High Survival of Dome Pelvic Osteotomy in Patients with Early Osteoarthritis from Hip Dysplasia

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Received: 11 August 2011 / Accepted: 1 February 2012 / Published online: 22 February 2012
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Abstract

Background The Chiari osteotomy reportedly has a 60% to 91% survival rate at a minimum 20 years followup. The dome pelvic osteotomy (DPO) has the advantage of allowing a larger weightbearing surface, and congruity in the sagittal plane presumably would reduce the joint contact stress and perhaps increase longevity.

Questions/purposes We determined: (1) the survival after DPO at a minimum 25-year followup, (2) patient function, (3) acetabular coverage, and (4) factors influencing conversion to THA.

Each author certifies that he or she, or a member of their immediate family, has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request. Each author certifies that his or her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research. This study was performed at Osaka University Graduate School of Medicine.

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Methods We retrospectively reviewed 50 patients (59 hips) with developmental dysplasia of the hip (DDH) treated with DPO. The preoperative radiographic stages were graded as prearthrosis (18 hips), early osteoarthritis (25 hips), and advanced osteoarthritis (16 hips). We performed a Kaplan-Meier survival analysis with THA conversion as the end point. We determined various radiographic parameters reflecting coverage, and compared demographic information for hips without and with THA conversion using multivariate logistic regression analysis. The minimum followup was 25 years (mean, 27.5 years; range, 25–32 years).

Results Survival for all hips was 63.6% (95% CI, 51–76) at 27.5 years and that for hips with prearthrosis and early osteoarthritis before the surgery was 79.1% (95% CI, 63–91). Twenty-one hips (36%) had undergone THAs at a mean 18.3 years (range, 2.5–25 years). At the last followup, pain, walking ability, and acetabular coverage improved. We identified four factors predicting THA conversion: greater age, presence of a preoperative Trendelenburg sign, higher preoperative radiographic osteoarthritis grade, and smaller postoperative acetabular head index (AHI) predicted conversion to THA.

Conclusions DPO is a reasonable treatment option for patients with DDH and prearthrosis or early osteoarthritis, with high survival at greater than 25 years.

Level of Evidence Level IV, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Developmental dysplasia of the hip (DDH) frequently leads to osteoarthritis of the hip [34]. The intent of surgery for DDH is to relieve pain, restore function, and delay disease

progression. The original Chiari pelvic osteotomy (horizontally straight cut of the iliac bone on the lateral aspect) was intended for these purposes [2–6, 10–12, 15–17, 19, 23, 24, 26, 36, 37] and two studies have shown 60% to 91% survival rates without THA conversion at a minimum 20-year followup [15, 36]. At a minimum 27-year followup, a survival rate of 60% was reported for 66 selected patients (followup rate = 66/450 patients; 14.7%) [15].

The dome pelvic osteotomy (DPO) was introduced by Kawamura [13] for DDH as a modification of Chiari's procedure. With the DPO, a curved-shape is created in the lateral aspect of the ilium through a lateral transtrochanteric approach so as to match the sphericity of the femoral head and create a larger contact area [1, 13, 14, 18, 20]. The larger weightbearing surface and congruity in the sagittal plane presumably would reduce joint contact stresses [13]. Although an 82% survival rate for DPO at a minimum of 15 years of followup has been reported [20], it is unclear whether these findings will persist with longer followup.

Therefore, we determined: (1) the survival after DPO at a minimum of 25 years of followup, (2) patient function, (3) improvement in acetabular coverage, and (4) factors influencing long-term conversion of DPO to THA.

Patients and Methods

Between January 1978 and July 1986, DPOs were performed in 135 hips of 122 patients with DDH. The indications for DPO were moderate or severe acetabular dysplasia (1) without osteoarthritic change (prearthritism stage) [23, 28, 31], (2) early stage osteoarthritis, and (3) advanced stage osteoarthritis in the presence of pain and disability. The contraindications for DPO were: (1) hip pain in the absence of disability, (2) late stage osteoarthritis, and (3) highly subluxated hips (with superolateral extrusion of the femoral head by greater than $\frac{1}{2}$ the diameter of the head) [20]. During the study period we operated on an additional two patients with prearthritic DDH using tectoplasty [25]. Of the 122 patients we excluded 72 (76 hips [56%]): 11 patients (12 hips [9%]) did not return for followup after discharge from the hospital; 19 patients (22 hips [16%]) were lost to followup within 5 years; 25 patients (25 hips [19%]) were lost to followup within 15 years after the surgery; one patient (one hip) died before 10 years owing to problems unrelated to the surgery; and 16 patients (16 hips [12%]) who had been followed more than 10 years after the surgery only via a mailed questionnaire but without radiographs (these 16 patients had no hip pain and a Japanese Orthopaedic Association [JOA] hip score greater than 80 points [28]). These 72 excluded patients left 50 patients (59 hips [44%]) with clinical and radiographic evaluations. There were

