CLINICAL ARTICLE

Mid-Term Outcomes of Cemented Stem and Subtrochanteric Shortening Derotational Osteotomy in Total Hip Arthroplasty for Crowe IV Developmental Dysplasia

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Objective: Performing subtrochanteric osteotomy with cemented components in patients with Crowe IV developmental dysplasia of the hip (DDH) is technically challenging and not widely reported. This study aimed to evaluate the mid-term outcomes of cemented stem total hip arthroplasty (THA) with subtrochanteric femoral shortening and transverse derotational osteotomy in patients with Crowe IV DDH.

Methods: Data collected from patients with Crowe IV DDH who underwent cemented stem THA with subtrochanteric femoral shortening and transverse derotational osteotomy between 2010 and 2018 were retrospectively evaluated. The cemented Lubinus SP II femoral component and the cementless CombiCup acetabular component were used together in all cases. These data, including Harris hip scores, limb length discrepancy (LLD), severity of limp, Trendelenburg test, bone union, length of the resected femur, limb lengthening, level of the osteotomy site, and length bridging the osteotomy site, as well as complications, were analyzed. A paired Student *t*-test was used to analyze continuous variables, categorical data were compared using Fisher's exact probability test, and correlation analysis was performed using Spearman's rank correlation coefficient.

Results: Among 14 included patients (10 females and four males), the mean age was 60.4 years (range, 47–73). The mean follow-up period was 49.1 months, and no patient was lost to follow-up. The mean Harris hip score improved from 40.7 to 87.7. The mean LLD decreased from 52 to 12.7 mm. The mean length of the excised femoral segment was 38.4 mm, and the mean length of limb lengthening was 27.1 mm. The mean distance between the osteotomy site and the lesser trochanter was 21.1 mm after surgery. The mean length of the femoral stem bridging the osteotomy site was 97.6 mm. Finally, the mean osteotomy union time was 10.6 months. No statistically significant correlation was found between the osteotomy union time and these factors. No neurological deficits were noted. Delayed union was observed in one patient, and postoperative dislocation was observed in two patients. Cement leakage into the osteotomy gap was observed in one patient, however, no revisions were required, and no signs of loosening or migration were observed.

Conclusions: Cemented stem THA combined with subtrochanteric femoral shortening and transverse derotational osteotomy is safe and effective in treating patients with Crowe IV DDH. Rather than leading to nonunion, cement leakage may negatively affect bone healing.

Key words: cemented stem; Crowe IV developmental dysplasia of the hip; nonunion; subtrochanteric shortening derotational transverse osteotomy

Introduction

Total hip arthroplasty (THA) for Crowe IV developmental dysplasia of the hip (DDH) can be a very challenging procedure to perform on both the femoral and acetabular sides because of the severe anatomical abnormalities associated with this disease. These abnormalities include low acetabular bone stock, abnormal hip center location, narrow femoral canal measurements, excessive femoral anteversion, valgus neck-shaft angles, posteriorly located greater trochanters, soft tissue contractures, large lower limb length discrepancies, and poor hip abductor mechanisms.[1,2] One of the most important steps in THA is restoring the hip to the anatomical center of rotation, which corrects the functions of the abductor muscles,[3,4] resulting in long-term benefits. However, this step is associated with limb lengthening exceeding 40 mm, thus increasing the risk of neurologic traction injury.[5,6] Subtrochanteric femoral shortening and derotational osteotomy were introduced to address these limitations. Subtrochanteric femoral shortening osteotomy helps to pull down the femur, correct rotational abnormalities, preserve the proximal femoral metaphysis, and reduce the risk of nerve injury,[7] whereas derotational osteotomy corrects the excessive femoral anteversion and posterior positioning of the greater trochanter.[8]

Total hip arthroplasty can be performed with cemented or uncemented stems. Subtrochanteric femoral shortening osteotomy with uncemented THA has been extensively studied. In contrast, the data on subtrochanteric femoral shortening osteotomy with cemented stems are lacking.[8–13] Despite limited research, many surgeons believe that cemented stems pose a risk of cement leakage into the osteotomy gap, which can lead to nonunion at the osteotomy site. However, cemented stem THA with subtrochanteric transverse osteotomy have some advantages. For a femur weakened by osteoporosis, cemented stems provide more stability than uncemented stems,[14] and cemented stems almost avoid the intraoperative periprosthetic fracture that may occur with uncemented stems.[8] Moreover, the operation can be completed with conventional cemented stems, while performing uncemented stem THA may require special femoral stem, such as Wagner Cone stem (Zimmer, Warsaw, United States). Furthermore, four subtrochanteric osteotomy techniques are currently available. These techniques differ with respect to the osteotomy cutting shape, which may be transverse, oblique, double-chevron, or Z-shaped.[15–18] Among these, the most common is the transverse osteotomy because it is technically simple and allows the surgeon to adjust the anteversion angle and length of osteotomy with ease.[19,20]

