantation

	Normal (n = 36)	IV DDH (n = 42)
Acetabular Length (mm)	54.49 ± 2.05 (51.37 to 59.12)	39.74 ± 4.54 (30.53 to 50.65) **
Acetabular Height (mm)	34.10 ± 3.00 (28.20 to 42.40)	29.59 ± 4.37(19.41 to 38.27) **
Acetabular Width (mm)	50.14 ± 2.48 (46.74 to 54.90)	25.41 ± 5.37(15.38 to 37.33) **
Acetabular Depth (mm)	27.10 ± 2.60 (23.89 to 33.30)	15.06 ± 2.95(9.10 to 21.90) **
Acetabular Volume (mm ³)	35510.44 ± 7809.78 (27341.98 to 48034.93)	7549.46 ± 2535.61(5547.43 to 13757.24) **
Cup Size (mm)	52.67 ± 2.39 (50 to 56)	44.67 ± 1.44 (44 to 48) **
Cup Center Height (mm)	16.29 ± 1.44 (13.80 to 19.30)	13.32 ± 1.70 (8.67 to 16.25) **
Cup-CE (deg)	46.10 ± 5.53 (31.74 to 55.69)	23.44 ± 7.62 (8.20 to 40.13) **
Cup-Sharp (deg)	35.43 ± 4.07 (27.39 to 46.84)	49.01 ± 5.60 (34.95 to 59.51) **
Acetabular Anteversion Angle (deg)	20.46 ± 7.48 (7.13 to 37.68)	34.62 ± 6.37 (20.74 to 50.14) **
Medial Thickness (mm)	3.58 ± 1.22 (2.21 to 6.66)	6.30 ± 2.77 (2.53 to 14.31) **
Values are presented as the mean and the standard deviation, with range in parentheses; ** p < 0.01, when compared with control group;		

Acetabular Coverage Angles and Component Coverage Ratio

As described in the previous studies[20, 7], the abnormally distributed bone stock mainly located at the posterior rim of the true acetabulum. The coverage angles in Crowe IV hips were significantly smaller in the four directions, with exception of the posterior one (t=-0.628, P = 0.549). In comparison, the most severe dysplastic bone stock was in the anterosuperior direction, whose mean sector angle decreased more than 35° than normal hips. Further, the component coverage ratio was also significantly smaller in the dysplastic hips (79.89% vs 94.51%) (**Table 3**).

Table 3
Measurements of 2D/3D Coverage Parameters

	Normal (n = 36)	IV DDH (n = 42)
A-ASA (deg)	73.32 ± 8.16 (56.24 to 100.23)	55.99 ± 8.72 (20.63 to 71.42) **
AS-ASA (deg)	119.05 ± 6.42 (107.35 to 132.24)	84.77 ± 11.83 (64.82 to 112.17) **
S-ASA (deg)	135.93 ± 5.42 (121.26 to 144.69)	113.44 ± 7.62 (98.20 to 130.13) **
PS-ASA (deg)	133.18 ± 6.47 (115.85 to 144.58)	115.10 ± 9.09 (94.49 to 135.56) **
P-ASA (deg)	108.88 ± 9.45 (72.50 to 126.66)	107.40 ± 12.10 (87.16 to 134.83)
Coverage Ratio (%)	94.51 ± 2.32 (88.39 to 98.60)	79.89 ± 4.82 (72.25 to 89.84) **
Values are presented as the mean and the standard deviation, with range in parentheses; *p < 0.05, ** p < 0.01, when compared with control group; AceAV = acetabular anteversion angle		

Location Analysis of the Acetabular Component

Regarding the coordinate system, acetabular component center was defined as the origin (O), and the projection of ipsilateral ASIS was defined as the direction of y-axis. The projections of three extreme landmarks of the acetabulum rim were also depicted in reference to the right hip (Fig. 4). As illustrated, the component center was positioned posteriorly and superiorly to the center of the triangular acetabulum. Thus, the midpoint (O₁) and upper one-third point (O₂) of the posterior side in projected triangle were digitized. Statistically, the mean distance from the origin towards O₁ was significantly shorter than O₂ (t=-11.22, P=0.01) (**Table 4**). There were 29 hips (69%) whose distance of OO₁ was within 5 mm, and the distance was within 10 mm in all the hips (100%). While, the distance of OO₂ was within 5 mm in 7 hips (16%) and within 10 mm in 35 hips (83%).

