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Total hip arthroplasty with a monoblock conical stem and subtrochanteric transverse shortening osteotomy in Crowe type IV dysplastic hips

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Abstract

Purpose This series assessed the clinical and radiographic outcomes of total hip arthroplasty (THA) with femoral shortening osteotomy for the management of patients with Crowe type IV hip dysplasia.

Methods Only patients with Crowe type IV hip dysplasia who underwent primary THA combined with a subtrochanteric transverse osteotomy with an uncemented monoblock conical stem were included. The clinical and radiographic evaluations were performed before and immediately after surgery, and at last follow-up. The hip function was assessed with the Harris Hip Score (HHS).

Results Seventy-four patients (102 hips) with a mean age of 53.9 (range, 20–83) were evaluated at an average follow-up of 11.3 years (range, 5–25). Stem revision occurred in two (1.9%) cases, with a survivorship of 95.9% (95%IC, 91.9–99.9%) at ten years. The average HHS increased from 44 (range, 15–78) pre-operatively to 90.3 (range, 62–100) at last follow-up ($p < 0.001$). Osteotomy site non-union and early dislocation were observed in 3.9 and 3.8%, respectively. No cases of nerve palsy were reported.

Conclusions THA with a monoblock conical stem associated with subtrochanteric transverse osteotomy provides good long-term survival, clinical and radiographic results. It may be considered an effective management of patients with Crowe IV hip dysplasia.

Keywords Crowe type IV dislocation · Total hip arthroplasty · Monoblock conical stem · Transverse femoral shortening

Introduction

Developmental dysplasia of the hip (DDH) is a congenital disease characterised by joint incongruity due to an inadequate development of the acetabulum and dislocation of the femoral head [1]. The classification of Crowe et al. is still widely used to describe the severity of DDH according to the cranial migration of the femoral head. The DDH type IV is characterised by the migration of 100% or an iliac luxation of the femoral head. Surgical management is technically demanding because the dislocated femoral head must be reduced into the true acetabulum [2]. Moreover, relevant anatomical abnormalities must be taken into account, such as a restricted femoral canal with an excessive antetorsion, a valgus and anteverted femoral neck, a retroverted and hypoplastic great trochanter, and a small anteverted acetabulum [2].

The cup position in the original acetabulum should be achieved to restore the proper hip biomechanics and centre of rotation (COR) associated with the reduction of forces inside the joint and increase of the moment arm of the abductor muscles [3]. The restoration of the anatomical hip COR in dislocated hip may cause a limb lengthening more than 4 cm with the risk of sciatic nerve palsy [1]. To overcome this complication, several subtrochanteric osteotomies have been described for femoral shortening, including transverse, step, oblique or double-chevron cuts [4–6].

Although several uncemented non-modular and modular or cemented stems have been investigated [4, 7–9], only one

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previous study investigated the use of a non-modular conical stem combined with a subtrochanteric transverse shortening osteotomy (STSO) for the management of patients with high dislocated hip [10]. Because it was characterised by a very small sample and a short mean follow-up, further larger independent cohort studies are required.

The aim of this retrospective series was to assess the clinical and radiographic outcomes of monoblock conical cementless stem with STSO for the management of patients with Crowe IV DDH with a minimum follow-up of five years.

Patients and methods

In the study were included patients affected by Crowe IV DDH who underwent primary THA with a monoblock conical cementless stem (Wagner Cone Prosthesis, Zimmer Biomet) combined with STSO. The minimum follow-up was five years.

Clinical and radiographic evaluations were performed before and immediately after surgery, and at last follow-up. The hip function was assessed with the Harris Hip Score (HHS). The final score ranged from 0 to 100 points and it was classified as follows: excellent (between 90 and 100), good (80 to 89), fair (70 to 79) and poor (< 70) [11].

