


## CLINICAL ARTICLE

# One-Stage Total Hip Arthroplasty with Modular S-ROM Stem for Patients with Bilateral Crowe Type IV Developmental Dysplasia

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**Objective:** The aim of the present paper was to evaluate the results of one-stage total hip arthroplasty (THA) for patients with bilateral Crowe type IV developmental dysplasia of the hip (DDH).

**Methods:** Data for 58 patients (116 hips) with bilateral Crowe type IV DDH who had one-stage THA performed by the same surgeon during the period of April 2008 to February 2019 were retrospectively reviewed. The mean age of the patients was 37.3 years; 5 were men and 53 were women. All patients underwent THA through the posterolateral approach using the Pinnacle acetabular cup, a ceramic-on-ceramic bearing, and the modular S-ROM stem. Subtrochanteric shortening osteotomy was performed on 86/116 hips. Intraoperative conditions were recorded. Radiographic and functional outcomes were evaluated, and complications were recorded.

**Results:** All patients were followed up for an average of  $71.3 \pm 37.6$  months (range, 12–140). The mean operative time was  $276.5 \pm 57.9$  min (range, 175–540). The mean intraoperative blood loss was  $933.6 \pm 400.8$  mL (range, 300–2000). The mean transfusion requirement was  $1778 \pm 798.0$  mL (range, 575–4550). The mean length of hospital stay was  $8.6 \pm 3.7$  days (range, 5–22). At the final follow-up, no loosening of acetabular and femoral components was observed. No osteolysis and heterotopic ossification occurred. The mean Harris hip scores were improved from  $55.4 \pm 14.3$  preoperatively to  $91.3 \pm 4.2$  postoperatively ( $P < 0.001$ ). In terms of complications, no perioperative deaths were recorded. Deep vein thrombosis occurred in 1 hip, with no pulmonary embolism. Intraoperative femur fracture occurred in 3 hips, nerve injury in 1 hip, and leg length discrepancy in 1 patient. Postoperative dislocation occurred in 5 hips and nonunion in 1 hip.

**Conclusion:** Our data demonstrated that one-stage bilateral THA for bilateral Crowe type IV DDH is feasible and can effectively restore hip function.

**Key words:** Bilateral; Crowe type IV; Developmental hip dysplasia; One-stage; Total hip arthroplasty

## Introduction

Developmental dysplasia of the hip (DDH) encompasses a wide spectrum of disorders, including irreducible dislocation, instability, and dysplasia of both the femur and the acetabulum<sup>1, 2</sup>. DDH is one common cause of secondary osteoarthritis in young and active individuals, which

eventually requires total hip arthroplasty (THA)<sup>3, 4</sup>. The Crowe classification system<sup>5</sup> is widely used in the literature to characterize DDH of adults. Crowe IV DDH is generally recognized as the most complicated and is often characterized by poor acetabular bone stock, a highly dislocated proximal femur, a narrow femoral canal, and contracted soft

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tissues<sup>6</sup>. Thus, THA in patients with Crowe type IV DDH is technically demanding and presents a challenge to surgeons<sup>7, 8</sup>.

In Crowe type IV DDH patients, the acetabular cup should be introduced to the true acetabulum and modular implants are recommended to accommodate the femur abnormality<sup>9</sup>. True acetabulum placement is biomechanically optimal, and can decrease the joint reaction force and increase the lever arm of the abductor musculature<sup>10</sup>. However, restoration of the anatomical hip center in these patients will inevitably lead to unacceptable limb lengthening, which can result in potential complications, such as sciatic nerve palsy and injuries to arteries<sup>8</sup>. Subtrochanteric shortening osteotomy (SSTO) is sometimes necessary to achieve safe reduction and limb length adjustment.

We routinely selected a modular prosthesis, S-ROM, and ceramic-on-ceramic bearings for THA for Crowe type IV DDH. S-ROM can provide torsional stability, which makes it an ideal choice for SSTO stabilization<sup>11</sup>. The modularity of S-ROM allows for adjustment of anteversion, offset, and leg length, and enables biomechanical reconstruction in cases of Crowe type IV DDH<sup>9</sup>. Use of ceramic-on-ceramic bearings has become increasingly popular in THA, especially in young patients, because of the low rate of wear, corrosion, and periprosthetic osteolysis.

Previous studies indicated that one-stage THA was a valid alternative to two-stage THA for primary arthritis in proper cases with bilateral Crowe type IV DDH<sup>12</sup>. One-stage THA usually has the following advantages: a single hospital stay, a shorter rehabilitation time, and lower management costs per patient<sup>13, 14</sup>.

Most previously reported THA for Crowe IV DDH have been unilateral and the results have been favorable<sup>15</sup>. However, few studies have considered morbidity and mortality rates, or the functional outcomes in bilateral Crowe type IV DDH patients managed with one-stage THA. The aim of this study was: (i) to determine the functional outcomes pre-operation and postoperation for bilateral Crowe IV DDH; (ii) to investigate the intraoperative and postoperative complications in one-stage THA for bilateral Crowe IV DDH; and (iii) to summarize our experience in the management of bilateral Crowe IV DDH.