For these reasons, in the present study, we elected to focus on cemented stem THA with subtrochanteric femoral shortening transverse osteotomy in patients with Crowe IV DDH. The purposes of the present study were as follows: (i) to interrogate the mid-term follow-up outcomes of patients with Crowe IV DDH who were treated with cemented stem THA with subtrochanteric femoral shortening and transverse derotational osteotomy; (ii) to clarify the advantages of cemented stem THA combined with subtrochanteric transverse osteotomy; and (iii) to determine if there was an association between osteotomy union time and other clinical factors, such as the length of the femoral resection, extent of limb lengthening, distance of the osteotomy site from the lesser trochanter, and the length of the stem to bridge the osteotomy site.

Methods

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (i) adult patients with Crowe type IV DDH with extreme impairment of daily life; (ii) patients who underwent THA with subtrochanteric femoral shortening and transverse derotational osteotomy combined with implantation of the cemented stem and the cementless acetabular component at our institution; and (iii) the follow-up time should aim for ranging from 24 to 144 months for a mid-term follow-up study.[21] The exclusion criteria were as follows: (i) prior hip or pelvic surgery, residual DDH due to infection or trauma, surgery on the tibia, flexion contracture of the hip, and knee flexion deformity; and (ii) history of cerebral palsy and poliomyelitis.

Surgical Technique

All operations were performed by a senior author via a posterolateral approach with the patient in the lateral decubitus position. The sciatic nerve was initially identified to avoid iatrogenic injury. The joint capsule, femoral head, osteophytes, and any fibrous scar tissue were excised carefully and completely.

Acetabular Process

After identifying the true acetabular floor and the transverse ligament, which are the landmarks for the center of the hip, the acetabulum was gradually thinned with hemispherical reamers until bleeding cancellous bone was visualized, indicating that the medial wall of the true acetabulum had been reached. If the acetabular bone was insufficient, a femoral head and neck bone autograft was used to enlarge and reinforce the acetabular roof. The acetabular component (CombiCup, Waldemar Link, Hamburg, Germany) was then inserted into the anatomical acetabular position via the press-fit technique and fixed with dome screws. The outer diameter of the acetabular cup was 44–50 mm.

Femoral Process

The femoral trial component was implanted at the level of the lesser trochanter. The need for subtrochanteric osteotomy was determined based on the preoperative plan and the intraoperative assessment of soft tissue tension while attempting the reduction of the femoral head into the acetabulum. This was tested by pulling the leg with the knee flexed at approximately 90° while persistent distal traction was applied. If the femoral head was not reduced into the

acetabulum, the distance between the top of the acetabular implant and the femoral head needed to be measured. According to Huang et al.[22] initial osteotomy was performed at an optimal level below the lesser trochanter (the mean level of the initial osteotomy site was 21.1 mm [range, 15–30 mm]). The trial stem was then inserted into the proximal fragment, and the trial head was reduced into the cup. Manual traction was applied to the distal femur with the knee flexed at approximately 90°. The length of the bony overlap at the osteotomy level was measured, and this length was excised from the distal femur. The distal shaft of the femur should be broached again to account for the total length of the resected bone. The femoral trial component was then reinserted, which transfixed the osteotomy site. Reduction was then performed. Sciatic nerve tension was reassessed by palpating the nerve with the knee flexed at approximately 20°. The LLD, range of movement, and impingement were also assessed.

Next, the hip was prepared for the cemented implant. The contact faces of the proximal and distal cortical bones were planarized and three to five 3-mm holes were drilled near the osteotomy sites of both fragments. Both femoral fragments were held in place by bone clamps with the great trochanter towards outside, and the cement was subsequently applied. The final cemented Lubinus SP II femoral component (Waldemar Link, Hamburg, Germany) was inserted into the proximal femur, with the implant anteverted at 10–15°. Ceramic-on-ceramic wear-bearing material was used in all patients.