In both pre-operative and follow-up assessments, conventional radiographs in anteroposterior (AP) view of the pelvis and lateral view of the hip were achieved. A radiologist interested in musculoskeletal system performed all radiographic measurements. The cranial migration of the hip COR was defined as the vertical distance from COR to a line drawn through the teardrop distal edge. The lateral migration of the hip COR was defined as the horizontal distance, along the line tangent to the teardrops, from COR to a line crossing the middle of the teardrop. The height of the greater trochanter was defined as the vertical distance from its top to the line tangent to the teardrops [12]. The measurements were performed with the software Hip Arthroplasty Templating 2.4.3 running with OsiriX v.5.8.1 64-bit in preoperative and post-operative AP view digital radiographs [13].

In the postoperative radiographs, the radiolucencies around the acetabular cup were recorded according to DeLee and Charnley [14], whereas those adjacent to the femoral stem were described according to Gruen et al. [15]. Osteolysis was defined as a zone of radiolucency adjacent to the implant developed during the radiographic follow-up after THA. Loosening of the acetabular cup was defined by a change > 2 mm in the horizontal and/or vertical position with an adjacent radiolucent zone, or a radiolucent zone > 3 mm [16]. Loosening of the stem was defined as a progressive axial radiolucency > 3 mm, or a varus/valgus deviation from the femoral shaft axis > 3° [16]. The presence of heterotopic ossification was evaluated according to Brooker's classification [17]. The bone union at the osteotomy site was defined as the image of cross-linking trabeculae throughout the entire gap. The lack of this finding 6 months after surgery was defined as non-union.

Surgical procedure

All procedures were performed through the posterolateral approach with the patient in lateral decubitus. After head-neck resection, a transverse subtrochanteric osteotomy was performed at 8 up to 10 cm distal to the tip of the greater trochanter. The proximal femoral fragment was retracted anteriorly, capsular tissue was removed to expose the true acetabulum and then it was prepared with small reamers. The acetabular component was inserted in the anatomic acetabular position, by using the remnant transverse ligament as landmark. A femoral head autograft was used in 15 cases (14.7%) for acetabular reconstruction. To shorten the femur according to the preoperative planning, another distal transverse femoral osteotomy was performed. A mean of 3.3 cm (range, 2 to 5 cm) of femoral bone was resected. The distal part of the femur, below the site of the shortening osteotomy, was then prepared for the cementless implant. After the proper size of femoral rasp was established, the proximal fragment of the femur was prepared accordingly. To allow the distalisation of the proximal fragment, the tenotomy of the femoral insertion of the gluteus maximus, iliopsoas and gluteus minimus muscles were performed preserving the insertion of the gluteus medius. Then, the proximal and distal fragments were aligned and were properly rotated on the trial prosthesis, and the hip was reduced. Therefore, the definitive stem was impacted into the femur giving an anteversion according to the cup position. The combined anteversion between cup and stem was evaluated as previously described [18]. The stability of the osteotomy site was obtained with the press-fit of the stem and a cerclage wire binding proximal and distal femoral fragments. Characteristics of the prosthetic implants are reported in Table 1.

After surgery, patients were allowed to walk with crutches and a 50% of weight-bearing. During the four weeks following the surgery, the rehabilitation program was focused on the improvement of the range of motion. After one month, patients were allowed to progressively increase abductor resistance and weight-bearing. Ambulation without crutches and full weight-bearing was allowed at the radiological evidence of bone union at the osteotomy site.

Statistical analysis

All the analyses were performed using SPSS for Mac (version 23.0, SPSS Inc., Chicago, IL). Descriptive statistics were calculated. The two-tailed Wilcoxon signed-rank test for paired sample was used to perform the comparison between pre-operative and post-operative HHS values, and cranial and

