Original Article

Gradual Reduction Using Overhead Traction for Developmental Dysplasia of The Hip After Walking Age: A 30-year Retrospective Study

Hiroshi Kaneko[1] MD, PhD, Hiroshi Kitoh[1] MD, PhD, Koji Iwata[1] MD, Kenichi Mishima[2] MD, PhD, Masaki Matsushita[2] MD, PhD, Tadashi Hattori[1] MD, PhD


Dr. Hiroshi Kaneko


Dr. Hiroshi Kitoh


Dr. Koji Iwata


Dr. Kenichi Mishima


Dr. Masaki Matsushita


Dr. Tadashi Hattori

Address of Correspondence
Dr. Hiroshi Kitoh,
Department of Orthopaedic Surgery, Aichi Children's Health and Medical Center,
7-426 Moriokacho, Obu, Aichi, 474-8710, Japan
E-mail: hiroshi_kitou@sk00106.achmc.pref.aichi.jp

[1]Department of Orthopaedic Surgery, Aichi Children's Health and Medical Center, Obu, Aichi, Japan.
[2]Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Aichi, Japan.

DOI- 10.13107/ijpo.2020.v06i02.084

Abstract

Background: The optimal management for untreated developmental dysplasia of the hip (DDH) after walking age remains controversial.

Methods: We retrospectively reviewed 80 DDH patients (85 hips) diagnosed at one through 3 years of age who underwent gradual reduction (GR) using overhead traction (OHT) with a mean follow-up of 8.2 years. We investigated radiological severity of DDH, successful reduction, avascular necrosis (AVN) of the femoral head, residual dysplasia, secondary procedures, and Severin classification. The data were compared between patients under (42 hips) and over (43 hips) 18 months of age at diagnosis.

Results: Eighty-three hips (98%) were successfully reduced by OHT. Three hips (4%) re-dislocated later and needed closed reduction or open reduction with Salter osteotomy. No AVN occurred during follow-up. Sixty-eight hips were observed without further treatment beyond 5 years of age, of which 52 (76%) remained acetabular dysplasia and 47 (69%) underwent Salter osteotomy with or without femoral osteotomy. We could finally evaluate 69 hips using Severin classification, and 52 (75%) were classified in Group I, 10 (14%) in Group II, and seven (10%) in Group III. Radiological severity of DDH at diagnosis was the only significant variable between the groups: High hip dislocation was more frequently observed in the older age group ($p = 0.0131$).

Conclusions: GR using OHT is a beneficial initial treatment with a high reduction rate and a low incidence of complications for DDH after walking age, from 1 to 3 years of age. Salter osteotomy performed during preschool ages can provide a satisfactory mid-term outcome for hips with residual acetabular dysplasia after OHT.

Level of Evidence: Therapeutic studies, level IV (case series).

Keywords: Developmental dysplasia of the hip; Walking age; Gradual reduction; Overhead traction; Salter innominate osteotomy.

Introduction

Developmental dysplasia of the hip (DDH) is a common pediatric orthopedic condition and is usually diagnosed before walking age by screening of newborn and young infants [1]. Nevertheless, delayed diagnosis of DDH still occurs and complicates the treatment [2]. Many authors agree that closed reduction is recommended as an initial treatment in DDH after walking age [2, 3, 4, 5, 6], although these patients, especially over 18 months of age, usually require surgical procedures such as open reduction with or without femoral and/or pelvic osteotomies [7, 8, 9]. Closed or open reduction in older patients, however, is associated with numerous complications such as re-dislocation and avascular necrosis (AVN) of the femoral head [6, 7, 8, 10] The optimal management for DDH after walking age still remains controversial.

Gradual reduction (GR) using continuous traction is one of the non-surgical methods for delayed-diagnosed DDH. There are few evidences that the GR can achieve good outcome with low incidence of complications [3, 11]. We have applied GR using overhead traction (OHT) for DDH patients over 6 months of age since 1964, and demonstrated a reduction rate of 96% and an AVN incidence of 2.7% in 75 hips under 4 years of age [11]. The previous report, however, included some pre-walking infants previously treated with the Pavlik harness.

We retrospectively reviewed 80 DDH patients (85 hips) who underwent GR using OHT as an initial treatment from 1 to 3 years of age in recent 30 years. The purpose of this study is to evaluate the outcome of our GR using OHT in the initial treatment of DDH after walking age. In addition, we investigated whether our treatment method is available even over 18 months of age.

Material and methods

This is an Institutional Review Boards-approved retrospective study. Inclusion criteria were the patients who had been diagnosed as DDH from 1 to 3 years of age and initially treated with the OHT method at our two institutions with a minimum follow-up of 1 year. Between 1988 and 2017, 58 patients (60 hips) enrolled at one institution and 30 patients (33 hips) enrolled at the other institution. Four patients (four hips) who had not started walking at diagnosis, two patients (two hips) who had insufficient radiological data, and two patients (two hips) who were lost to follow-up were excluded from the study. A total of 80 patients (85 hips) were included in this study. There were 76 girls and four boys, with a mean age of 19 months (range, 12 to 47 months) at diagnosis. The left side was affected in 46 patients, the right side in 29 patients, and bilateral involvement occurred in five patients. The mean follow-up duration after reduction was 8.2 years (range, 1 to 21 years).