47 females and three males. Their mean age at the time of the surgery was 29 years (range, 14–48 years), mean height was 153.8 cm (range, 140–166 cm), and mean weight was 52.4 kg (range, 42–74 kg). The mean BMI was 22.4 kg/m² (range, 17.3–31.4 kg/m²). The minimum followup was 25 years (mean, 27.5 years; range, 25–32 years).

The JOA classification system of hip osteoarthritis was used to evaluate radiographic grading of osteoarthritis secondary to dysplasia [23, 28]. There are four grades in the classification system: prearthritism stage, acetabular dysplasia without other abnormal findings; early stage, slight narrowing of the joint space and/or abnormal subchondral sclerosis; advanced stage, marked narrowing of the joint space with or without cysts or sclerosis; and terminal stage, widespread obliteration of the joint space with cysts and formation of osteophytes. Concerning the interobserver variability of the JOA classification system, the value of the kappa statistic was 0.600 [31].

We performed the DPO through a lateral transtrochanteric approach as previously described [1, 20]. Briefly, after dissection of the greater trochanter, a 2.4-mm K-wire was passed into the lateral aspect of the iliac bone from the uppermost border of the capsule superomedially at an angle of 0° to 20° from the horizontal. After confirming an acceptable angle and height of the osteotomy by an intraoperative radiograph, we started the curved-shape osteotomy at the most superolateral site of the acetabular rim. The surface of the ilium was cut progressively using a chisel with a 1-cm width flat blade, and then the entire layer of the ilium was cut using a Tuke saw (Finsbury Orthopaedics Ltd, Leatherhead, Surrey, UK) (Fig. 1A–D). After completion of the osteotomy, the leg was forced into abduction and external rotation, which displaced the distal pelvic fragment medially (10–15 mm) (Fig. 1E). In this series, we did not internally fix the acetabular osteotomy. The greater trochanter was reattached to the femur using cancellous screws and circular wires. An additional femoral osteotomy was performed in 15 hips: two in the prearthritism stage, six in the early stage, and seven in the advanced stage.

All patients received prophylactic intravenous antibiotics; 2 g of second-generation cephalosporins were given at the time of anesthesia, and then a 2-g dose was administered every 12 hours for 1 week. Postoperatively, the hips were immobilized in 20° flexion and 30° abduction in a hip spica cast for 3 weeks postoperatively. After cast removal, patients were allowed use of a wheelchair without weightbearing for 3 weeks. At 6 weeks, partial weightbearing was allowed, and at 12 weeks postoperatively, full weightbearing was allowed.

Patients were evaluated clinically and radiographically at 3 months, 6 months, 12 months, and every year thereafter. At each visit we obtained JOA hip scores [28], which has a maximum score of 100, to evaluate pain (0–40 points),

Fig. 1A–E (A) For the dome osteotomy, on the lateral aspect of the iliac bone, an arch-shaped osteotomy was made. (B) From the AP view, the osteotomy was made superomedially at an angle of 0° to 20° from the horizontal. (C) An arch-shaped osteotomy is shown three-

dimensionally. (D) The surface of the ilium was cut progressively using a chisel with a 1-cm width flat blade, and then the entire layer of the ilium was cut using a Tuke saw. (E) The distal pelvic fragment was displaced medially 10 mm to 15 mm.

ROM (0–20 points), walking ability (0–20 points), and activities of daily living (0–20 points). Patients also were evaluated for the presence of limping and Trendelenburg sign. AP and oblique radiographs were taken preoperatively and at each followup.

All radiographs were evaluated independently by two of the authors (TS, NS), with no previous knowledge of the results. On the AP radiographs taken before and just after surgery, the Sharp angle [27], center-edge angle [35], and acetabular head index (AHI) were measured (Fig. 2A). The deformity of the femoral head before the surgery was evaluated by measuring the ratio of its major and minor axes on the AP view [7]. A value of 1.1 or less indicated a spherical head and a value greater than 1.1 indicated a deformed head. The osteotomy angle and height were measured on the AP radiographs just after the surgery (Fig. 2B) [1]. The radiographic stage was evaluated at the latest followup using the JOA classification.