Table 1 Characteristics of the prosthetic implants

	No. of hips ($n = 102$)
Stem type	
Wagner Cone 125°(Zimmer, Warsaw, IN)	40
Wagner Cone 135°(Zimmer, Warsaw, IN)	62
Stem size	
13 mm	6
14 mm	36
15 mm	21
16 mm	25
17 mm	4
18 mm	7
19 mm	3
Cup type	
Harris Trilogy (Zimmer, Warsaw, IN)	66
Delta TT (Lima Corporate, Friuli, Italy)	29
Delta PF (Lima Corporate, Friuli, Italy)	1
Delta Custom	1
Delta Motion (DePuy, Leeds, UK)	2
CLS Spotorno (Zimmer, Warsaw, IN)	2
Cup diameter	
42 mm	8
44 mm	43
46 mm	28
48 mm	16
50 mm	5
52 mm	2
Femoral head diameter	
22 mm	18
28 mm	43
32 mm	39
36 mm	2
Bearing surface	
Metal on polyethylene	31
Ceramic on polyethylene	36
Ceramic on ceramic	35

lateral migration of the hip COR, and height of the greater trochanter. A p value < 0.05 was considered significant.

The Kaplan-Meier method was used to estimate the implant survival that was defined as the time from primary surgery to revision of acetabular and/or femoral components for any reason. Ninety-five percent confidence intervals were calculated.

Results

Between 1993 and 2013, 128 hips (101 patients) were eligible to be included in the study. Fifteen patents died before last follow-up for causes unrelated to the surgery, nine patients were not interested to participate in the study and two were lost to follow-up. The details of the patients included in the study are reported in Table 2.

The last follow-up HHS value significantly improved when compared with the preoperative value (Table 3). The final scores were excellent in 58 hips, good in 29, modest in 11 and poor in 4. The cranial and lateral migration of the hip COR were significantly reduced after surgery (Table 3, Fig. 1).

Heterotopic ossifications were found in 18 (17.6%) out of the 102 hips. Of these, 7 were grade I ossifications, 5 grade II, 4 grade III and 2 grade IV. No patients required further surgery for ossification's removal.

Radiolucent lines around the stem were found in 11 (10.7%) out of the 102 hips, specifically in the Gruen zones 1 ($n = 6$), 2 ($n = 2$), in both 2 and 3 ($n = 1$), in both 2 and 7 ($n = 1$), and in 2, 3 and 5 ($n = 1$). Non-progressive radiolucent lines of the acetabular components were noted in nine (8.8%) out of the 102 hips, specifically in zone 1 ($n = 5$), in 1 and 2 ($n = 3$), and in 1, 2 and 3 ($n = 1$).

With a mean follow-up of 11.3 years, five (4.9%) out of 102 hips underwent acetabular component revision surgery and two (1.9%) underwent femoral stem revision surgery. The stem survivorship was 99% (95%IC 97–100%) at five years of follow-up and 97.8% (95%IC 94.8–100%) at ten years (Fig. 2). The cup and stem survivorship was 97.1% (95%IC 93.7–100%) at five years of follow-up and 95.9% (95%IC 91.9–99.9%) at ten years.

Four post-operative early dislocations (3.9%) were observed. Three cases were treated non-operatively, while one required surgical reduction. One dislocation occurred two years post-operatively and it was treated with acetabular component revision. No recurrence of dislocation was observed.

One intraoperative great trochanter fracture occurred and it was treated with cable grip device. This fracture healed within five months post-operatively. Non-union of osteotomy occurred in 4 cases (3.8%) (Fig. 3). No cases of nerve palsy, periprosthetic infection, deep venous thrombosis, pulmonary

Table 2 Characteristics of the included patients ($n = 74$)

	Mean (range) or n (%)
Gender	
Female	57 (77%)
Male	17 (13%)
Affected side	
Right	20 (27%)
Left	26 (35.2%)
Bilateral	28 (37.8%)
Follow-up (years)	11.3 (5–25)
Age (years)	53.9 (20–83)

Table 3 Radiographic and clinical outcomes

	Preoperative [mean (range)]	Postoperative [mean (range)]	*p*
COR (mm)			
Medialisation	37.8 (24–55)	23.8 (15–33)	< 0.001
Distalisation	83.6 (45–105)	14.2 (11–18)	< 0.001
Height of GT (mm)	89.3 (75–105)	22.6 (15–30)	< 0.001
HHS	44 (15–78)	90.3 (62–100)	< 0.001

COR centre of rotation, *GT* great trochanter, *HHS* Harris Hip Score

embolism or death were reported as a result of the surgical procedure.