The OHT method was comprised three phases and described in detail in our previous report [11]. Briefly, the first phase was horizontal skin traction with the traction force from 1.0 to 2.5 kg for each leg, depending on the patient's body weight, to obtain a gradual descent of the dislocated femoral head. We standardized the traction weight in 1/5 through 1/7 of the body weight. The sufficient descent usually needed for 4 weeks. The second phase of vertical traction began with the hip flexed in 90^{O}-100^{O} and the knee extended using the OHT device [11]. Hip abduction was increased daily up to 70^{O} for 1 week. The final phase was above-knee traction with the knees moving freely for 1 week. The dislocated hip was almost reduced at an early stage of the final phase, which could be confirmed by ultrasound imaging. After successful reduction, dynamic arthrography under general anesthesia was performed to assess the stability of the reduced hip [12]. Then, bilateral hips were immobilized in a double hip spica cast for 5 weeks followed by a flexion-abduction brace for 3 months to maintain concentric reduction.

Anteroposterior pelvic radiographs with full extension of the hips and knees and neutral rotation of the legs in the supine position were assessed by two authors. The distance between the midpoint of the proximal metaphyseal border of the femur and the Hilgenreiner line was termed "distance *a*" (Fig. 1) [13]. Positive values indicate the

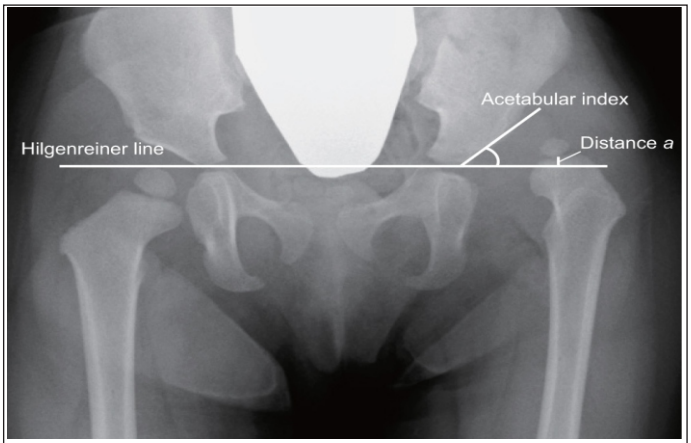

Figure 1: An anteroposterior pelvic radiograph taken before initial treatment. Distance *a* representing the distance between the midpoint of the proximal metaphyseal border of the femur and the Hilgenreiner line. The left hip showing dislocation [acetabular index of 41 degrees and distance *a* of -2 mm].

midpoint below the Hilgenreiner line and negative values indicate the midpoint above the line. The acetabular index (AI) [1] and the distance *a* on the initial radiographs were measured to quantitatively assess the severity of acetabular dysplasia and hip dislocation, respectively (Fig. 1). The presence of the proximal femoral epiphyseal ossification nucleus at diagnosis was also evaluated on the initial radiographs. On subsequent follow-up radiographs, the presence of AVN of the femoral head following reduction was assessed according to the diagnostic criteria established by Salter et al. [14], and the degree of AVN was classified using the method of Kalamchi and MacEwen [15]. At the age of 5-6 years, the AI and the center-edge angle (CEA) of Wiberg [16] were measured for the decision-making of acetabuloplasty with or without femoral osteotomy for residual acetabular dysplasia or subluxation. We performed Salter innominate osteotomy for the hips with either the AI of $\geq 30^{O}$ or the CEA of $\leq 5^{O}$ in this age range [17]. We combined Salter osteotomy with proximal femoral varus derotation osteotomy for residual subluxation. Radiographic outcome at the latest follow-up was evaluated by the Severin classification system [18] and the Kellgren and Lawrence classification system [19]. The lateral edge of the sourcil was used for all measurements.

The patients were divided into two groups according to age at diagnosis: Forty-two hips under 18 months of age (range, 12-17 months) and 43 hips over 18 months of age (range, 18-47 months). Univariate analysis was performed between the groups to assess differences with regard to radiological severity of DDH, success rate of reduction by the OHT method, complications, residual deformities, secondary surgery, and Severin classification at final visits. Categorical variables were examined with the Fisher exact test or the Chi-squared test, and continuous variables were examined with the Mann-Whitney *U* test. Statistical analyses were performed using the SPSS version 25 software package (IBM, Tokyo, Japan), and $p<0.05$ was considered significant.

Results

The AI and the distance a at diagnosis averaged 41^{O} (range, 30^{O}-56^{O}) and -1 mm (range, -14 mm to 9 mm), respectively. All hips had ossification nucleus of the femoral head at diagnosis, which was smaller in the affected hip than in the contralateral hip in unilateral involvement (Fig. 2a).