Table 4
Location Analysis of the Acetabular Component

	O ₁	O ₂
x-axis	-2.53 ± 3.61 (-9.76 to 5.81)	-3.25 ± 3.85 (-10.40 to 6.73) **
y-axis	0.38 ± 2.00 (-4.90 to 5.09)	5.04 ± 2.88 (-4.89 to 10.22) **
Distance	4.12 ± 2.53 (0.58 to 9.76)	7.18 ± 2.67 (2.14 to 14.58) **
Values are presented as the mean and the standard deviation, with range in parentheses; *p < 0.05, ** p < 0.01,		

Reproducibility

Intraclass correlation coefficient results of the intra-observer and inter-observer reliabilities for all the measurement indices, evaluated by the one-way random effects model, ranged from 0.92 to 0.97 and

from 0.88 to 0.95, respectively. Post-hoc power analysis showed a power > 0.94 for detecting a significant difference.

Discussion

When performing a primary THA for a patient with Crowe IV DDH, the acetabular reconstruction especially presents considerable technical challenges to orthopedic surgeons. Further, Component revision in high dislocated hips was significantly more associated with the acetabular osteolysis, cup instability and severe polyethylene wear both in mid-term and long-term clinical studies[21, 9, 22, 23]. During the prior surgery, we noted that the acetabular anatomy and bone stock distribution was relatively constant in patients with Crowe IV dysplastic dislocation. Several studies[15, 13, 4] have reported that 3D simulation not only can provide high resolution visualization of morphological changes in skeletal disorders, but also can predict the postoperative rotation center and the orientation of prosthesis with high validity and accuracy. In the present study, we presented the first quantitative 3D morphological to determine feasibility, availability and optimal placement of standard-sized cup for acetabular reconstruction in Crowe IV hip, with excellent midterm outcomes while applying this technique.

Compared with other Crowe types, the true acetabulum in Crowe IV was thoroughly separated from the dislocated femoral head, resulting in remarkably dysplastic and deformed. Similar with previous description[7], Crowe IV acetabulum presented as a narrow, shallow and low-volume socket. Worth to mention, the acetabular volume in triangular acetabulum was approximately one fifth of normal one, resulting in an extremely smaller component size and lower implanted height. Due to the lack of articular contact, the Harris fossa is covered by few osteophytes and hard to identify. Further, correct recognition of the inferior edge of the true acetabulum is of particular importance for anatomic implantation intraoperatively[24, 25].

After simulated implantation, the Crowe IV acetabulum tended to be sharply abductive, with smaller Cup-CE and larger Cup-Sharp. Fujii et al[26] suggested that Cup-CE angle by host bone should be greater than 0° for satisfactory bony fixation in a five year follow-up study. Herein, the Cup-CE was 23.44 ± 7.62 according to the lateral edge of the host bone which provides possibility that there is no need for structural bone graft in most Crowe IV acetabular reconstruction[27, 9, 28]. In this study, autogenous bone augmentation was used in 9 hips (21.43%) and no implant failure was found. Moreover, the dysplastic acetabulum had a more excessive anteversion and thicker medial wall, similar as we reported previously[4]. In the present study, component was uniformly oriented at 20 anteversion and tangent to the inner cortex of the medial acetabular wall. Surgeons generally apply the technique of combined anteversion and acetabular cotyloplasty for better bony coverage. Although there was relatively sufficient bone stock medially, spongy bone condition and inadequate bone stock in the anteroposterior direction should also be taken careful consideration during acetabular reaming.

Regarding the limitation of the thin polyethylene liner and extremely small femoral head, standard-sized component with ceramic-on-ceramic bearing is recommended in recent studies[13, 12, 10]. Quantitative

coverage analysis suggested that segmental deficiency located at the entire acetabular rim, excepted for the posterior direction. In comparison, the most severe dysplastic bone stock was in the anterosuperior direction, whose sector angle decreased more than 35° than normal hips. Due to the great anteversion, there is no significant difference in the posterior cover angles between Crowe IV and control group. Further, posterosuperior deficiency was also less severe than that in the anterosuperior and superior direction, which is consistent with the description of abnormal bone distribution in the previous studies[7, 5]. A careful reaming for protection of the anterior acetabular wall is of particular important for stable acetabular component fixation, especially in Crowe IV hips[29, 5].

Reliable bony landmark can not only provide surgeon accurate identification but avoid intraoperative complications as well[29]. Based on the component opening plane, useful bone landmarks were projected by 3D simulation. Our data showed the optimal component center mainly located at the midpoint between the superolateral and posteroinferior points in the coordinate system, which was also proved to have good feasibility and repeatability intraoperatively (Fig. 5). The average distance between selected point and component center was only 4.12 mm, with 2.53 mm horizontally and 0.38 vertically. Similarly, Xu et al[13] suggested the component center in Crowe IV should be placed posterosuperiorly, described to be 4.55 mm superior and 4.37 mm posterior to the center of true acetabular circumcircle. Yoshitani et al[5] revealed that ideal center position located at the upper third point of posterior bony wall. In contrast, the mean distance in our data was smaller and variation range was within 10 mm in all hips. Compared with acetabular wall, the extreme poles of the acetabulum had better recognition and lower risk of abrasion and impingement. Midterm results also showed satisfactory outcomes in this study.