Kaplan-Meier survival analysis was performed with THA conversion as the end point. The 95% CI also was calculated. We determined differences in age, height, weight, BMI, followup period, JOA hip score, sphericity, osteotomy angle,

osteotomy height, Sharp angle, center-edge angle, and AHI between hips without and with THA conversion, using the Mann Whitney U test. We determined differences in gender and preoperative Trendelenburg sign between hips without and with THA conversion using Fisher's exact probability test. We determined differences in radiographic osteoarthritis grade and sphericity using the chi-square test. We then performed multivariate logistic regression analysis for the six selected variables (age, preoperative Trendelenburg sign, preoperative radiographic osteoarthritis grade, sphericity of the femoral head, postoperative center-edge angle, and postoperative AHI) between hips without and with THA conversion presuming 10 samples would provide adequate power for six variables and given the 59 hips in this study.

Results

Survival analysis with THA conversion as the end point was 63.6% (95% CI, 51%–76%) at 27.5 years postoperatively (Fig. 3). For hips with prearthrosis and early osteoarthritis before the surgery, the probability was 79.1%

Fig. 2A–B The (A) Sharp angle, center-edge (CE) angle, acetabular head index (AHI, a/b) before and after surgery, and the ratio of major and minor axes of the femoral head before the surgery (major axis/minor axis) are shown. (B) The angle and height immediately after surgery are seen in this AP view.

(95% CI, 63%–91%). Twenty-one hips (36%) underwent THAs at a mean 18.3 years (range, 2.5–25 years) postoperatively. Radiographically, at the latest followup, there were five hips in the prearthrosis stage (Fig. 4), 22 in the early stage (Fig. 5), 19 in the advanced stage, and 13 in the terminal stage. Of the 18 hips in the prearthrosis stage before surgery, five subsequently were in the prearthrosis stage, 10 were in the early stage, two were in the advanced stage, and one was in the terminal stage. Of the 25 hips in the early stage before surgery, 12 subsequently were in the early stage, 10 were in the advanced stage, and three were in the terminal stage. Of the 16 hips in the advanced stage before surgery, seven subsequently were in the advanced stage and nine were in the terminal stage.

At the last followup the mean pain scores and walking ability improved, but hip ROM did not (Table 1). The mean JOA pain score improved from 23.9 (range, 20–30 points) to 28.2 points (range, 10–40 points), and the mean walking ability score improved from 13.7 (range, 10–20 points) to 15.5 points (range, 10–20 points) at the latest followup. However, the mean ROM score decreased from 19.3 (range, 15–20 points) to 15.1 points (range, 3–20 points) at the latest followup, and the mean total score was similar (74.3 points; range, 61–90 points before surgery and 74.5 points; range, 28–100 points at the latest followup).

Acetabular coverage of the hip improved after surgery. The mean Sharp angle improved from 52.1° (range, 43° – 60°) before surgery to 39.7° (range, 27° – 50°) after surgery. The mean center-edge angle and AHI improved from -2.1° (range, -29° – 15°) and 50.4% (range, 20%–77%) before surgery to 39.5° (range, 20° – 65°) and 95.6% (range, 75%–100%) after surgery, respectively. Concerning the deformity

Fig. 3 Kaplan-Meier survival analysis with THA conversion as the end point showed a 63.6% probability (95% CI, 51%–76%) at 27.5 years postoperatively.

of the femoral head before the surgery, 29 hips had spherical heads whereas 30 had deformed heads. The osteotomy angle ranged from 0° to 20° (mean, 12.3°) and the osteotomy height ranged from 1.5 mm to 10 mm (mean, 5.5 mm).

Comparing hips without THA conversion (38 hips) and hips with THA conversion (21 hips), we found differences in preoperative factors including age (27 versus 32 years; $p = 0.007$), preoperative Trendelenburg sign (positive/

Fig. 4A–B (A) A radiograph taken before surgery for prearthrosis of the hip in a 19-year-old woman shows a center-edge angle of 0° and her AHI was 56%. (B) Twenty-nine years after surgery, the patient's prearthrosis stage was maintained with a center-edge angle of 40° and AHI of 100%.

