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ORIGINAL PAPER

Bernese-type triple pelvic osteotomy through a single incision in children over five years: a retrospective study of twenty eight cases

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Abstract

Introduction Bernese-type triple pelvic osteotomy (BTPO) combines periacetabular and triple innominate osteotomy techniques. However, studies that evaluate the clinical and radiographic outcomes of BTPO are scarce. The aim of this study is to report on the clinical and radiographic outcomes of ambulatory children with developmental dysplasia of the hip (DDH) or Legg-Calvé-Perthes disease (LCPD) managed with BTPO that were older than five years of age at the time of surgery.

Materials and methods We retrospectively reviewed the records of 27 consecutive patients with DDH or LCPD (mean age 7.6 ± 1.8; 28 hips) who were treated with the reported technique. All patients had regular clinical and radiographic follow-up. Post-operatively, changes in the acetabular index (AI) and centre-edge angle of Wiberg (CEA) were measured in all patients. The presence/absence of avascular necrosis of the femoral epiphysis was also noted in patients with DDH. Final radiographic results were evaluated with the Severin and Stulberg classifications. The Harris hip score was used in the functional evaluation of all patients.

Results In patients with DDH, the mean age at the time of surgery was 7.5 ± 1.8 years and the mean follow-up time was 22.2 ± 10.7 months. Prior to surgery, the mean AI was 37.9° ± 7.6°. At their final follow-up visit, the mean AI and CEA were 10.8° ± 5.4° and 40.9° ± 8.6°, respectively. Moreover, 66.7% of hips (14/21) were graded as Severin type I, and 33.3% (7/21) were graded as type II. The overall AVN rate was 14.3% (3/21). The mean Harris score was 92.1 ± 7.7. In patients with LCPD, the mean age at the time of surgery was 7.9 ± 1.8 years, and the mean follow-up time was 18.4 ± 6.1 months. Prior to surgery, 85.7% of hips were graded as Herring C, and 14.3% were graded as grade B. Prior to surgery, the mean AI and CEA were 19.4° ± 5.3° and 19.1° ± 12.6°, respectively. At the final follow-up visit, the mean AI and CEA were 5.8° ± 3.4° and 50.3° ± 12.0°, respectively, and 57.1% of hips were graded as Stulberg II. The mean Harris score was 94 ± 5.4. Ischial osteotomy non-unions were recorded in three patients (10.7%).

Conclusions BTPO through a modified anterior Smith-Peterson approach is an alternative treatment for DDH and LCPD in older children who are skeletally immature. It not only provides for a large acetabular correction but also achieves good biomechanical stability.

Keywords Bernese-type osteotomy · Triple osteotomy · Development dysplasia of the hip · Legg-Perthes disease · Surgical technique · Children

Introduction

Pelvic osteotomies have been developed to address a number of paediatric hip disorders, such as development dysplasia of the hip (DDH), Legg-Calve-Perthes disease (LCPD), and hip dysplasia associated with neuromuscular conditions [1–4]. Several types of "redirectional" and "reshaping" osteotomies of the acetabulum have been described by several authors. Among the "redirectional" osteotomies, the triple innominate

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osteotomy, first introduced by Le Coeur in 1965 [5], has been widely used to correct residual acetabular dysplasia and insufficient femoral head containment in patients with DDH and LCPD, respectively [3, 6–8]. After its first description [5], the procedure underwent several modifications [7–9] with respect to the osteotomy site at the level of the pubis and the ischium. Osteotomies can either be closer to the symphysis, as in the Le Coeur and Sutherland procedure, or closer to the acetabulum, as recommended by Steel and Tonnis. The latter two provide a greater degree of freedom for the acetabulum and more efficiently improve the coverage of the femoral head [7, 8].

Bernese-type triple pelvic osteotomy (BTPO) is a redirectional acetabular osteotomy that combines Ganz periacetabular [10] and triple innominate osteotomies [7, 8]. The first report on BTPO appeared in 2009 [4]. BTPO not only provides for a large acetabular correction in complex situations but also achieves better biomechanical stability compared with the Steel [8] and Tönnis [7] triple osteotomy [4]. Like other redirectional pelvic osteotomies, it does not violate the triradiate cartilage and can be used in skeletally immature patients.