Postoperative Weight-Bearing
Patients were started immediately on partial weight-bearing exercises lasting approximately 8 weeks. If osseous healing was noted at the osteotomy site at 8–12 weeks, the patients gradually progressed to full weight-bearing exercises.

Clinical Data
The retrospective study protocol was approved by the appropriate Institutional Review Board (L2021023). Written informed consent was obtained from all patients.

We identified all patients who were treated at our institution for Crowe IV DDH and who underwent subtrochanteric femoral shortening and transverse derotational osteotomy between June 2010 and October 2018. Pre- and postoperative data, including clinical, operative, and radiological findings, as well as any identified complications, were compiled.

Clinical follow-up was conducted at 4, 12 weeks, and 6 months after surgery and annually thereafter until the last follow-up, left to the discretion of the attending surgeon. Patients were evaluated based on their Harris hip scores, pre-operative and postoperative limb length discrepancy (LLD), severity of limp, and Trendelenburg test results. LLD was calculated by measuring the distance between the anterior superior iliac spine and the medial malleolus.

Bone Union
Bone union at the osteotomy site was visualized using post-operative radiographs and was assessed based on the criteria for bone union described by Masonis et al.[8].

Length of the Resected Femur
The length of the excised femoral segment was measured and is defined as the length of the resected femur in this work.

Radiological Analyses
Serial radiographs of the pelvis were used for radiographic analysis by two coauthors. Any discrepancies in findings were discussed to reach consensus. On the pelvic side, acetabular component loosening was diagnosed if any of the following were observed: a progressive radiolucent line with a thickness of more than 2 mm around the inserted cup, migration of the component, or a change in the cup position.[23] On the femoral side, we investigated the evolution of radiolucent lines in the seven femoral zones.[24] Loosening was defined according to the criteria described by Johnston et al.[25].

Limb Lengthening
Limb lengthening was calculated using pre- and postoperative radiographs by subtracting the length of the resected femur from the distance between the tip of the greater trochanter.[26]

Level of the Osteotomy Site
The level of the osteotomy site was measured as the distance from the osteotomy site to just below the lesser trochanter, according to a report published in 2020.[22]

Length Bridging the Osteotomy Site
The length of the tip of the cemented stem relative to the osteotomy site was defined as the length of the cemented stem bridging the osteotomy site. This was measured as the distance from the tip of the cemented stem to the osteotomy site.

Statistical Analysis
Data are presented as mean values with ranges or mean ± standard deviation. A paired Student t-test was used to analyze preoperative and postoperative continuous variables (Harris hip scores and LLD). Categorical data were compared using Fisher's exact probability test (severity of limp and Trendelenburg test results). For the severity of limp, the slight, moderate, and severe grades of limp were classified as positive, and no limp was classified as negative, then Fisher's exact probability test was used. Analyses of the correlation between the osteotomy union time and the length of femoral resection, length of limb lengthening, distance of the osteotomy site from the lesser trochanter, and length of the femoral stem bridging the osteotomy site were performed using Spearman's rank correlation coefficient. A p value

<0.05 was considered statistically significant. Statistical analyses were performed using SPSS software version 24.0 (IBM, Armonk, New York, United States).

Results

Demographic Results
Among 14 patients with Crowe IV DDH who underwent THA using a cemented Lubinus SP II stem with subtrochanteric femoral shortening and transverse derotational osteotomy between 2010 and 2018 ($n = 14$ hips), there were 10 females and four males with a mean body mass index of 24.4 (range, 20.5–29.3) and 26.2 (range, 24.3–28.1), respectively, and a mean age of 60.4 years (range, 47–73 years) at the time of the operation. The mean follow-up period was 49.1 months (range, 30–70 months) (Table 1). No patient was lost to follow-up.

Clinical Results
The mean Harris hip score improved significantly from 40.7 preoperatively to 87.7 postoperatively, and the mean LLD was significantly reduced from 52 to 12.7 mm. No postoperative neurologic deficits were noted. One patient had bilateral Crowe IV DDH. No obvious leg length discrepancies were noted preoperatively; however, obvious LLDs were noted postoperatively. Preoperative Trendelenburg tests were positive for all patients, but postoperative Trendelenburg tests were negative for all patients at the last follow-up. A slight postoperative limp was noted in two patients, and no limp was noted in 12 patients (Table 2).