Fig. 5A–B (A) A radiograph taken before surgery for early stage hip osteoarthritis in a 29-year-old woman shows a center-edge angle of -5° and her AHI was 44%. (B) Thirty-one years after surgery, the patient's early stage was maintained with a center-edge angle of 65° and AHI of 100%.

negative = 2/36 versus 12/9; $p < 0.001$), and preoperative limping (positive/negative = 7/31 versus 15/6; $p < 0.001$). We also found differences in preoperative radiographic osteoarthritis grade (prearthrosis/early/advanced = 17/17/4 versus 1/8/12; $p < 0.001$) and sphericity of the femoral head (1.13 versus 1.26; $p = 0.017$). Concerning the postoperative factors, there were differences in postoperative JOA

(87.2 points versus 51.4 points; $p < 0.001$) (Table 1), postoperative center-edge angle (43.6° versus 32.1° ; $p < 0.001$), and AHI (97.4% versus 92.2%; $p = 0.004$) (Table 2). Greater age ($p = 0.028$), preoperative Trendelenburg sign ($p = 0.031$), higher preoperative radiographic osteoarthritis grade ($p = 0.016$), and smaller postoperative AHI ($p = 0.011$) predicted conversion to THA.

Table 1. Clinical evaluation between hips with and without THA conversion

Parameters	Without THA (38 hips)	THA conversion (21 hips)	p value
Age (years)	27.3 ± 8.0 (14–48)	32.0 ± 6.4 (20–42)	0.007 [#]
Gender (men/women, hips)	2/36	2/19	0.61 ^{##}
Height (cm)	154.8 ± 6.0 (140–166)	152.1 ± 2.7 (145–156)	0.09 [#]
Weight (kg)	52.4 ± 7.3 (42–74)	52.4 ± 6.3 (42–66)	0.83 [#]
Body mass index (kg/m ²)	22.2 ± 3.2 (17.4–30.0)	22.7 ± 3.2 (18.2–31.4)	0.61 [#]
Followup (months)	330 ± 26 (300–382)	220 ± 97 (32–300)	< 0.001 [#]
Preoperative limping (+/–, hips)	7/31	15/6	< 0.001 ⁺
Preoperative Trendelenburg sign (+/–, hips)	2/36	12/9	< 0.001 ^{##}
Combined femoral osteotomy (+/–, hips)	7/30	8/12	0.18 ⁺
JOA hip score			
Preoperative pain	24.5 ± 5.0 (20–30)	22.3 ± 4.5 (20–30)	0.23 [#]
ROM	19.5 ± 1.2 (15–20)	18.9 ± 1.6 (15–20)	0.11 [#]
Walking ability	14.1 ± 2.5 (10–20)	13.1 ± 2.4 (10–15)	0.17 [#]
Activities of daily living	17.2 ± 2.1 (12–20)	16.8 ± 2.2 (14–20)	0.35 [#]
Total	75.8 ± 7.4 (61–90)	71.6 ± 7.8 (61–85)	0.08 [#]
Latest pain	35.1 ± 4.8 (20–40)	16.0 ± 8.6 (10–40)	< 0.001 [#]
ROM	17.4 ± 2.9 (7–20)	11.0 ± 4.6 (3–20)	< 0.001 [#]
Walking ability	17.5 ± 2.8 (10–20)	12.4 ± 2.7 (10–18)	< 0.001 [#]
Activities of daily living	17.2 ± 2.8 (10–20)	12.0 ± 2.4 (10–18)	< 0.001 [#]
Total	87.2 ± 10.5 (54–100)	51.4 ± 15.1 (35–91)	< 0.001 [#]

[#] Mann Whitney U test; ^{##}Fisher's exact probability test; ⁺chi-square test; JOA = Japanese Orthopaedic Association.