At present, only one study that assesses the clinical and radiographic outcomes of BTPO is available in the English literature. However, all patients included in the study by Rebello et al. had neuromuscular hip dysplasia associated with neuromuscular and/or teratologic conditions, and most were non-ambulatory [4].

The aim of this study is to report on the clinical and radiographic outcomes of ambulatory children with developmental dysplasia of the hip (DDH) or Legg-Calvé-Perthes disease (LCPD) managed with a BTPO that were older than five years of age at the time of surgery.

Materials and methods

Following the approval of the Ethical Committee at our Institution (No. 2015020904), the records of 27 consecutive patients (28 hips) aged five years or older, diagnosed with DDH or LCPD, and managed with the BTPO technique from 2011 to 2016 were retrospectively reviewed.

Inclusion criteria for patients carrying the diagnosis of DDH were as follows: (a) residual hip dysplasia with or without an associated hip dislocation; (b) open triradiate cartilage; and (c) a minimum of five years of age. Similarly, inclusion criteria for patients with LCPD were as follows: (a) lateralization of the femoral head, insufficient femoral head coverage, and/or subluxation of the femoral head; (b) a minimum of five years of age.

The following demographic and clinical data were recorded: sex, gender, diagnosis, side involved, age at the time of surgery, intraoperative blood loss, immediate post-operative immobilization, length of hospital stay, and total follow-up period. Complications such as neurologic or vascular injuries, non-unions of the pubic or ischial branches, superficial or deep infections, and heterotopic ossification were also documented.

Surgical technique

Patients are placed supine on the operating table, with the hip in full extension. An incision is made for a modified Smith-Peterson approach along the anterior third of the iliac crest and the anterior border of the tensor fasciae latae (TFL). The incision then swings laterally to reach the posterior border of the TFL. The skin, subcutaneous tissue, and deep fascia are cut and dissected. The cartilage of the anterior third of the iliac crest is chiseled and dissociated subperiosteally. The sartorius and the TFL are pulled to the inside and outside, respectively, to expose the proximal rectus femoris. The lateral femoral cutaneous nerve is protected. The origin of the rectus femoris is incised and reflected to expose the hip joint capsule. The fibres of the iliacus that insert onto the anterior aspect of the capsule are dissected off the capsule until the tendon of the psoas muscle is exposed. This tendon is incised only in DDH patients.

The ischial ramus is exposed via the interspace between the medial side of the hip capsule, the iliopsoas tendon, and the femoral neck. Two Hohmann retractors are then inserted on both sides of the ischial ramus to clearly expose it and to protect the neurovascular structures. Fluoroscopy is used at this point to check the level of the osteotomy. A Ganz osteotome is used to make a complete ischial osteotomy, just inferior to the margin of the acetabulum and perpendicular to the bone.

After the ischial osteotomy is completed, the sartorius and iliopsoas muscles are pulled to the inside. The superior pubic rami are exposed subperiosteally, and the soft tissues are protected by placing a Hohmann retractor on each side of the bone. A Ganz osteotome is used to make a complete osteotomy of the superior pubic rami.

The osteotomy of the ilium is performed similarly in the Bernese-type triple pelvic osteotomy as in those described by Rebello et al. [4] and by Sankar et al. [11, 12], with an angled cut of the ilium (Figs. 1 and 2). Three crossed 3.5–4.5 mm cannulated screws are used to stabilize the osteotomy (Figs. 3 and 4).

Lastly, the origins of the rectus and sartorius muscles are reinserted through the bone. The TFL and the external and internal oblique muscles are repaired back to the iliac crest in a near anatomic position. In DDH patients, the surgical procedure requires an open reduction. A femoral shortening osteotomy is performed in high dislocated hips. All patients are immobilized in a spica cast after surgery for ten to 12 weeks.