Limitations

The limitations of our study should be noted. First, the sample size was relatively small. However, the Crowe IV hips are uncommon and the results of statistical analysis indicated reliable reproducibility. Second, all the components were oriented at 40 abduction and 20 anteversion during preoperative planning, while implantation may be adjusted to be more abductive and anteverted individually in actual operation and implanted orientation cannot precisely match the preoperative planning without intraoperative navigation. Third, since the actual weight-bearing area was difficult to define in the 3D environment, we chose to weight the uncovered portions equally in the coverage evaluation.

Conclusion

To summarize, the distinctively triangular acetabulum in Crowe IV DDH presented to be more anteverted and abductive, with a significantly narrow and low-volume opening. The most satisfactory coverage was achieved at the level of true acetabulum by using standard-sized cup, whose prominent deficiency mainly locate in the anterosuperior and superior direction. Optimal component center was determined to be the midpoint between superolateral and posteroinferior points. Midterm outcomes were excellent in patients with Crowe IV DDH undergoing THA while applying this technique. Adequate preoperative planning and cautious reaming should be carefully considered to avoid small-sized component in Crowe IV hips.

Declarations

Ethics approval and consent to participate: This study was approved by the institutional review board of Guangdong Provincial People's Hospital (IRB: 2019528HR1). All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained in writing from all the individual participants included in the study.

Consent for publication: We have consent in writing for publication.

Availability of data and materials: All the data used and/or analyzed during this study are available upon reasonable request from the corresponding author.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: Study design: YHY, HD and QJZ. 3D reconstruction and measurement performance: YHY and YCM. Surgery performance and Data collection: YCM, QTL and JXL. Data analysis and data interpretation: YHY. Drafting manuscript: YHY. Approving final version of manuscript: QJZ and HD. QJZ takes responsibility for the integrity of the data analysis. All authors read and approved the final manuscript.

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Figures

Figure 1

3D Reconstruction and Acetabular Size Analysis A. Anterior pelvic plane, L-ASIS and R-ASIS= left and right anterior superior iliac spines, PS = pubic tubercle; B. The anatomical landmarks; DPCN: distal part of the cotyloid notch, T= most superolateral point of the acetabulum, O'= midpoint of T and DPCN; C. Coronal image, H=acetabular height, L=acetabular length; D. Axial image, W=acetabular width, D=acetabular depth; E. Acetabular volume analysis;

Figure 2

Morphological and coverage parameters analysis after implantation A. Cup-Sharp angle (a) and Cup-CE angle (b), measured with the coronal plane passing through the component center; Point O is the component center, point E and F were superolateral and inferomedial borders between component and the true acetabulum. B. Acetabular anteversion angle (a), anterior (A-ASA) and posterior (P-ASA) acetabular sector angles and thickness of medial acetabular wall (d), measured with the axial plane passing through the component center. Point O was the component center, points A and P= anterior and posterior borders of the true acetabulum, points A' and P'= anterior and posterior borders between the component and the true acetabulum. The direction of the medial wall thickness measurement is perpendicular to the acetabular opening (line AP). C. Acetabular sector angles through the component center (point O) were measured in 5 directions: anterior (a), anterosuperior (b), superior (c), posterosuperior (d), and posterior (e), which were showed in both 3D environment and the sagittal plane passing through the component center. D. The coverage ratio of the acetabular component was calculated according to the covered surface area and the total surface area. O was the component center, DPCN: distal part of the cotyloid notch.

Figure 3

Acetabular reconstruction at different vertical levels in the coronal plane A. Different vertical levels from DPCN were marked; B. Acetabular reconstruction was performed at different vertical levels, DPCN= distal part of the cotyloid notch.

Figure 4

The projections of the bony landmarks to the component opening plane in the reference of the right hip. O= the component center. Blue, grey and orange triangles represent projections of point T, A and P respectively. Black dots represent projections of point DPCN. Red and green dots represent projections of midpoint (O1) and upper one-third point (O2) of posterior side in the projected triangle (grey dotted line).

Figure 5

Perioperative radiographs and intraoperative photographs of a 38-year-old female patient with Crowe type-IV DDH. A. Preoperative anteroposterior pelvic view; B. Intraoperative images of dysplastic acetabulum (blue dotted line) and reaming center (yellow point); C. Intraoperative images of prepared acetabulum; D. Intraoperative images of component implantation; E. Verification of component center by matching the preoperative 3D pelvis (white model) to the postoperative 3D pelvis (yellow model); a: coronal image; b: transverse image; c: sagittal image; d: 3D reconstructive image; F. Postoperative AP pelvic view 3 month after surgery, with 84.39% coverage by host bone.