Table 2. Radiologic evaluation between hips with and without THA conversion

Parameters	Without THA (38 hips)	THA conversion (21 hips)	p value
Radiologic osteoarthritis grade (hips)			
Preoperative (prearthrititis/early/advanced)	17/17/4	1/8/12	< 0.001 ⁺
Latest (prearthrititis/early/advanced/terminal)	5/22/11/0	0/0/7/14	< 0.001 ⁺
Sphericity	1.13 ± 0.21 (1–2)	1.26 ± 0.32 (1–2.3)	0.017 [#]
Preoperative radiologic grade and sphericity (hips)			
Prearthrititis/early spherical	6	11	
Prearthrititis/early deformed	15	2	
Advanced spherical	1	1	
Advanced deformed	6	7	0.09 ⁺
Osteotomy angle	13.2 ± 4.9 (2–20)	11.0 ± 5.3 (0–20)	0.17 [#]
Osteotomy height	5.4 ± 2.0 (2–10)	5.6 ± 2.1 (1.5–10)	0.64 [#]
Sharp angle (degrees)			
Preoperative	53.0 ± 3.4 (45–60)	49.1 ± 4.8 (43–58)	0.21 [#]
Postoperative	38.7 ± 4.5 (27–50)	42.2 ± 5.1 (30–50)	0.13 [#]
Center-edge angle (degrees)			
Preoperative	–1.7 ± 7.8 (–20–14)	–2.9 ± 10.3 (–29–15)	0.48 [#]
Postoperative	43.6 ± 9.3 (25–65)	32.1 ± 10.3 (20–50)	< 0.001 [#]
Acetabular head index (%)			
Preoperative	51.4 ± 11.6 (20–77)	49.4 ± 10.2 (26–71)	0.15 [#]
Postoperative	97.4 ± 5.1 (75–100)	92.2 ± 7.9 (77–100)	0.004 [#]

[#] Mann Whitney U test; ⁺chi-square test.

Discussion

Patients with congenital dislocation of the hip are screened after birth, early treatment is possible, and the number of patients who have residual sequelae is decreasing. However, Japanese females with acetabular dysplasia are common, and osteoarthritis of the hip secondary to acetabular dysplasia occurs in approximately 90% of all cases of hip osteoarthritis [30]. Hip pain and functional problems in adulthood are not uncommon in these patients. Therefore, surgical intervention to create new acetabular coverage is available for young adult patients with acetabular dysplasia. To increase the acetabular coverage, DPO has the advantage of allowing a larger weightbearing surface to be created [1, 13, 14, 18, 20] and congruity in the sagittal plane would reduce the joint contact stress [13]. Chiari proposed performing the osteotomy through the anterior approach [3], whereas the DPO is performed through a lateral transtrochanteric approach and the greater trochanter is osteotomized and retracted with the abductor muscles because the procedure allows good exposure and precise osteotomy of the acetabulum [13]. Although an 82% survival rate for DPO at a minimum of 15 years of followup has been reported [20], it remains unclear whether these findings will persist with longer followup. Therefore, we elucidated (1) the survival after DPO at a minimum of 25 years of followup, (2) patient function, (3) improvement in acetabular coverage, and (4) factors influencing long-term conversion of DPO to THA.

There are some limitations to this study. First, the followup rate for our patients was 42%. Although we cannot ensure the data are representative, we believe it is of value owing to the minimum 25 years of followup as there is no such report and only one report with greater than 25 years of followup for the original Chiari osteotomy [15]; that latter report had a followup rate of 14.7%. Second, the weight of the patients, a mean 52.4 kg (range, 42–74 kg), was comparatively low. Therefore, our findings may not translate to a typical Western population. Third, we had no control (untreated) patients with which to compare the natural history, and no comparative treatments of alternate methods. Therefore, we can only compare our findings with those in the literature.

We found a survival rate with THA conversion as the end point of 63.6% (95% CI, 51%–76%) at a mean of 27.5 years postoperatively. For prearthrosis and early stage hips before the surgery, the probability was 79.1% (95% CI, 63%–91%). Our survival rate of DPO at a minimum of 25 years of followup was comparable to that of the original Chiari osteotomy at a minimum 27 years followup (60%) [15], that of Salter osteotomy at a minimum of 42 years followup (54%) [32], and that of the Ganz osteotomy at a minimum 19 years followup (60.5%) [29] (Table 3).

The THA conversion rate of DPO (36%) also was comparable to that of the original Chiari osteotomy (40%). Although DPO reportedly does not compromise subsequent THA [8], it may contribute to delaying the disease process.

Although the survival rate for our patients was expectedly lower than the 82% survival reported at 15 years [1, 20], the mean JOA pain score improved at last followup in patients without conversion. However, hip ROM got worse at the minimum 25-year followup, as was the case with the original Chiari osteotomy at a minimum 20-year followup [15, 36, 37]. Windhager et al. reported that a range of hip flexion less than 90° is a contraindication because postoperative ROM deteriorates [36]. Other surgical interventions to create new acetabular coverage for DDH, including acetabular rotational osteotomy [21, 22] and Ganz osteotomy [29], also have indicated that postoperative ROM did not improve while pain and walking ability improved.