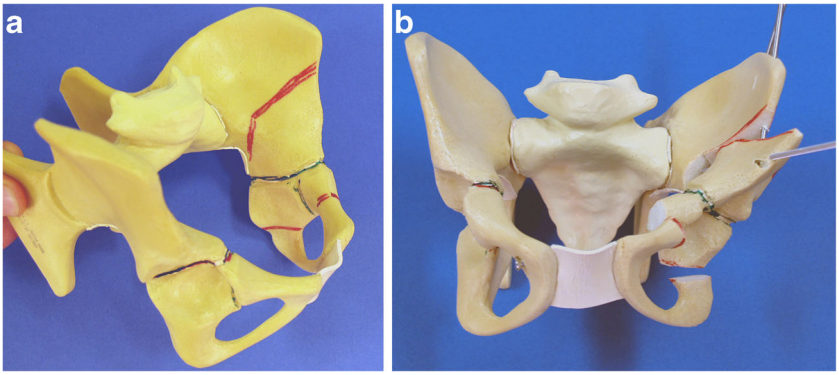

Fig. 1 An angled ilium cut (**a**) increases bony contact at the osteotomy site and contributes to improved pelvic stability (**b**)

Clinical and radiographic evaluation

All patients underwent regular clinical and radiographic follow-up for at least 12 months after surgery. At each follow-up visit, antero-posterior (AP) pelvic radiographs with the hips in the neutral and frog-leg positions were taken to assess ongoing osteotomy consolidation and to detect complications such as secondary displacement, hardware migration, non-union, or malunion.

At the last follow-up visit, the range of motion of both hip joints was recorded (Fig. 5), and the Harris hip score was used in the functional evaluation of all patients [13].

Using AP pelvis radiographs, acetabular index (AI) and center-edge angles (CEA) were measured in all patients before BTPO and at their final follow-up visit.

Avascular necrosis (AVN) of the proximal femoral epiphysis was also assessed in patients with DDH and was graded according to the Kalamchi and MacEwen criteria [14]. As type I AVN is considered to be a transient ischemia of the femoral head, which can recover completely [15, 16], we grouped type 1 AVN with normal hips. Final radiographic outcomes were classified according to Severin's criteria [15].

In contrast, the hips of patients with LCPD were graded prior to BTPO according to the criteria published by Herring

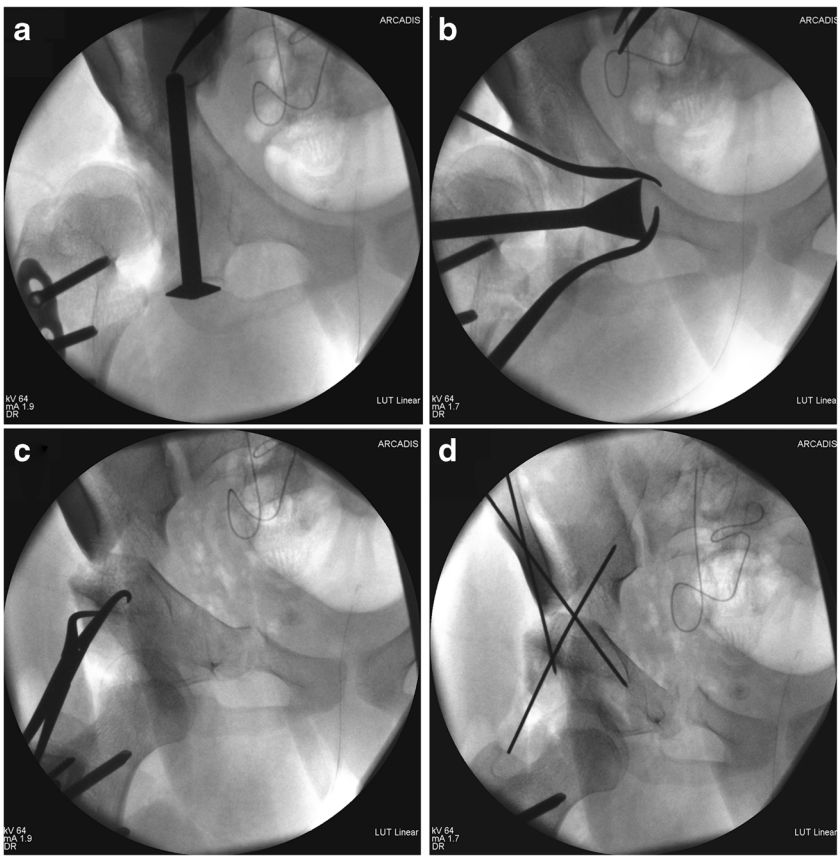

Fig. 2 A Ganz osteotome is used to make a complete ischial osteotomy, just inferior to the margin of the acetabulum and perpendicular to the bone (**a**); superior pubic rami osteotomy (**b**); ilium osteotomy with angled cut (**c**); temporary fixation of BTPO osteotomy, before cannulated screw insertion (**d**)