Bone Union
The mean osteotomy union time was 10.6 months (range, 7.6–18 months). One patient experienced delayed union, continuous partial weight-bearing and oral anti osteoporosis drugs were applied, and finally bone healing occurred

18 months after surgery. In this case, radiographic examination revealed that some cement had leaked into the osteotomy gap (Figure 1).

Length of the Resected Femur
The mean length of the excised femoral segment was 38.4 mm (range, 33–45 mm).

Radiological Results
The mean length of limb lengthening was 27.1 mm (range, 16–38 mm). We also measured the distance between the osteotomy site and lesser trochanter. The mean distance was 21.1 mm (range, 15–30 mm). The mean length of the femoral stem bridging the osteotomy site was 97.6 mm (range, 76.5–106.2 mm). No statistically significant correlation was found between the osteotomy union time and these factors (Table 3).

Complications
Two patients experienced hip dislocation within 3 months of the index surgery (Figure 2). Both patients underwent closed reduction and had no recurrence of hip dislocation at the last follow-up. No cases of infection, nerve palsy, or intraoperative fractures were noted during the study. No implant loosening was noted on radiographic analysis. No revision was performed for any reason.

Discussion

Mid-Term Follow-up Results
In the present study, we presented the mid-term follow-up data for patients who underwent cemented stem THA with subtrochanteric femoral shortening transverse osteotomy for Crowe IV DDH. Our results indicate that this procedure is safe and effective based on clinical and radiological outcomes.

TABLE 1 Patient demographics and outcome measures									
						Harris hip score			
Cases	Age (years)	Gender	BMI	Follow-up (months)	Side	Preoperative	last	Length of femoral resection	Osteotomy union time
1	50	Female	25	70	Right	38	88	33	9.9
2	47	Female	20.5	66	Right	36	86	40	11.1
3	68	Male	28.1	53	Right	40	84	38	11.8
4	73	Female	23	45	Right	42	89	45	7.6
5	51	Female	24.4	43	Right	37	93	35	18.0
6	62	Male	24.3	38	Right	44	91	38	10.4
7	72	Female	29.3	30	Right	48	83	40	11.1
8	52	Male	26.4	55	Left	37	86	35	10.6
9	65	Female	25.9	63	Left	38	87	43	8.2
10	59	Female	25.2	30	Right	40	89	35	11.7
11	66	Male	26	46	Left	40	87	40	11.5
12	51	Female	22.7	65	Left	45	92	35	8.5
13	62	Female	25	38	Left	40	90	40	8.5
14	68	Female	23.1	45	Right	45	83	41	9.1

TABLE 2 Clinical results

Outcomes	Preoperative	Last follow-up	t Value	p Value*
Harris hip score			−28.243	<0.001
Mean (range)	40.7 (36–48)	87.7 (83–93)		
Limp (no. of hips)				<0.001
Severe	9	0		
Moderate	3	0		
Slight	2	2		
None	0	12		
Limb length discrepancy (mm) (no. of hips)			3.635	0.003
<10	1	9		
10–20	0	4		
>20	13	1		
Trendelenburg sign (no. of hips)				<0.001
Positive	14	0		
Negative	0	14		

*Paired Student t-test used for continuous variables and Fisher's exact probability test used for categorical variables.