The mean postoperative center-edge angle was 40° in our patients. It is comparable to that for the original Chiari osteotomy (29°–42°) [12, 15, 17, 23, 36, 37], acetabular rotational osteotomy (37°) [22], Tönnis osteotomy (28°) [33], Ganz osteotomy (34°) [29], and Salter osteotomy (40°) [32] (Table 3). Macnicol et al. stated that the ideal center-edge angle should be 30° or greater after the original Chiari osteotomy [17].

We identified four factors predicting THA conversion: age, preoperative Trendelenburg sign, preoperative radiographic stage, and postoperative acetabular head index using multivariate logistic regression analysis. Greater age [1, 12, 15, 20, 29, 36], preoperative Trendelenburg sign [29], higher preoperative radiographic osteoarthritis grade [1, 12, 20, 23, 29, 32, 33, 36, 37], and smaller postoperative AHI [12] were indicated as the related factors that influenced postoperative results at the latest followup in our study. Consistent with our observations, the original Chiari osteotomy [12, 15, 36], DPO [1, 20], and Ganz osteotomy [29] reportedly show less progression of osteoarthritis in younger patients. As other studies of the original Chiari osteotomy [12, 23, 36, 37] and other pelvic osteotomies [29, 32, 33] showed, hips with advanced radiologic stage before the surgery show progression of osteoarthritis. Studies of the original Chiari osteotomy [12, 23] also showed the preoperative Sharp angle, center-edge angle, or AHI did not affect the postoperative radiographic results. Postoperative radiographic measurements indicated that technical factors and inadequate coverage of the femoral head led to the advanced radiographic stage. Although the interposed capsule after the DPO or original Chiari osteotomy changes to fibrous cartilage [9], insufficient coverage may inhibit proper cartilage transformation of the interposed capsule. The postoperative AHI, as for original Chiari osteotomy [12], might be a better index than the center-edge

Table 3. Pelvic osteotomies for DDH

Study	Osteotomy	Hips	Age (years)	Followup (years)	Followup rate (%)	Survival (%)	Function	Acetabular coverage	Factors influencing conversion to THA
Nozawa et al. [22]	Rotational	50	32 (13–53)	11 (10–14.5)	91	98	JOA pain 36; ROM 18; walking 18; total 91	CE 37°; AHI 88%	–
van Hellemond et al. [33]	Tönnis	48	28 (14–46)	15 (13–20)	94	88	–	CE 28°	Advanced radiologic stage, poor preoperative clinical score
Steppacher et al. [29]	Ganz	68	29 (13–56)	20 (19–23)	91	60.5	ROM not improved	CE 34°	Greater age, preoperative limp, advanced radiologic stage, poor preoperative clinical score, preoperative anterior impingement test, undercorrected postoperative extrusion index
Thomas et al. [32]	Salter	80	2.8 (1.5–4.7)	46 (42–51)	79	54	HHS total 88	CE 40°	Advanced radiologic stage
Ohashi et al. [23]	Chiari	86	18 (6–48)	17 (4–37)	81	68.6	JOA total 89	CE 29°	Advanced radiologic stage, ovoid femoral head, lower osteotomy level
Macnicol et al. [17]	Prearthrosis/Early	17	37 (11–54)	16 (1–27)	81	72.2	JOA total 84	CE 31°	–
Yanagimoto et al. [37]	Chiari	86	16 (SD 9.5)	18 (5–30)	40	85.5	–	CE 42°	Greater age
Ito et al. [12]	Chiari	173	29 (9–54)	30 (10–32.5)	74	85.9	Pain/walking ability improved ROM not improved HHS total 81	CE 30° CE 38°, AHI 92%	Advanced radiologic stage, spherical femoral head Greater age, advanced radiologic stage, smaller postoperative AHI/CE
Windhager et al. [36]	Chiari	236	22 (11–28)	25 (20–34)	60	91	ROM deteriorated	VCA 44°	Greater age
Kotz et al. [15]	Chiari	80	30 (12–54)	32 (27–48)	15	60	HHS pain 33; function 37; Total 79	CE 42°	Greater age
Current study	Dome	59	29 (14–48)	27.5 (25–32)	42	63.6	Pain/walking ability improved; ROM not improved; JOA pain 28; ROM 15; walking 16; total 75	CE 40°, AHI 96%	Greater age, positive preoperative Trendelenburg sign, advanced radiologic stage, small postoperative AHI

HHS = Harris hip score; JOA = Japanese Orthopaedic Association; CE = center-edge angle; AHI = acetabular head index; VCA = vertical center anterior angle.

angle because the patients in our study had deformed femoral heads (30 of 59 hips [51%]). It was difficult to determine the center of the deformed head when measuring the center-edge angle. Sphericity of the femoral head was not a related factor that influenced postoperative results by the latest followup in our patients. The femoral head shape in the original Chiari osteotomy is controversial; Ohashi et al. reported that the spherical head showed less progression of osteoarthritis [23], whereas Yanagimoto et al. reported that the spherical head showed early progression because advanced DDH with a spherical head frequently is associated with bone atrophy, a poor repair response, and acetabular labrum tears [37].