## Patients and Methods

### Inclusion and Exclusion Criteria

The inclusion criteria were: (i) adult patients with bilateral Crowe type IV DDH with impairment of daily life activities; (ii) patients who underwent one-stage THA with modular S-ROM stem by a single surgeon in our institution; (iii) knowledge of preoperative hip function and postoperative hip function for patients with bilateral Crowe type IV DDH; (iv) outcome measures were length of hospital stay, operative time, intraoperative blood loss, transfusion requirement, Harris hip scores (HHS), and complications; and (v) retrospective study. The exclusion criteria were: (i)

patients with coagulopathy, severe cardiovascular diseases, or neoplasms who could not tolerate THA; (ii) patients with a history of cerebral palsy or poliomyelitis; and (iii) patients with staged procedures of THA for bilateral Crowe type IV DDH.

### Patients

A total of 61 patients (122 hips) managed with bilateral Crowe type IV DDH were retrospectively reviewed in our department from April 2008 to February 2019. A total of 3 patients with staged THA for bilateral Crowe type IV DDH were excluded: 2 patients for coagulopathy and 1 patient for cardiovascular disease. The remaining 58 patients (116 hips) were included in our study. This study was approved by the Institutional Review Board of our Hospital.

### Surgery

#### Anesthesia and Position

All the operations were completed by one senior surgeon (Y. G. Zhou) under single general anesthesia with the patient in the lateral decubitus position. We described the procedure in detail in a previous study<sup>9</sup>.

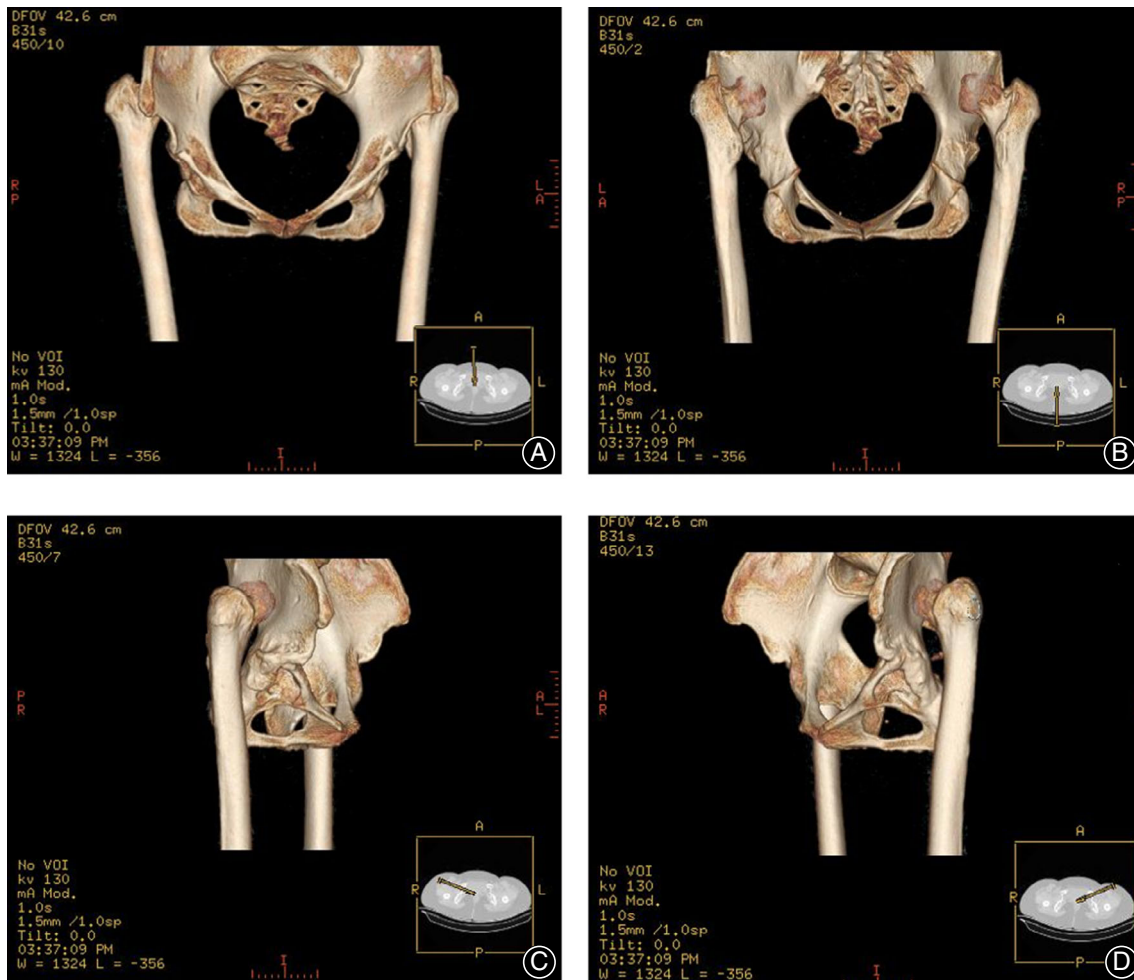
All procedures were performed *via* a posterolateral approach. Exposure of the anatomical acetabulum was performed by capsulectomy. We found that abductor muscle was weakened, and the capsule was hypertrophied.