Management of Acetabulum in Patients with Crowe IV DDH

Performing THA in patients with Crowe IV DDH is an effective but difficult procedure. To improve the prosthesis survival rate and reduce limb length discrepancies, proper positioning of the acetabular component within the real acetabulum is necessary.[27] The true acetabulum is characterized by deficiencies both anterolaterally and superiorly, which always presents as triangular in shape. In order to improve the initial cup stability, an acetabular cup should be used to ensure a coverage of at least 70%[6]; if this is not achieved, other methods should then be considered,
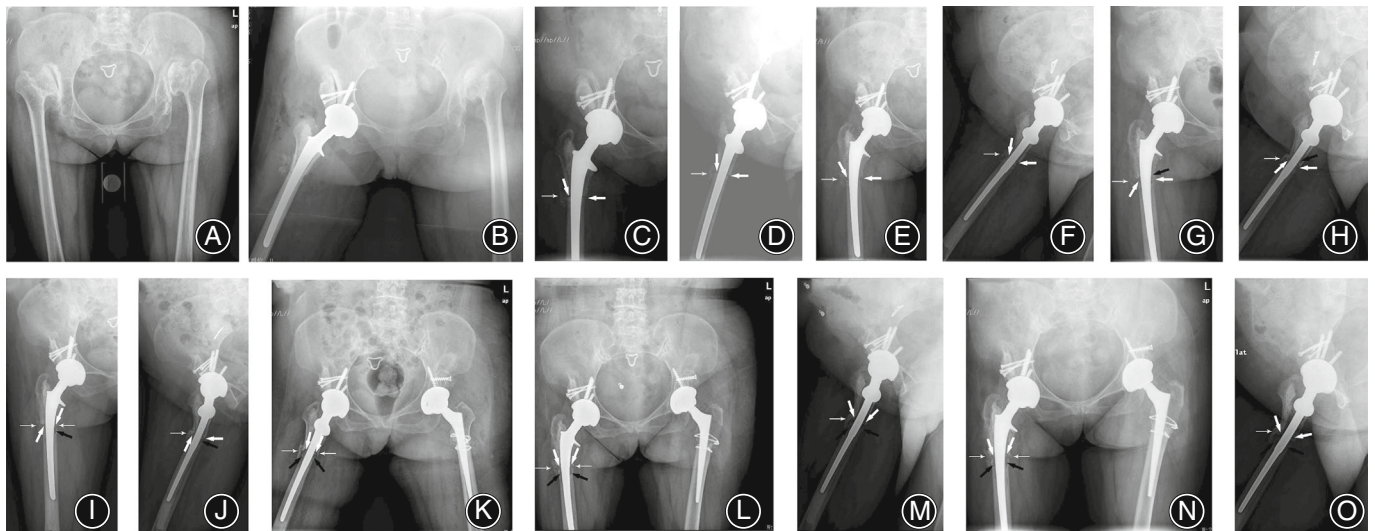

Fig. 1 Radiographs of a 51-year-old woman with bilateral Crowe IV developmental dysplasia of the hip. (A) Preoperative anteroposterior view. (B) Postoperative radiographic image from the first postoperative day. Right total hip arthroplasty was performed with a cemented stem using subtrochanteric femoral shortening and transverse derotational osteotomy. (C–O) Postoperative radiographs showing cement within the osteotomy gap. The radiographs show the bone bridge located at the cortical bone periphery at 3-month follow-up (C-D), 5-month follow-up (E–F), 10-month follow-up (G–H), 17-month follow-up (I–J), 18-month follow-up (K), 21-month follow-up (L–M), and 31-month follow-up (N–O). From the 10-month follow-up until the last follow-up, bone resorption is noted in the cortical bone around the osteotomy site. At the 18-month follow-up, a mature bone bridge is noted around the osteotomy site. The contralateral hip also shows a cementless hip implant. Both hips show autogenous femoral head structural bone grafts for acetabular deficiency. No signs of component loosening are identified. The thick white arrows indicate cement within the osteotomy gap; the thin white arrows indicate the bone bridge around the osteotomy site; and the thick black arrows indicate bone resorption within the cortical bone.

TABLE 3 Correlation of several factors with the osteotomy union time

	Mean ± SD	p value*
Osteotomy union time	10.6 ± 2.6	
Length of femoral resection	38.4 ± 3.5	0.098
Limb lengthening	27.1 ± 7.9	0.171
Level of osteotomy site	21.1 ± 5.0	0.373
Length of stem to bridge osteotomy site	97.6 ± 8.6	0.682

* Spearman's rank correlation coefficient.

including structural autograft with bulk femoral head,[28] controlled fracture of the medial wall,[29] medial protrusion technique,[30] and use of extra-small cups.[31] The structural autograft technique may result in bone graft nonunion, collapse, and absorption, however some studies had reported this technique provided encouraging long-term clinical results.[32,33] For this study, the structural autograft technique was applied in one patient, the medial protrusion technique was used in some patients, whereas others underwent routine surgery without using the above methods; additionally, all cups were not less than 44 mm in size. The structural autograft finally achieved bony union (Figure 1), and all cups showed no aseptic loosening, which was consistent with the results of a previous study.[28]