Our findings at a minimum of 25 years of followup suggest that DPO can relieve hip pain and improve walking ability. We believe the data suggest DPO is a reasonable treatment option for patients with prearthrititis and early stage osteoarthritis secondary to DDH.

Acknowledgment We thank Hideki Yoshikawa MD, PhD, Keisuke Akiyama MD, Satoru Tamura MD, and Wataru Yamanashi MS for technical support.

References

- Anwar MM, Sugano N, Matsui M, Takaoka K, Ono K. Dome osteotomy of the pelvis for osteoarthritis secondary to hip dysplasia: an over five-year follow-up study. *J Bone Joint Surg Br.* 1993;75:222–227.
- Calvert PT, August AC, Albert JS, Kemp HB, Catterall A. The Chiari pelvic osteotomy: a review of the long-term results. *J Bone Joint Surg Br.* 1987;69:551–555.
- Chiari K. Medical displacement osteotomy of the pelvis. *Clin Orthop Relat Res.* 1974;98:55–71.
- Colton CL. Chiari osteotomy for acetabular dysplasia in young subjects. *J Bone Joint Surg Br.* 1972;54:578–589.
- De Waal Malefijt MC, Hoogland T, Nielsen HK. Chiari osteotomy in the treatment of congenital dislocation and subluxation of the hip. *J Bone Joint Surg Am.* 1982;64:996–1004.
- Fernandez DL, Isler B, Mullier ME. Chiari's osteotomy: a note on technique. *Clin Orthop Relat Res.* 1984;185:53–58.
- Harry JD, Gross RH. A quantitative method for evaluating results of treating Legg-Perthes syndrome. *J Pediatr Orthop.* 1987;7:671–676.
- Hashemi-Nejad A, Haddad FS, Tong KM, Muirhead-Allwood SK, Catterall A. Does Chiari osteotomy compromise subsequent total hip arthroplasty? *J Arthroplasty.* 2002;17:731–739.
- Hiranuma S, Higuchi F, Inoue A, Miyazaki M. Changes in the interposed capsule after Chiari osteotomy: an experimental study on rabbits with acetabular dysplasia. *J Bone Joint Surg Br.* 1992;74:463–467.
- Hogh J, Macnicol MF. The Chiari pelvic osteotomy: a long-term review of clinical and radiographic results. *J Bone Joint Surg Br.* 1987;69:365–373.
- Ito H, Matsuno T, Minami A. Chiari pelvic osteotomy for advanced osteoarthritis in patients with hip dysplasia. *J Bone Joint Surg Am.* 2004;86:1439–1445.
- Ito H, Tanino H, Yamanaka Y, Nakamura T, Minami A, Matsuno T. The Chiari pelvic osteotomy for patients with dysplastic hips and poor joint congruency: long-term follow-up. *J Bone Joint Surg Br.* 2011;93:726–731.
- Kawamura B. The transverse pelvic osteotomy. *J Jpn Orthop Assoc.* 1959;32:1181–1188.
- Kawamura B, Hosono S, Yokogushi K. Dome Osteotomy of the Pelvis. In: Tachdjian MO, ed. *Congenital Dislocation of the Hip.* New York, NY: Churchill Livingstone; 1982:609–623.
- Kotz R, Chiari C, Hofstaetter JG, Lunzer A, Peloschek P. Long-term experience with Chiari's osteotomy. *Clin Orthop Relat Res.* 2009;467:2215–2220.
- Lack W, Windhager R, Kutschera HP, Engel A. Chiari pelvic osteotomy for osteoarthritis secondary to hip dysplasia: indications and long-term results. *J Bone Joint Surg Br.* 1991;73:229–234.
- Macnicol MF, Lo HK, Yong KF. Pelvic remodelling after the Chiari osteotomy: a long-term review. *J Bone Joint Surg Br.* 2004;86:648–654.
- Matsuno T, Ichioka Y, Kaneda K. Modified Chiari pelvic osteotomy: a long follow-up study. *J Bone Joint Surg Am.* 1992;74:470–478.
- Migaud H, Duquennoy A, Gougeon F, Fontaine C, Pasquier G. Outcome of Chiari pelvic osteotomy in adults: 90 hips with 2–15 years' follow-up. *Acta Orthop Scand.* 1995;66:127–131.