Discussion

The present study demonstrated that THA with monoblock conical cementless stem combined with STSO is an effective management for patients with Crowe IV DDH providing an excellent survivorship in the long-term follow-up and restoring the anatomical hip COR with a low risk of sciatic nerve palsy.

The surgical management of Crowe IV DDHs is challenging on both acetabular and femoral sides. Although some authors supported the cranial positioning of the cup [19], this technique prevents a favourable lever arm of the abductor muscles, a proper restoration of limb length discrepancy and a placement of the cup in a region with good bone quality. Indeed, the iliac region is thin with limited bone stock, therefore is not suitable for a proper load transfer [2]. The positioning of COR in the original cotyloid area allows to restore the proper joint biomechanics and to manage the limb length discrepancy [3]. Although the true cotyloid area provides a greater bone stock allowing a proper positioning of the cup, acetabular reconstruction procedures can be required to maintain an extended contact surface between the cup and host bone [20].

Because the restoration of the anatomical hip COR in dislocated hip may cause sciatic nerve palsy due to the limb lengthening [1], a shortening femoral osteotomy is recommended. Although oblique, step-cut or chevron osteotomy was proposed to achieve a good torsional stability of the fragments, these osteotomies are technically demanding and could prevent a proper correction of the angular and rotational deformities [4–6]. The STSO is technically much easier to perform than the other methods and it allows to correct the abnormal version of the great trochanter. The major concern related to the STSO is the insufficient rotational stability resulting in the osteotomy site non-unions. In the present technique, the stability of the fragments is achieved with a monoblock conical tapered stem with longitudinal sharp ribs. First, the position of the osteotomy is planned in order to have a proper length of engagement between the stem and both proximal and distal fragments. Second, the taper shape fits with both the wider proximal and narrower distal fragment resulting in a continuous surface press-fit that provides a uniform load transfer [10]. On the other hand, modular stems are characterised by a different size of the proximal body of the implant compared with the distal one. It could lead to the proximal fixation of the stem with the proximal loading of the bone preventing a proper fixation and load transfer in the distal part of the stem. Moreover, the on-shelf modular prosthesis may not be an ideal choice in Crowe IV DDH because of the dramatic narrowing of medullary canal around the level of the lesser trochanter [21]. Finally, the longitudinal sharp ribs enhance the rotational stability of the stem. Although a proper stability of the osteotomy site should be obtained with the stem, the synthesis can be further enhanced with a cerclage

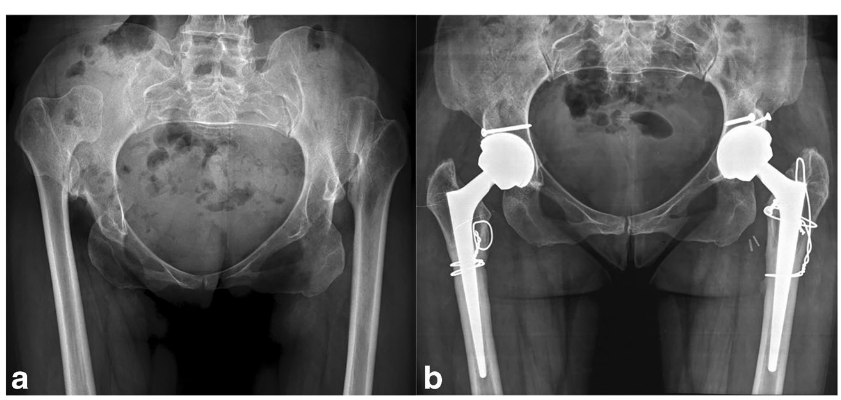

Fig. 1 **a** Bilateral dislocated hip in a 33-year-old female patient. **b** Staged bilateral total hip arthroplasty combined with 4 cm shortening femoral transverse osteotomy and acetabular reconstruction at 5 years of follow-up