Analysis of Bone Healing at the Osteotomy Site

Placing the acetabular component in its true position may cause the pulling-down distance of the hip center to exceed 40 mm, which can jeopardize neurovascular structures.[5,6] In order to address this limitation, subtrochanteric femoral shortening and derotational osteotomy were introduced; however, they were also associated with a higher risk of other complications, particularly nonunion at the osteotomy site. Nonunion at the osteotomy site may lead to varus angulation, pain, loss of rotational stability, and prosthetic loosening.[7,34] Proper union of the osteotomy site depends on several factors, including the stability of the osteotomy site,[35] size of the contact area between the proximal and distal segments,[22] available bone stock, and degree of vascularization. Among these factors, the stability of the osteotomy site is the most important and is contingent on the osteotomy type, stem fixation method, stem morphology, and use of additional fixation materials such as cables or plate and screws.[34,36] However, the impact on osteotomy site stability associated with the osteotomy type and stem fixation method remains contested in the literature.

Comparison of Different Subtrochanteric Osteotomy Techniques

As a technique, subtrochanteric osteotomy is very adaptable and can be performed with transverse, oblique, double-chevron, and Z-shaped osteotomy shapes.[15–18] Transverse osteotomy reportedly has lower rotational stability than other techniques.[7,35] However, Muratli et al.[35] conducted a biomechanical study that compared the four osteotomy shapes and demonstrated that no single inherent feature increased osteotomy site stability. In addition, a comprehensive meta-analysis by Li et al.[19] reported no significant differences in
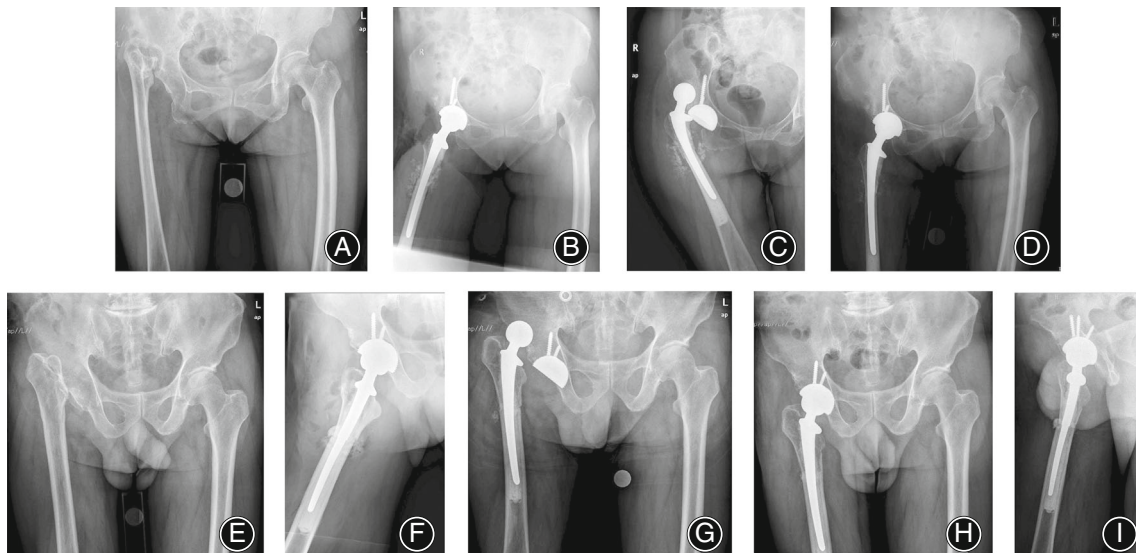

Fig. 2 Radiographs of two patients with Crowe IV developmental dysplasia of the hip. (A, E) Preoperative anteroposterior view of a 73-year-old woman and a 68-year-old man, respectively. (B, F) Postoperative radiographic images on the first postoperative day. Total hip arthroplasty was performed with a cemented stem using subtrochanteric femoral shortening and transverse derotational osteotomy. (C, G) Postoperative radiographs show hip dislocation during the first and third months after surgery, respectively. (D, H–I) At the 8- and 11-month follow-ups, respectively, the bone union is detected at the osteotomy site. No evidence of loosening is observed.

complications and survival rates according to the four cutting shapes. However, transverse osteotomy is the preferred approach because it is a relatively simple technique that allows surgeons to adjust the anteversion angle with minimal damage to the periosteum at the osteotomy site.[19,20]