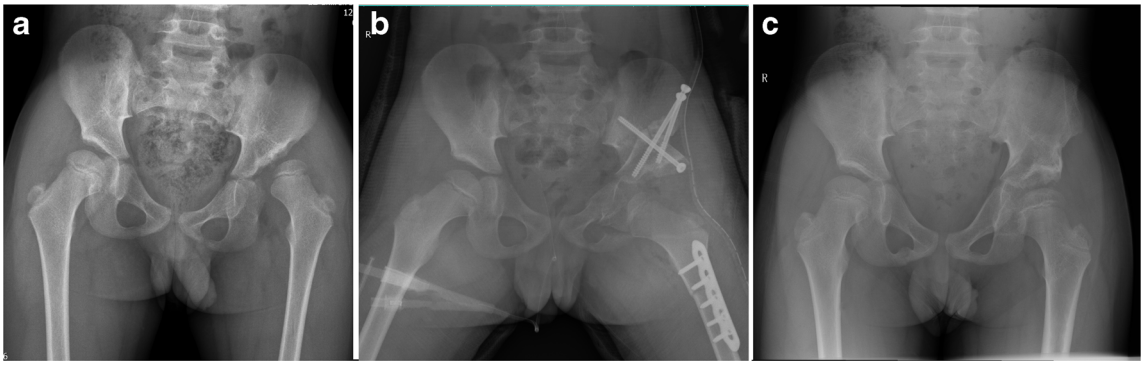

Fig. 3 AP pelvis radiographs of a 5-year girl with left DDH: Pre-operative (**a**), immediate post-operative (**b**), and final follow-up (**c**)

et al. [17]. Final radiographic outcomes were classified according to Stulberg's classification system [18].

Results

This study included a total of 28 hips in 27 patients, 20 with DDH (74.1%; one bilateral) and seven with LCPD (25.9%) (Tables 1 and 2). Sixteen patients were female (59.3%) and 11 were male (40.7%). The right side was involved in 16 cases (57.1%), and the left side was involved in 12 (42.9%). The average age at the time of surgery was 7.6 ± 1.8 years (range 5–11.9). The mean follow-up period was 21.2 ± 9.8 months (range 12–53).

Clinical and radiographic evaluation

In patients with DDH, the mean age at the time of surgery was 7.5 ± 1.8 years (range 5.1–11.9), mean blood loss was 472.4 ± 251.8 ml (range 150–1200), hospital length of stay was 10.2 ± 6.3 days (range 4–26), and mean follow-up time was 22.2 ± 10.7 months (range 12.5–52.9). Table 3 highlights hip range of motion. Hardware was removed an average of 14.2 ± 6.4 months (range 7.1–39.4) after the index procedure (Fig. 2).

Prior to surgery, the mean AI was 37.9° ± 7.6°. Six hips were rated as Tonnis grade 2 (28.6%), nine hips as Tonnis type 3 (42.8%), and six as Tonnis type 4 (28.6%). At the final follow-up visit, the mean AI and CEA were 10.8° ± 5.4° and 40.9° ± 8.6°, respectively. Further, 66.7% of hips (14/21) were graded as Severin type I, and 33.3% were graded (7/21) as type II. The mean Harris score was 92.1 ± 7.7 (Table 1).

In patients with LCPD, the mean age at the time of surgery was 7.9 ± 1.8 years (range 6–11), mean blood loss was 407.1 ± 237.0 ml (range 150–800), mean hospital length of stay was 6.7 ± 1.7 days (range 4–9), and mean follow-up time was 18.4 ± 6.1 months (range 12.6–28.4). Table 3 highlights hip range of motion. Hardware was removed an average of 10.8 ± 1.8 months (range 8.7–12.6) after the index procedure (Fig. 3).