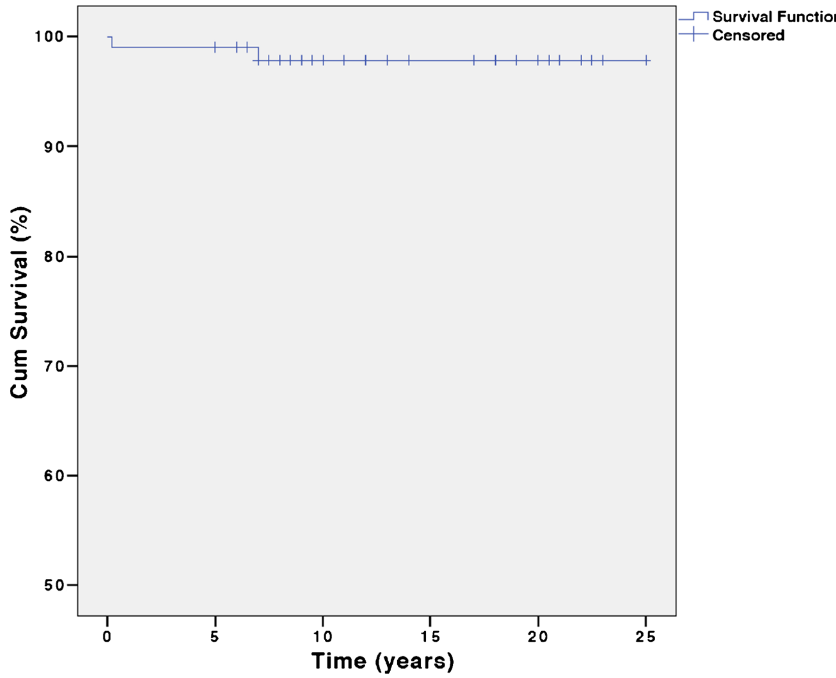

Fig. 2 The Kaplan-Meier analysis: cumulative stem survival calculated with 95% confidence intervals. The endpoint is the revision of the stem for any reason. The vertical hatches on the curve represent the censored patients: participants who dropped out of the study or who did not develop the event by the end of the study

wire binding proximal and distal femoral fragments. Cerclage showed adequate rotational stability and decreased the operating time when compared with plate fixation of STSO [22].

In literature, the non-union rate of the osteotomy site ranges from 0 to 12.5% with uncemented stems combined with subtrochanteric osteotomy [12], and up to 20% with cemented stems [9]. In the study of Zhu et al. [10], the Wagner Cone stem combined with STSO was associated with a non-union rate of 4.8%, while in this series, the rate was 3.8%. Therefore, STSO showed to address easily the rotational correction other than femoral shortening with a low risk of non-union.

Other severe complications resulting from THA and femoral shortening include neurological complications, occurring up to 14% [10], and post-operative dislocation occurring up to 15% [23]. Indeed, the altered Sharp angle in hip dysplasia has been demonstrated to significantly increase the risk of acetabular cup malpositioning [24]. In this series, no case of nerve palsy and only four cases of post-operative early dislocations