- Nakata K, Masuhara K, Sugano N, Sakai T, Haraguchi K, Onzono K. Dome (modified Chiari) pelvic osteotomy: 10- to 18-year followup study. *Clin Orthop Relat Res.* 2001;389:102–112.
- Ninomiya S, Tagawa H. Rotational acetabular osteotomy for the dysplastic hip. *J Bone Joint Surg Am.* 1984;66:430–436.
- Nozawa M, Shitoto K, Matsuda K, Maezawa K, Kurosawa H. Rotational acetabular osteotomy for acetabular dysplasia: a follow-up for more than ten years. *Bone Joint Surg Br.* 2002;84:59–65.
- Ohashi H, Hirohashi K, Yamano Y. Factors influencing the outcome of Chiari pelvic osteotomy: a long-term follow-up. *J Bone Joint Surg Br.* 2000;82:517–525.
- Reynolds DA. Chiari innominate osteotomy in adults: technique indications and contra-indications. *J Bone Joint Surg Br.* 1986;68:45–54.
- Saito S, Takaoka K, Ono K. Tectoplasty for painful dislocation or subluxation of the hip: long-term evaluation of a new acetabuloplasty. *J Bone Joint Surg Br.* 1986;68:55–60.
- Scher MA, Jakim I. Combined intertrochanteric and Chiari pelvic osteotomies for hip dysplasia. *J Bone Joint Surg Br.* 1991;73:626–631.
- Sharp IK. Acetabular dysplasia: the acetabular angle. *J Bone Joint Surg Br.* 1961;43:268–272.
- Shima Y. Standard for evaluation of osteoarthritis of the hip. *J Jpn Orthop Assoc.* 1971;45:813–833.
- Steppacher SD, Tannast M, Ganz R, Siebenrock KA. Mean 20-year followup of Bernese periacetabular osteotomy. *Clin Orthop Relat Res.* 2008;466:1633–1644.
- Sugano N, Nishii T, Takao M. The Asian hip. *The Adult Hip.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2006:1060–1077.
- Takatori Y, Ito K, Sofue M, Hirota Y, Itoman M, Matsumoto T, Hamada Y, Shindo H, Yamada H, Yasunaga Y, Ito H, Mori S, Owan I, Fujii G, Ohashi H, Mawatari T, Iga T, Takahira N, Sugimori T, Sugiyama H, Okano K, Karita T, Ando K, Hamaki T, Hirayama T, Iwata K, Matsuura M, Jingushi S; Investigation Group into Coxarthrosis and Acetabular Dysplasia in Japan. Analysis of interobserver reliability for radiographic staging of coxarthrosis and indexes of acetabular dysplasia: a preliminary study. *J Orthop Sci.* 2010;15:14–19.
- Thomas SR, Wedge JH, Salter RB. Outcome at forty-five years after open reduction and innominate osteotomy for late-presenting developmental dislocation of the hip. *J Bone Joint Surg Am.* 2007;89:2341–2350.
- van Hellemond GG, Sonneveld H, Schreuder MH, Kooijman MA, de Kleuver M. Triple osteotomy of the pelvis for acetabular dysplasia: results at a mean follow-up of 15 years. *J Bone Joint Surg Br.* 2005;87:911–915.

34. Weinstein SL. Natural history and treatment outcomes of childhood hip disorders. *Clin Orthop Relat Res.* 1997;344:227–242.
35. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint with special reference to the complication of osteoarthritis. *Acta Chir Scand Suppl.* 1939;83:1–130.
36. Windhager R, Pongracz N, Schonecker W, Kotz R. Chiari osteotomy for congenital dislocation and subluxation of the hip: results after 20 to 34 years follow-up. *J Bone Joint Surg Br.* 1991; 73:890–895.
37. Yanagimoto S, Hotta H, Izumida R, Sakamaki T. Long-term results of Chiari pelvic osteotomy in patients with developmental dysplasia of the hip: indications for Chiari pelvic osteotomy according to disease stage and femoral head shape. *J Orthop Sci.* 2005;10:557–563.