#### Pathological Changes and Preparation

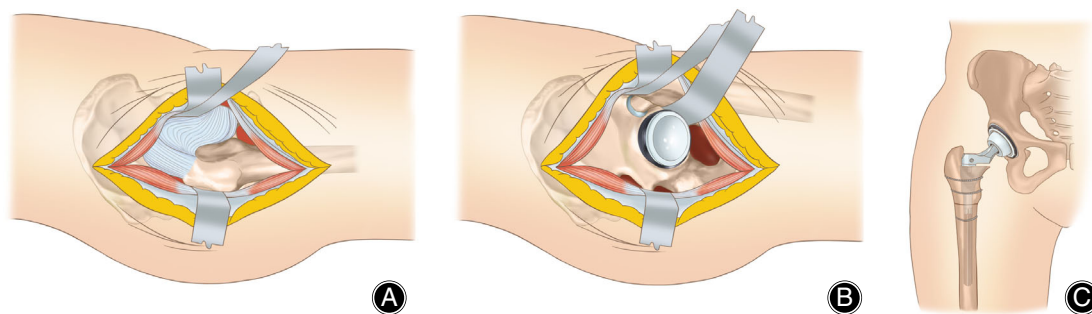
Crowe type IV DDH was often characterized by small and shallow true acetabulum, completely dislocated femoral head, excessive anteversion of the femoral neck, and narrow femur canal (Fig. 1). The malformed and undeveloped acetabula was too small to accommodate the smallest ceramic cup (46 mm in size), but we found that the bone at the posterior part was abundant. By reaming the acetabulum posteriorly and inferiorly, a 44-mm socket could be made. All of the acetabular components were placed at the anatomical position (Fig. 2). Structural autograft was used in 2 hips to increase the coverage (Fig. 3). Primary stability of the acetabular component was mainly achieved by press-fitting. Two or three screws were usually fixed to improve the primary stability.

The femoral canal was prepared before the osteotomy. During the process, we found that: (i) the femur anteversion obviously increased; (ii) the proximal femur was narrow and not well developed; and (iii) the anterior–posterior diameter was wider than the medial–lateral diameter in most bilateral Crowe type IV DDH patients. Then the trial component was inserted, and reduction was attempted. Contracted soft tissue often need to be released: release of the gluteus maximus tendon on the upper part of the femur, the tensor fascia lata, the iliopsoas tendon, and the adductor was performed until the desired tissue tension was achieved.

If the reduction was not successful, the distance between the center of the acetabulum cup and the femoral



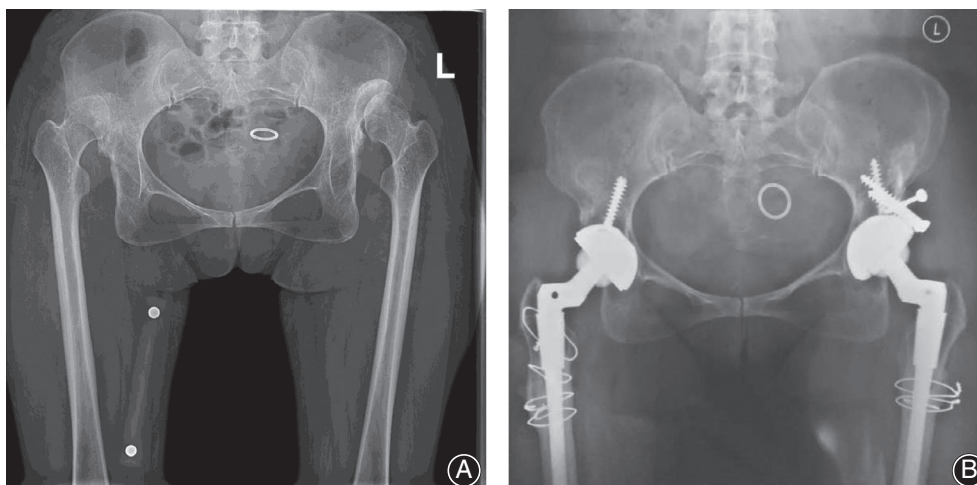
**Fig. 1** CT-based three-dimensional reconstruction image showing pathological changes in bilateral Crowe type IV developmental dysplasia of the hip. (A, B) Image showing the bilateral femoral heads completely dislocated. (C, D) Image showing small and shallow true acetabulum, completely dislocated femoral head, and narrow proximal femur canal.



**Fig. 2** Intraoperative pictures of total hip arthroplasty with subtrochanteric shortening osteotomy for patients with Crowe type IV developmental dysplasia of the hip. (A) Exposure of the capsule through posterolateral approach. (B) The acetabular component is placed at the anatomical position. (C) Subtrochanteric shortening osteotomy with modular S-ROM stem.

head component during trial reduction was measured and SSTO was performed (Fig. 2) The osteotomy site was as close to the sleeve as possible and osteotomy length was

determined with reference to the distance previously measured. Prophylactic cable fixation was routinely used before inserting the prosthesis to prevent iatrogenic splitting of the



**Fig. 3** One-stage bilateral total hip arthroplasty was performed on a 36-year-old male patient with Crowe type IV developmental dysplasia of the hip. Subtrochanteric transverse osteotomy was performed on both sides. The removed femoral segments were split longitudinally and fixed with cerclage wires at the osteotomy site. The left acetabular reconstruction was augmented with structural autograft. (A) Preoperative and (B) postoperative radiographic image at 6-year follow-up; femoral segments were absorbed, and union could be detected at the osteotomy site. The structural autograft was partially absorbed.

proximal femur. Prostheses with a modular S-ROM stem (DePuy, Warsaw, IN, USA) were used in all hips. The removed femoral segments were split longitudinally and fixed with cerclage wires at the osteotomy site to enhance the rotational stability and to promote bone union when necessary.

#### Placement of Prosthesis

Following the method we have described, a 44/46-mm porous coated acetabular prosthesis, Pinnacle (DePuy), was inserted and, consequently, a 28-mm ceramic-on-ceramic femoral head could be used. We attempted to set the acetabular orientation at approximately 25° of anteversion and 40° of inclination. A titanium modular femoral stem, S-ROM (DePuy, Warsaw, Indiana, USA), was selected to best match the abnormal femoral intramedullary canal.