Prior to surgery, 85.7% of hips (6/7) were graded as Herring C, and 14.3% (1/7) were graded as grade B. Prior to surgery, the mean AI and CEA were 19.4° ± 5.3° and 19.1° ± 12.6°, respectively. At the final follow-up visit, the mean AI and CEA were 5.8° ± 3.4° and 50.3° ± 12.0°, respectively. At the final follow-up visit, four hips (57.1%) were classified as Stulberg II, two hips (28.6%) as Stulberg III, and one hip (14.3%) as Stulberg IV (Table 2). The mean Harris score was 94 ± 5.4.

Complications

Minor complications were recorded in seven patients (25.9%): three patients developed asymptomatic non-unions (10.7%) of the ischial osteotomy, and four had a transient dysesthesia in the territory of the lateral cutaneous nerve.

Fig. 4 AP pelvis radiographs of a 5-year old boy with left LCPD: Pre-operative (**a**), immediate post-operative (**b**), and final follow-up (**c**)

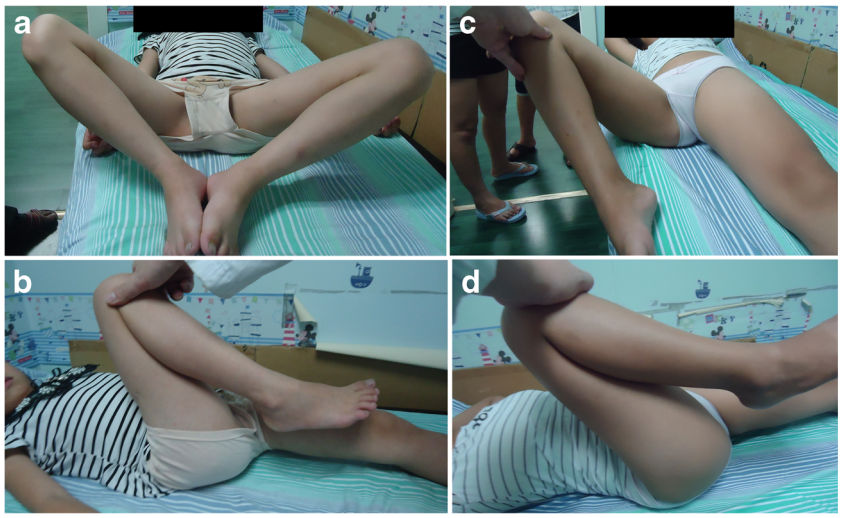

Fig. 5 Post-operative clinical picture. 6.1-year-old girl with right DDH: hip abduction (**a**) and hip flexion (**b**). 6-year-old girl with right LCPD: hip abduction (**c**) and hip flexion (**d**)

Three hips with DDH and 4 hips with LPCD were overcorrected with CEA larger than 50°. However, only three hips (1 DDH and 2 LCPD) had CEA larger than 60°.

No patients showed signs of growth arrest or growth disturbance of the triradiate cartilage, based on radiographic and clinical assessments during follow-up. There was no radiographic evidence of a delayed union of the iliac and pubic osteotomies, and no cases of hardware migration.

In DDH patients, the overall rate of AVN was 14.3% (3/21) (Table 1).

Table 1 Demographics and outcomes of patients with DDH treated with a Bernese triple pelvic osteotomy

Hip no.	Gender	Age (year)	FU (month)	Side (L/R)	Tönnis grade	FO (yes/no)	Pre-OP AI (degree)	Final FU (degree)		AVN type	Complications	Severin grade	Final Harris
								AI	CEA				
1	M	8.9	52.9	L	3	Yes	47	18	38	III		2	84
2	M	7.9	15.3	L	4	Yes	47	15	28			1	97
3	M	7.3	28.0	L	3	Yes	45	19	30		LFCND	1	97
4	F	6.3	32.0	R	3	No	37	4	49			1	93
5	F	9.2	14.7	L	4	Yes	46	11	40			1	66
6	F	7.6	12.6	L	3	Yes	38	19	51			1	97
7	F	11.9	39.4	R	3	Yes	42	10	35			2	97
8	F	5.5	28.2	L	3	No	31	0	45			1	100
9	F	9.0	20.0	R	2	Yes	21	5	40		LFCND	2	87
10	F	8.9	21.4	L	2	No	31	14	55		NU	1	97
11	F	8.1	14.2	R	4	Yes	29	7.5	35		NU	1	96
12	F	6.3	14.5	R	3	No	38	6.7	60	III		2	88
13	F	5.1	12.5	R	4	No	47	17	45			2	97
14	F	9.4	12.8	L	4	Yes	45	13.5	42			2	89
15	F	9.4	13.2	L	2	Yes	36	10	41			1	96
16	F	6.1	30.4	R	3	Yes	38	14	26		LFCND	1	100
17	F	6.3	30.6	L	2	Yes	32	3	38			1	90
18	F	5.8	14.7	R	4	Yes	31	12	42.5	III		2	87
19	F	6.6	26.7	L	2	Yes	36.5	13	34.9			1	96
20*	F	6.1	12.7	R	2	Yes	30	6	48			1	87
21*	F	5.5	19.3	L	3	Yes	48	10	36			1	94