Comparison of Cemented Stems and Uncemented Stems for Subtrochanteric Osteotomy

Many surgeons also prefer performing subtrochanteric osteotomy with an uncemented femoral stem[15–18] because cemented stems are prone to failure from cracking or fatigue owing to a narrow cement mantle.[37] Aseptic loosening has also been reported in young and middle-aged patients who received cemented stems.[38] Moreover, cemented stems perform worse in revision surgeries because of the inadequate residual bone stock.[39] They are also associated with a risk of cement leakage into the osteotomy gap,[40] which can lead to nonunion at the osteotomy site. Some studies have reported that cemented THA with subtrochanteric osteotomy is an effective treatment for severely dislocated hips.[8–13] Howie et al.[9] reviewed 26 patients (33 hips) who underwent cemented THA with subtrochanteric osteotomy for DDH, with a mean follow-up period of 5.6 years (range, 2–14 years). They reported that femoral components remained well fixed at the last follow-up and that no revisions for aseptic femoral loosening were required. On the other hand, Charity et al.[10] evaluated 15 patients (18 hips) with Crowe IV dysplasia of the hip who were treated using subtrochanteric osteotomy in combination with a cemented stem and followed up all cases for a mean period of 9.5 years (range, 4–14 years). In their study, only one femoral osteotomy failed to unite and was revised, and no patient had aseptic femoral loosening. Kawai et al.[11] reported 19 cases of cemented THAs with subtrochanteric osteotomy for Crowe IV hip, with a mean follow-up period of 3.2 years (range, 0.5–12 years); all osteotomy sites became united, and none of the components exhibited any evidence of migration or loosening. Akiyama et al.[12] reviewed 11 patients (15 hips) who underwent cemented THA with subtrochanteric osteotomy, with a mean follow-up period of 6.3 years (range, 3–10 years); nonunion occurred at three osteotomy sites, and revision surgeries were performed. No radiological loosening was detected in the cemented femoral components. Oe et al.[13] also reported 34 cases of cemented THAs with subtrochanteric osteotomy for Crowe IV hip, with an average follow-up period of 5.2 years (range, 3–10 years). They observed that none of the hips required revision and no patient had aseptic femoral loosening. All of these studies showed that no aseptic femoral loosening was observed once the osteotomy site became united. Additionally, most of these above-mentioned studies were mid-term follow-up studies according to the study of Ahmad et al.[41]. Consequently, it was easy to draw the conclusion that subtrochanteric osteotomy with a cemented stem for Crowe IV dysplasia of the hip had a good mid-term survival rate. However, the nonunion rate with cemented prostheses is 0%–20%,[8–13] as compared with 0%–12.5% with uncemented prostheses.[1,42,43] Recent improvements in prosthesis materials, product manufacturing processes, and cementing techniques have led to better results with cemented stems.[44] In the clinical setting, the main concern is that the cement will leak into the osteotomy site, leading to nonunion. However, Kawai et al.[11] reported that cemented THA with subtrochanteric transverse osteotomy provides satisfactory short-term results with no major complications in patients with Crowe IV DDH. Sound union of the osteotomy site was noted in all patient hips in the present study despite some patients having cement in the osteotomy gap. This result is encouraging for surgeons who prefer to use cemented stems with subtrochanteric transverse osteotomy for patients with Crowe IV DDH.

When there is potential fragility in the femur, cemented stems are preferred over uncemented ones because they provide more rotational stability.[14] It is important to note that the surgical procedure itself weakens the femur, especially during the femoral trial step, and cementless stems are associated with a higher risk of intraoperative fractures, with an incidence of 0%–22%.[36,42,43] Femoral fractures decrease the stability of the standard-length stem, as a result a longer stem with or without additional fixation, such as a cable or plate, is needed. In comparison, intraoperative fractures rarely occur with cemented stems.[8–13] Should they occur, the cemented stem itself provides good fixation. As cement stems in THA showed higher initial stability and lower incidence of periprosthetic fractures, all patients in the study were started immediately on weight-bearing exercises, and no prosthesis failure occurred.

Osteotomy Union and Other Clinical Factors

To promote union, one study recommends an optimal osteotomy level that depends on the length of the resected femur.[22] Furthermore, the osteotomy ends should be smooth[45] and parallel[10] to maximize the surface contact between the bones. Periosteal stripping should also be kept to a minimum.[45] To reduce the likelihood of cement leakage into the osteotomy gap, we drilled three to five 3-mm holes near the osteotomy sites of the proximal and distal cortical bones for patients included in the present study. The holes allowed the excess cement to leak out rather than deposit into the osteotomy gap during cementing. Another reason was to increase the stability of the cement mantle by the cement column. In addition, it was important to hold both femoral fragments using bone clamps during the process to avoid collecting cement leakage in the osteotomy site.