#### Postoperative Management and Reconstruction

After completing the operation on one side, the patient's general status was evaluated. If the patient's status was stable, we proceeded with the operation on the other side. All patients had a suction drain placed in each hip and received prophylactic antibiotic therapy, as well as thromboembolism prevention with low-molecular-weight heparin for 30 days.

Partial weight-bearing and motion were allowed with crutches on the third day postoperatively. Flexion of the hip and knee at 40°–50° was maintained to protect the neurovascular tissue during the first 2 weeks postoperatively. At 6 weeks postoperatively, the ipsilateral crutch was no longer required and full weight-bearing was initiated; 1 week later, the contralateral crutch was no longer required.

#### Outcome Assessment and Follow-Up

The intraoperative conditions and length of stay were obtained from the patient medical records: operative time; intraoperative blood loss; transfusions requirement; length of hospital stay; and intraoperative complications.

Follow-up was performed by phone interview and outpatient visit and postoperative complications were noted. Standard radiographs were acquired during the follow-up period (at least 3 months following the operation) for each patient and radiographic assessment was used to determine whether the implant was loosening and whether osteolysis and heterotopic ossification were present. The HHS system was used to evaluate hip function. Intraoperative or postoperative complications were also recorded.

#### Implant Loosening

The diagnosis of prosthesis loosening was based on the serial radiographs at different times. Prosthetic position change within the femur involving subsidence of 2 mm or more or 5° or more of varus or valgus tilting was defined as loosening<sup>16</sup>. The acetabular components were also defined as loosening if they had tilted more than 5° or had migrated 2 mm or more<sup>16</sup>. Prosthesis loosening was one of the important factors affecting prosthesis survivability.

#### Osteolysis

Osteolysis was defined as areas of localized trabecular bone loss or cortical erosion which presented as circular or oval areas of obvious bone loss. Osteolysis was evaluated based on their location: femoral osteolysis according to the zones of Gruen *et al.*<sup>17</sup>, and pelvic osteolysis according to zones

defined by DeLee and Charnley<sup>18</sup>. Severe osteolysis was one of the main reasons for revision.

### Heterotopic Ossification

Heterotopic ossification was evaluated using the serial anteroposterior radiographs. It was graded using the Brooker classification<sup>19</sup>. No identifiable ectopic bone formation was defined as class 0; ectopic bone islands in the soft tissues represented class I; class II was demonstrated by ectopic bone extending from the pelvis to the femur separated by a 1-cm gap or more; ectopic bone extending from the pelvis to the femur separated by a <1 cm gap was defined as class III; and bone bridging between the pelvis and the femur was defined as class IV<sup>19</sup>. Severe heterotopic ossification could obviously affect hip function.

### Harris Hip Score

The patients were evaluated based on the HHS preoperatively, at 3, 6, and 12 months, and at final follow-up. The HHS system mainly includes four aspects: pain, function, absence of deformity, and range of motion<sup>20</sup>. The score standard has a maximum of 100 points. Outcomes are defined as excellent (90 to 100/100), good (80 to 89/100), fair (70 to 79/100), or poor (<70/100).

### Statistical Analysis

SPSS version 25 (IBM, Armonk, NY, USA) was used for statistical analysis. Continuous data were given as the mean and standard deviation. A two-sided, paired *t*-test was used for statistical analysis of the preoperative and postoperative HHS at different times. Statistical differences were significant when the *P*-value was <0.05.

## Results

### Demographic and Clinical Characteristics of One-Stage Total Hip Arthroplasty with Bilateral Crowe Type IV Developmental Dysplasia of the Hip

The mean follow-up period was 71.3 ± 37.6 months (range, 12–140 months). The mean age was 37.3 ± 11.0 years (range, 18–67 years). The mean BMI was 22.1 ± 3.5 (range, 16.0–30.6). The mean length of hospital stay was 8.6 ± 3.7 days (range, 5–22 days). Subtrochanteric transverse osteotomy was performed on 86 hips (74.1%); 30 THA (25.9%) were performed without a subtrochanteric transverse osteotomy. The mean osteotomy length was 3.81 ± 0.80 cm (range, 2.00–5.50). The mean operative time was 276.5 ± 57.9 min (range, 175–540). The mean intraoperative blood loss for bilateral THA was 933.6 ± 400.8 mL (range 300–2000). The mean blood transfusion requirement was 1778 ± 798.0 mL (range, 575–4550). (Table 1).

### Radiographic Results

All the acetabular were placed at the true acetabulum level. The average inclination was 40.9 ± 7.3 (range, 24.8–59.9). The average time of union at the subtrochanteric osteotomy

**TABLE 1 Demographic and clinical characteristics of patients**

Variable	Mean ± SD or n (%)
Gender	
Female	53 (91.4%)
Male	5 (8.6%)
Age (years)	37.3 ± 11.0
BMI (kg/m <sup>2</sup> )	22.1 ± 3.5
Hospital stay (day)	8.6 ± 3.7
Operative time (min)	276.5 ± 57.9
Intraoperative blood loss (mL)	933.6 ± 400.8
Transfusion requirement (mL)	1778.0 ± 798.0
Follow up (months)	71.3 ± 37.6

BMI, body mass index; SD, standard deviation.

site was 5.6 ± 1.5 (range, 3–12), excluding the 1 case of hip nonunion.

At the final follow-up, no radiolucency, osteolysis, or migration was observed in association with acetabular and femoral components.