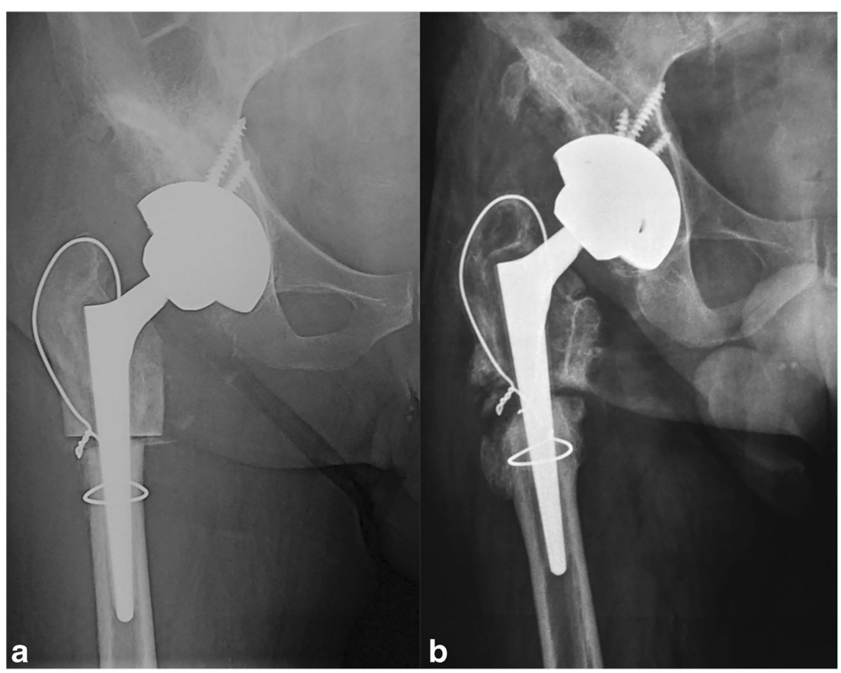

Fig. 3 **a** Total hip arthroplasty combined with 3 cm shortening femoral transverse osteotomy in a 65-year-old male patient at the immediate postoperative. **b** Non-union of the osteotomy site at 6 years of follow-up

(3.9%) were reported. Finally, peri-operative femoral fracture can be a major complication associated with press-fit stem in patients who previously underwent femoral osteotomy for hip dysplasia [25]. In this series, no patients had femoral osteotomy before THA with STSO, and only one intra-operative great trochanter fracture was reported.

In cementless THA, the stem must adapt to the variable femoral geometry in order to provide a good primary fixation. Therefore, to achieve the desired stem, anteversion could be difficult in DDH due to femoral abnormalities such as excessive antetorsion of the femur, valgus inclination and anteversion of the femoral neck, and retroversion of the great trochanter. Given its cylindrical section, the Wagner Cone stem allows the surgeon to achieve the desired anteversion regardless the proximal femoral anatomy. Moreover, it allows to perform a rotational correction of the great trochanter position when associated with a transverse osteotomy. Finally, the Wagner Cone stem demonstrated in this series an excellent long-term fixation with a survivorship of 97.8% at ten years. This revision rate was consistent with the National Institute of Clinical Excellence (NICE) benchmark of 5% or less at ten years of follow-up for primary THA, despite in this series the stem was used in complex hip replacement combined with femoral shortening osteotomy.

Major limitations of the study are the retrospective design and the lack of a control group. The uncontrolled design prevents us to prove that the cementless THA with a STSO is superior to other techniques described to manage these patients, including cemented implants and different types of femoral osteotomy such as step, oblique or double-chevron cuts.

In conclusion, the monoblock conical cementless stem represents an effective strategy to perform a primary THA with STSO in patients with Crowe IV DDH. The stem has an excellent survivorship in the long term, whereas the transverse osteotomy allows to restore the hip biomechanics with low risk of non-union and sciatic nerve palsy.

Compliance with ethical standards

Conflict of interest Guido Grappiolo received honoraria for speaking at symposia, financial support for attending symposia and educational programs from Zimmer Biomet, and royalties from Zimmer Biomet and Innomed. Giuseppe Mazziotta, Giuseppe Santoro, Mattia Loppini and Antonello Della Rocca received financial support for attending symposia and educational programs from Zimmer Biomet. Francesco La Camera has no conflict of interest.

Ethical approval This was a retrospective and observational study with medical records of patients included in a registry of orthopaedic surgical procedures. The study protocol for the development of this registry was approved by the Ethical Committee of Humanitas Research Hospital (approval number 618/17) and in strict accordance with the Helsinki Declaration.

Informed consent All individual participants signed a written informed consent before the surgical procedure and a written informed consent to be included in the registry of orthopaedic surgical procedures.

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