There is evidence that the stem bridging the osteotomy site is vital for achieving stability; however, the recommended length varies in each study. Ozan et al.[46] proposed that the femoral stem should pass the osteotomy site by at least 4–5 cm, whereas Yang et al.[47] suggested that at least 3 cm was sufficient. On the other hand, Kawai et al.[11] proposed that surgeons should insert the standard-length stem to a depth of at least 7 cm below the osteotomy site.

This allows the stem to function as an intramedullary nail, providing stability. Charity et al.[10] concluded that the stem should bypass the osteotomy site by at least twice the diameter of the diaphysis, especially in patients who require more robust fixation, such as in young men. In this study, the average stem length used to bridge the osteotomy site was 97.6 mm (range, 76.5–106.2 mm), consistent with the data presented in the studies mentioned.

We also analyzed the correlation between osteotomy union time and several other factors, such as the length of the femoral resection, length of limb lengthening, distance of the osteotomy site from the lesser trochanter, and length of the stem to bridge the osteotomy site. The results suggest that there is no statistically significant correlation among these factors. Our data are similar to those presented by Akiyama et al.[12] In contrast, Kawai et al.[48] demonstrated a significant correlation between the length of bone resection and the incidence of delayed union. However, Kawai et al.[48] divided the resected femoral fragments into two or three longitudinal segments and fixed these to the osteotomy site as autologous bone plates. This difference in technique may be the reason behind the differing results in the two studies.

Analysis of Complications

While all patients in the present study demonstrated significant improvement after surgery, some postoperative complications were noted. Two patients experienced hip dislocation within 3 months after surgery (Figure 2). This represents a dislocation rate of 14.3% (2/14), which corresponds with the published dislocation rate of 3.8%–15% in patients with Crowe IV DDH who undergo subtrochanteric osteotomy[1,7–9,12,42]. Both patients underwent closed reduction, were required to wear a brace, and were put on bed rest for 4 weeks. No dislocations recurred throughout the study. Moreover, while all osteotomy sites demonstrated good union, one patient showed delayed healing at 18 months postoperatively (Figure 1). Analysis of her postoperative radiographs revealed a linear hyperdense shadow in the osteotomy gap, which persisted throughout follow-up. Because no bone growth was observed within the shadow, we suspected that the shadow was cement within the osteotomy gap. The piece of cement prevented bone healing and promoted bone resorption, which was represented by the presence of a low-density shadow within the cortical bone around the osteotomy site. In the serial radiographs of this patient, new bone formation only occurred at the cortical bone periphery, which prolonged bone union time. No other complications occurred during the study period.

Limitations of the Study

This study had some limitations. First, there was no control group (uncemented stem THA with subtrochanteric transverse osteotomy). Second, the number of enrolled patients was relatively small, with data obtained from only 14 individuals. However, Crowe IV DDH is relatively uncommon; hence, obtaining a larger sample from a single institution may be difficult[9]. Third, our follow-up period was limited to a maximum of 70 months. Continued follow-up past 70 months may be beneficial to establish more long-term results associated with this procedure.

Conclusion

Cemented stem THA combined with subtrochanteric femoral shortening and transverse derotational osteotomy is safe and effective for the treatment of patients with Crowe IV DDH. The cemented femoral component showed promising mid-term follow-up results. The long-term results of this procedure should be evaluated in future studies. Rather than leading to nonunion, cement leakage may negatively affect bone healing. As such, osteotomy and the cementing process should be performed with great care.

Author Contributions

Conception and design of study: ZYH, JHZ, ZLD, KT. Performing the operation: ZLD. Acquisition of data: ZYH, KT. Analysis and interpretation of data: ZYH, JL, ZMZ, ZLD, KT. Manuscript drafting: ZYH, KT. Revising the article: All of authors.

Ethical Statement

The manuscript submitted does not contain information about medical drug(s) or device(s). The research was performed according to the principles of the Declaration of Helsinki and was approved by our institutional ethics review board (Ningbo No.6 Hospital Ethical Approval Form: Human Research Projects No. L2021023).

Consent for Publication

The manuscript does not contain any individual person's data in any form.

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