### Clinical Outcomes

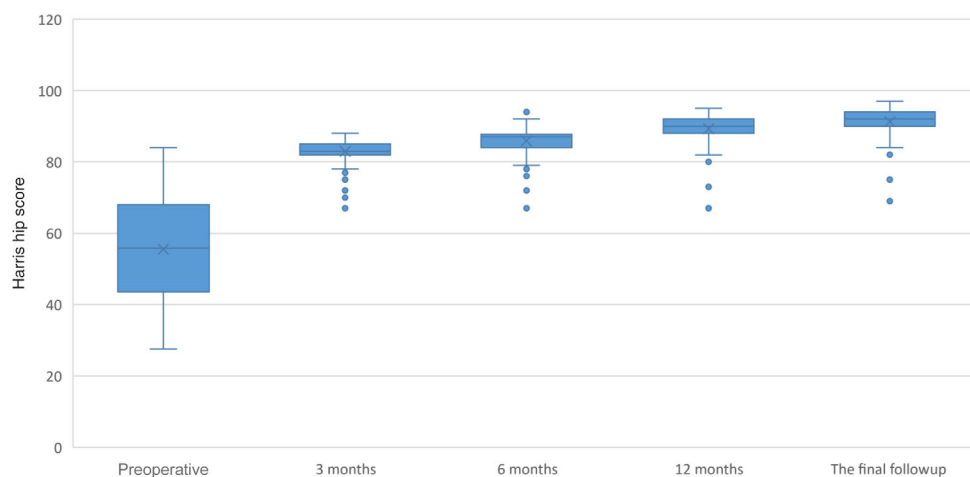
At the final follow-up, the mean HHS increased from 55.4 ± 14.3 to 91.3 ± 4.2 (*P* < 0.001). In all, 57 patients (114 THA) had a good or excellent result, with the remaining 1 patient (2 THA) having a fair result; 92 (79%) were scored as having an excellent result (90–100), 22 (19%) had a good result (80–89), 1 (1%) had a fair result (70–79), and 1 (1%) had a poor result (<70).

### Subgroup Analysis of Functional Results According to the Different Follow-up Time

We compared the HHS at different times: preoperatively, at 3 months, 6 months, and 1 year, and at final follow-up. The mean HHS was 55.4 points (range, 27–84 points) preoperatively, 82.9 points (range, 67–88 points) at 3 months postoperatively, 85.9 points (range, 67–94 points) at 6 months postoperatively, 89.3 points (range, 19–95 points) at the 1-year follow-up, and 91.3 points (range, 69–97 points) at the final follow-up. The hip function at 3 months improved obviously compared with preoperation (*t* = 19.83, *P* < 0.01). The hip function at 6 months improved compared to that at 3 months (*t* = 15.08, *P* < 0.01). The hip function at 12 months improved compared to that at 6 months (*t* = 23.19, *P* < 0.01). The functional scores improved obviously in 3 months. After 3 months, the functional results were stable, with slight improvement. (Fig. 4).

### Intraoperative and Postoperative Complications

The major complications are listed in Table 2. Nerve palsy occurred in 1 hip. The patient presented with dorsum numbness of the ipsilateral foot. Symptoms disappeared completely within 1 year. There was 1 hip with nonunion at the osteotomy site. One patient had a leg length discrepancy of 1.5 cm after THA. Revision of the femoral stem was



**Fig. 4** Temporal trends for Harris hip scores from preoperation to the final follow-up. Data are means (95% confidence interval). Outliers are marked with “o” (more than 1.5 to 3.0 times the interquartile range away from the median), while the extreme values are represented by “\*” (more than three times the interquartile range away from the median).

**TABLE 2** Complications with one-stage total hip arthroplasty for bilateral Crowe type IV developmental dysplasia of the hip

Indices	Values
Death	None
Pulmonary embolism	None
Deep-seated infection	None
Component loosening	None
Deep vein thrombosis	1
Intraoperative fracture	3
Dislocation	5
Nonunion	1
Leg length discrepancy	1
Nerve palsy	1

performed to adjust the leg length. Three femur fractures occurred in three patients and the fractures were fixed with a cerclage band. (Fig. 5) Deep venous thrombosis occurred in 1 hip, which was treated successfully with low-molecular-weight heparin subcutaneous injection (4100 units twice daily for 30 days). Five cases of hip dislocation occurred postoperatively; 3 cases of hip dislocation occurred within 1 month and 2 cases occurred in the second and third year after THA, respectively. Of the 5 cases of hip dislocation, 3 were managed with closed reduction and 2 with open reduction. (Fig. 6).

## Discussion

### *Application of One-Stage Total Hip Arthroplasty for Bilateral Hip Disease*

Total hip arthroplasty for high-riding DDH is a challenging and technically demanding procedure for surgeons in cases of acetabular and femoral morphologic abnormalities<sup>7, 21</sup>. Using one-stage THA for bilateral coxarthrosis is enticing because it reduces the length of hospital stay as well as costs, and patients recover quickly. However, concerns about poor outcomes and possible increases in the perioperative