*Hip 20 and hip 21 belong to the same patient, a female with bilateral DDH; FU = follow-up; AVN = avascular necrosis of the femoral epiphysis; NU = non-union of the ischial osteotomy; OP = operation; FO = femoral osteotomy; LFCND = lateral femoral cutaneous nerve dysesthesia

Table 2 Demographics and outcomes of patients with LCPD treated with a Bernese triple pelvic osteotomy

Hip no.	Gender	Age (year)	FU (month)	Side (L/R)	Pre-OP (degree)		Final FU (degree)		Pre-OP Herring	Complications	Final Stulberg	Final Harris
					AI	CEA	AI	CEA				
22	M	11.0	20.0	L	11	42	6	54	B		2	97
23	M	6.7	13.6	R	20	17	6	45	C	NU	2	100
24	M	9.1	12.6	L	23	17	8	37	C		3	87
25	M	7.1	24.2	R	17	12	3	61	C	NU	4	86
26	M	6.0	28.4	L	27	0	11	35	C		2	97
27	F	6.5	17.4	L	17	22	0	66	C	LFCND	2	97
28	F	9.1	12.7	R	27	25	7	56	C		3	94

FU = follow-up; NU = non-union of ischial osteotomy; OP = operation; LFCND = lateral femoral cutaneous nerve dysesthesia

Discussion

BTPO is a redirectional acetabular osteotomy that combines Ganz periacetabular osteotomy [10] and the triple innominate osteotomy [5, 7–9]. Like other redirectional pelvic osteotomies, it does not violate the triradiate cartilage and can be used in skeletally immature patients.

This study reviewed 28 consecutive hips with DDH or LCPD treated with a BTPO. All osteotomies healed, although three non-unions of the ischial osteotomy were recorded. Regardless, the functional outcome was good in all patients with DDH, and it was good to satisfactory in 71.4% of patients with LCPD.

BTPO, which was developed from the periacetabular osteotomy, was first reported by Rebello et al. in 2009 [4] and further described by Sankar et al. [11, 12]. BTPO creates an angled cut in the ilium, which is different from previous triple pelvic osteotomies in which the ilium osteotomy is a Salter-like osteotomy. This alteration increases bony contact at the osteotomy site, thereby improving pelvic stability and favouring bone healing.

BTPO does not change the rotational centre of the acetabulum, nor does it increase pressure on the femoral head, thereby theoretically decreasing the risk of AVN. Rebello et al. reported good results of 31 hips surgically treated with a BTPO in skeletally immature patients. However, all patients had associated neuromuscular or teratologic conditions, and most were non-ambulatory, which made objective functional evaluation impossible [4]. In another work, Li et al. performed the same procedure on 33 hips of older children with late detected DDH. They found that 80% of hips had satisfactory functional and radiographic outcomes [19].