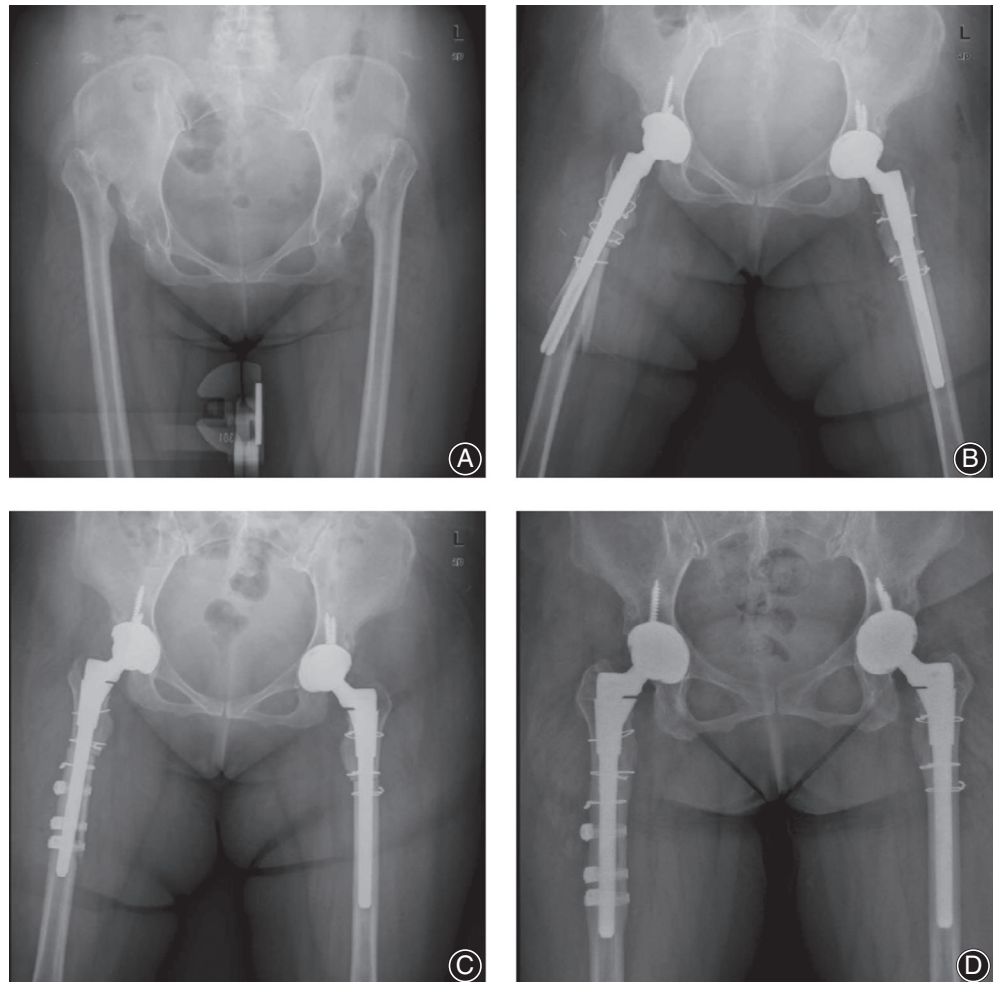
complication have limited the use of one-stage bilateral THA for complicated Crowe type IV DDH. Few studies have reported the functional outcomes as well as morbidity and mortality rates in Crowe type IV patients managed with one-stage THA.

Recent studies describing the results of THA for Crowe type IV DDH patients are summarized in Table 3<sup>15, 22–27</sup>. The results are favorable, but these studies examined small numbers of cases and few bilateral cases were included. Our study demonstrates that performed correctly, one-stage THA can yield excellent results in this special series of patients.

Hip function improved significantly and no prosthesis loosening or osteolysis was observed at the last follow-up. The cementless acetabular components had good bone ingrowth ability, which could avoid the acetabulum loosening caused by cement shell fracture<sup>17</sup>. The modular S-ROM stem allows the best fit and optimal placement of femoral components<sup>11</sup>. The ceramic-on-ceramic bearing surface could avoid osteolysis induced by polyethylene particle wear<sup>9</sup>.

### *Necessity of One-Stage Total Hip Arthroplasty for Patients with Bilateral Crowe Type IV Developmental Dysplasia of the Hip*

Dysplastic coxarthrosis mostly affects young and active individuals and the ASA classification is usually grade I or 2. The one-stage procedure is appropriate for this population<sup>28</sup>. Despite the greater effort in terms of physiotherapy, patients benefit more from one-stage THA for bilateral coxarthrosis given the earlier mobilization and rehabilitation<sup>29</sup>. Studies have demonstrated that the replaced hip is affected negatively by the contralateral joint and patients cannot gain optimal function until both hips have been replaced<sup>14, 30</sup>. For surgeons, one-stage THA could be beneficial for soft tissue release and leg length adjustment, and enable easier reduction. Can *et al.* compared unilateral THA with bilateral THA for high-riding DDH in a series of 69 hips (51 patients). One-stage THA was demonstrated to be an effective method; it did not



**Fig. 5** One-stage bilateral total hip arthroplasty was performed on a 49-year-old female patient with Crowe type IV developmental dysplasia of the hip using subtrochanteric transverse osteotomy. Femur fracture occurred in the right hip intraoperatively. The fracture was fixed with a cerclage band. The hips functioned well at last follow-up (A) Preoperative radiograph. (B) Femur fracture in right hip intraoperatively. (C) Femur fracture was fixed with a cerclage band. (D) At 3-year follow-up, the radiographic image reveals union at the fracture and osteotomy site; no radiolucent lines were found around the femoral stem.

increase the length of patients' hospital stay and had a low risk of postoperative complications<sup>15</sup>. In our research, the same surgeon performed one-stage THA on 116 hips (58 patients). The average length of hospital stay was 8.8 days, which was shorter than that for two-stage procedures in our hospital. The outcomes are similar to those of other studies that have examined THA for high-riding DDH<sup>9, 25, 27, 31</sup>.

#### **Application of Intraoperative Subtrochanteric Shortening Osteotomy with S-ROM Stem in Bilateral Crowe Type IV Developmental Dysplasia of the Hip**

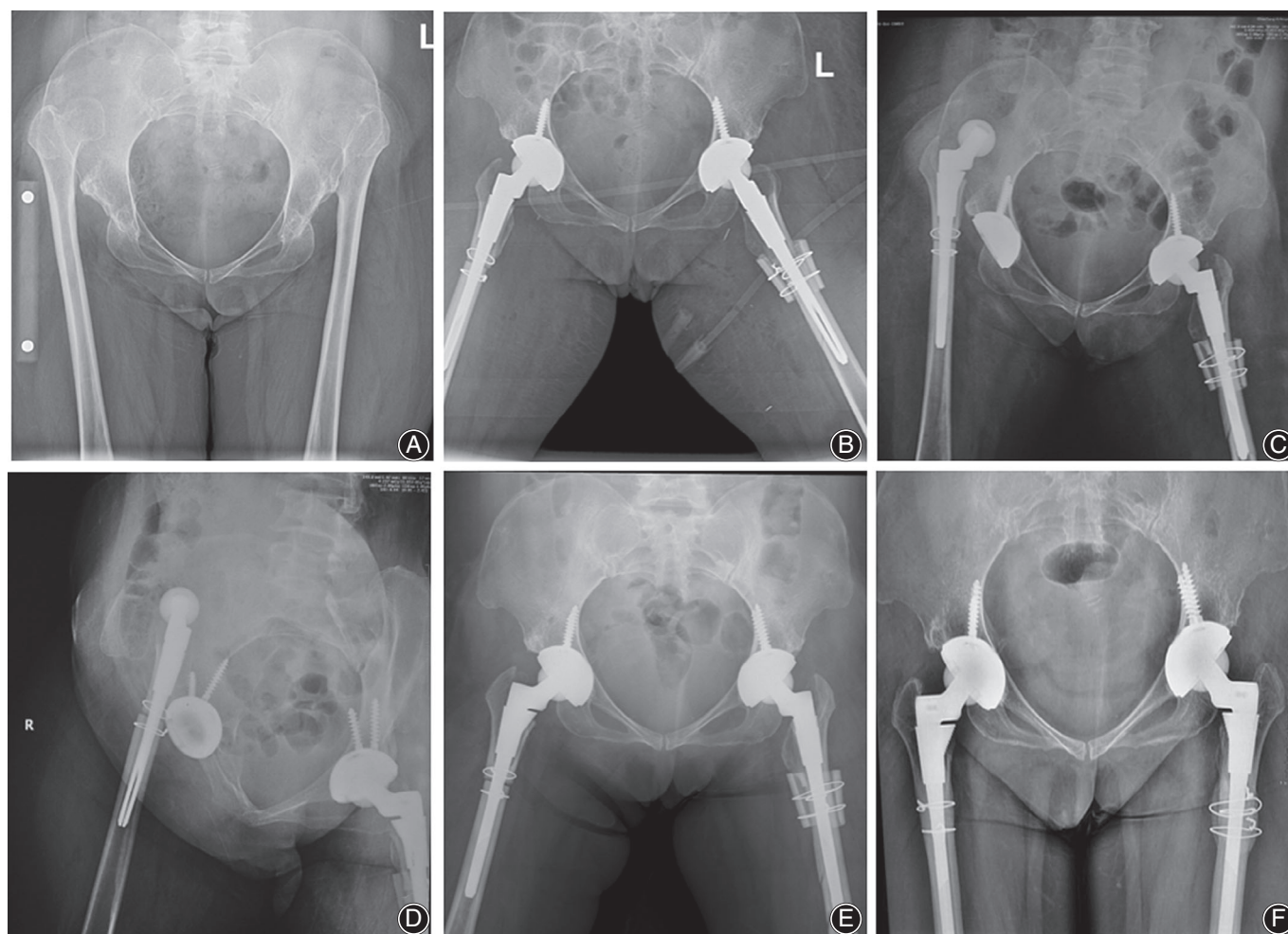
For patients with bilateral Crowe type IV DDH, osteotomy is often required. A variety of osteotomy methods have been proposed, but subtrochanteric shortening transverse osteotomy is one of the most common methods<sup>32, 33</sup>. In our study, subtrochanteric shortening transverse osteotomy was performed in 86 hips (74.1%). Osteotomy site union is a concern when osteotomy is performed. Akiyama *et al.* reported that the osteotomy nonunion rate was as high as 20% in 11 THA patients (15 hips) with Crowe type IV DDH undergoing transverse femoral osteotomy<sup>34</sup>. The nonunion rate was 1.4% in a study by Can *et al.* of 69 hips with Crowe type IV DDH<sup>15</sup>. In our

study, S-ROM prosthesis with subtrochanteric shortening transverse osteotomy was used for bilateral Crowe type IV DDH; there was only one hip nonunion. The modularity of the S-ROM stem allows the surgeon to decide the femoral anteversion independent of the position of best fit in the femur, making a technically challenging operation easier in regard to the optimal placement of the femoral component<sup>11, 35</sup>. Studies have proved that transverse subtrochanteric shortening osteotomy combined with S-ROM can provide sufficient primary stability and good healing ability<sup>25</sup>.