Table 3 Hip range of motion in patients with DDH and LCPD

Type of motion	DDH	LCPD
Flexion (degrees)	108.5 ± 14.0	125.3 ± 6.7
Extension (degrees)	14.6 ± 2.3	13.7 ± 1.9
Abduction in flog position (degrees)	65.6 ± 16.0	58.5 ± 11.8
Abduction in extension position (degrees)	31.3 ± 8.7	39.7 ± 4.6
Adduction (degrees)	24.9 ± 4.7	18.3 ± 1.5
Internal rotation (degrees)	33.1 ± 14.3	37.5 ± 6.0
External rotation (degrees)	29.8 ± 11.8	26.0 ± 17.3

Similarly, in our series, all patients with DDH had good functional and radiographic outcomes. In contrast, the results were worse in patients with LCPD, who had good clinical and radiographic outcomes in only 57.1% of cases. However, this percentage is similar to that of other published studies [20–22]. In particular, a similar rate of good results (42 to 58%) was reported by Camurcu [23], Pailhé [1], Wenger [24], and Vukasinovic [25].

Our findings, in conjunction with previously reported data [4, 19], suggest that BTPO may be a good choice for the treatment of complex hip dysplasia in skeletally immature patients with DDH, LCPD and dysplasia secondary to neuromuscular and teratologic conditions. This osteotomy not only provides a large acetabular correction but can also achieve better biomechanical stability thanks to an angled ilium cut.

There are some differences between our technique and the methods reported by Rebello et al. [4], Sankar et al. [11], and Li et al. [19]. Compared with previous studies that report on the use of two incisions (one medial incision in line with the adductor longus muscle, and one Bikini-type), we found that BTPO can be performed through a single modified Smith-Peterson incision. In particular, the ischial ramus can be cut through the interspace between the medial side of the hip capsule and the iliolumbar tendon and femoral neck, thus decreasing the risk of injury to nearby neurovascular structures (the internal pudendal artery, vein, and nerve medially; the external iliac artery and vein, and the femoral nerve laterally), which lie just deep to adductor longus muscle.

Another difference highlighted by our study is the use of three crossed screws instead of 3 to 4 parallel screws. It has

been demonstrated that crossed screws provide more stable fixation and decrease the risk of implant failure compared with parallel screws [26, 27].

Additionally, it is possible to perform a femoral shortening osteotomy through this same single anterior approach, if needed. Although the procedure is controversial [28, 29], most researchers believe that femoral shortening should be performed in cases of late detected DDH, especially in older children and high dislocations [30–36]. In our series, the mean patient age was 7.5 years, and we performed femoral shortening osteotomies in 76.2% of DDH hips (16/21).

The technique and potential complications of BTPO are similar to those of other triple osteotomies [7, 8, 37, 38]. In particular, we found that, overall, three hips with DDH (14.3%) and four hips with LCPD disease (57.1%) were overcorrected with CEA larger than 50°. However, overcorrection was mild in most hips with Harris' score of 96.2 on average at final outcome (Tables 1 and 2). Moreover, we encountered three non-unions of the ischial osteotomy (10.7%). The reported incidence of non-unions is variable. Conroy [39], Lipton [40], and Steel [7] report a 0% non-union rate. In contrast, Dungl et al. [41], van Hellemond et al. [42], Vukasinovic et al. [43], and Tschauner et al. [44] reported non-union rates of between 3.2 and 9.2%. All authors agree, however that the incidence of non-unions may be associated with older age, the use of a saw, and insufficient fixation [37, 38, 43, 44]. Our incidence of non-unions is comparable with these previous studies and was not associated with clinical symptoms (Tables 1 and 2). The incidence of lateral femoral cutaneous nerve dysesthesia was also similar to that reported in previously published studies, and we did not record any other vascular or nerve complications [38, 41, 42, 45].

Although our study has relatively low number of patients, the number of patients included in the study was similar to the average number of cases in other published series that investigated outcome of BPTO [4, 19]. Interestingly our patients also formed a homogeneous group in terms of age and ambulatory status. Moreover, we chose to keep patients clearly separated, as DDH and LPCD are different disease entity with different pathogenesis and outcome. In summary, beyond limitations inherent to all retrospective studies, our findings contribute to the understanding of the indications for this relatively new technique and outline its advantages and disadvantages, as only three reports, including the present study, are available in the medical literature [4, 19].

In conclusion, BTPO through a modified anterior Smith-Peterson approach is an alternative treatment for DDH and LCPD in older children who are skeletally immature. It provides for a large acetabular correction and achieves good biomechanical stability.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent No patients were involved. This is a retrospective study of patient's data, and an IRB approval was obtained.

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