#### **Intraoperative Complications in Crowe Type IV Developmental Dysplasia of the Hip**

The intraoperative fracture rate during insertion of the femoral component has been reported to be as high as 28%<sup>23</sup>. Femoral fracture occurred in 3 hips (2.6%) for an extremely narrow medullary cavity in our study. Transverse osteotomy with prophylactic fixation of the distal fragment using the S-ROM prosthesis is a safe method, and the one-stage procedure does not increase the risk of femur fracture.

Nerve injury can be caused by excessive limb lengthening during the introduction of the acetabular component in



**Fig. 6** Radiographs of a 60-year-old woman with bilateral Crowe type IV developmental dysplasia of the hip. (A) Preoperative radiographic image showing high dislocation of the bilateral hips. (B) Radiographic image showing that total hip arthroplasty with a 28 mm ceramic-on-ceramic femoral head was performed in the bilateral hips 3 days postoperatively. (C, D) Dislocation occurred at day 25 postoperatively. (E) Open reduction was performed. (F) At the 63-month follow-up, no further dislocation or loosening of the component was identified.

the normal anatomical location for patients with Crowe IV DDH<sup>36–38</sup>. Femoral shortening osteotomy could reduce the incidence of neurological complications<sup>39</sup>. Kong *et al.* reported 10.7% neural complications in a series of 56 unilateral high-riding DDH without intraoperative nerve monitoring<sup>40</sup>. In our study, 1 hip (1.6%) exhibited nerve palsy. SSTO were used in most hips, which might have played an important role in reducing neurological complications.

Blood loss is another issue we should focus on for one-stage THA for bilateral Crowe type IV DDH. Femoral shortening osteotomy is time-consuming and accompanied by medullary bleeding. Extensive soft tissue release also plays a role in blood loss. Can *et al.* reported a mean blood loss of 1494 mL in bilateral THA for high-riding DDH<sup>15</sup>. In our study, the mean intraoperative blood loss is 926 mL. However, a high blood transfusion requirement is expected following one-stage THA. The wide range of blood transfusion

may reflect the complexity of THA for Crowe type IV DDH based on a broad range of pathomorphologic changes. Thus, administration of tranexamic acid, in preparation for blood transfusion, is necessary for severe developmental dysplasia of the hip.

#### **Postoperative Complications in Crowe Type IV Developmental Dysplasia of the Hip**

Postoperative dislocation is reported to range from 1% to 17%<sup>41, 42</sup>. Postoperative hip dislocation occurred in 5 hips (4.3%) in our study. Zhou *et al.* reported that use of a larger femoral head and improved abductor muscle strength could help reduce the rate of postoperative dislocation.<sup>43</sup> A 28-mm ceramic femoral head was used in all the bilateral Crowe type IV DDH following the method we introduced. Due to the morphologic abnormalities in the acetabulum and the femur, placing the prosthesis at an ideal location is difficult and soft



**TABLE 3** Previously reported results of total hip arthroplasty for patients with Crowe type IV developmental dysplasia of the hip

Authors	Published year	Bilateral/unilateral	Mean age (years)	Mean follow up (years)	HSS (range)	Dislocation	Intraoperative fracture	Nerve palsy	Nonunion
Ollivier <i>et al.</i> <sup>22</sup>	2016	4/20	48.0	10	87	3 (10.7%)	5 (17.8%)	0	2 (7.1%)
Mu <i>et al.</i> <sup>23</sup>	2016	13/45	35.8	5.9	83	2 (2.8%)	20 (28.2%)	8 (11.3%)	2 (2.8%)
Wang <i>et al.</i> <sup>24</sup>	2017	14/48	46.5	10	86	3 (3.9%)	4 (5.2%)	2 (2.6%)	1 (1.32%)
Zeng <i>et al.</i> <sup>25</sup>	2017	7/38	40.6	9.8	89.8	2 (3.8%)	0	2(3.8%)	0
Can <i>et al.</i> <sup>15</sup>	2018	18/33	44.3	3.1	N/A	1 (1.4%)	2 (2.9%)	3 (4.3%)	1 (1.4%)
Necas <i>et al.</i> <sup>26</sup>	2019	5/18	49.9	7.8	84	2 (7.1%)	4 (14.3%)	0	0
Erdem <i>et al.</i> <sup>27</sup>	2019	1/24	41.0	7.1	86	1 (3.8%)	0	0	0

HHS, Harris hip score.

tissue balance is necessary. In addition, to facilitate reduction, neglected excessive osteotomy may be performed for bilateral Crowe type IV DDH, which may result in potential hip instability and dislocation risk. Further research is needed to explore the risk factors of dislocation in THA for bilateral Crowe type IV DDH.

In general, a high percentage of complications (10.3%) was observed. The high complication rates were related to the complexity of one-stage THA for bilateral Crowe type IV DDH. The complexity manifests itself in these aspects: the abnormal anatomy, contracted soft tissue, osteotomy procedure, and leg lengthening<sup>44</sup>. Only 1 of our cases required prosthesis revision. Despite the high complication rates, the patients had a good outcome at last follow-up.

### The Limitations of This Study

The present study has several limitations. First, this is a single-center retrospective study. The second limitation is that we did not conduct a comparative study of one-stage and two-stage procedures. Finally, the length of follow-up varied and long-term follow-up is required for prosthetic survival.

In conclusion, the research confirmed that patients with bilateral Crowe IV DDH who underwent one-stage THA experienced significant improvements in terms of their HHS. One-stage THA for bilateral Crowe IV DDH is feasible and can effectively restore hip function. However, the procedure is technically demanding, with a risk of complications and high blood transfusion requirements.

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