GR using OHT was tolerable in all patients. Eighty-three hips (98%) were successfully reduced by the OHT method (Fig. 2b) with a mean age at reduction of 21 months (range, 13-49 months). Two OHT-resistant hips were treated by closed reduction under general anesthesia. Re-dislocation occurred in three hips (4%). One of them re-dislocated during cast immobilization and was treated by closed reduction. The other two hips re-dislocated after completion of brace treatment, and one was treated by closed reduction but the other needed open reduction with Salter osteotomy. No hip developed AVN of the femoral

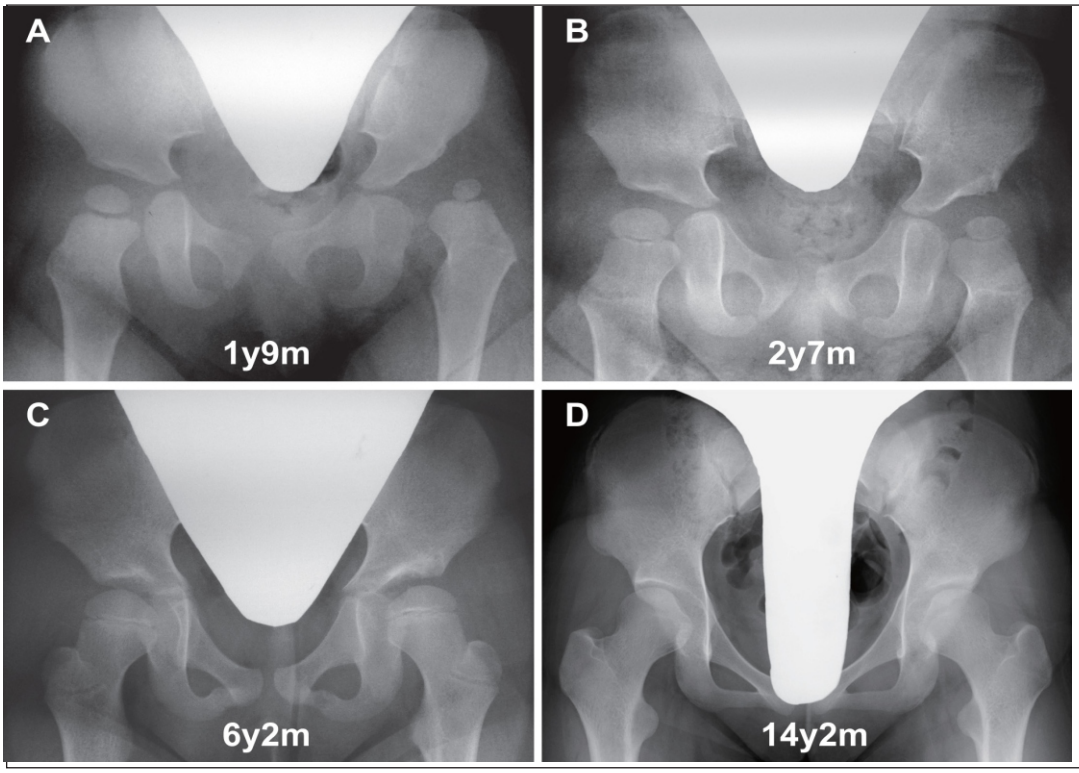

Figure 2: Anteroposterior pelvic radiographs in a girl with developmental dysplasia of the hip after walking age who was treated with gradual reduction using overhead traction. A, At 21 months of age, the left hip presenting dislocation and acetabular dysplasia. B, At 2.6 years of age, the left hip maintaining concentric reduction. C, At 6.2 years of age, the left acetabulum developing well. D, At final follow-up (14.2 years of age), the left hip showing Severin group I.

head during follow-up.

Sixty-eight hips were observed without further treatment after successful GR beyond 5 years of age, of which 16 (24%) showed favourable acetabular development (Fig. 2c), whereas 52 (76%) met our surgical indication for residual acetabular dysplasia. We performed Salter osteotomy for 46 dysplastic hips and did combined Salter and femoral osteotomies for one subluxed hip. The other five dysplastic hips were followed up without reconstructive surgery because we could not obtain paternal consent to undergo the surgery.

We could finally evaluate 69 hips using Severin classification. Fifty-two hips (75%) were classified in Group I, 10 (14%) in Group II, and seven (10%) in Group III (Fig. 2d and Table 1). Forty-six (98%) of the 47 hips that had undergone Salter osteotomy after GR were included in either Group I or II. Only one hip in Severin Group II was painful on daily activities and classified as Kellgren and Lawrence Grade II for joint space narrowing in the weight-bearing aspect at the age of 18 years. The patient additionally underwent rotational acetabular osteotomy.

There were no significant differences between the two age groups in all variables except the distance *a* at diagnosis, which was significantly lower in the older age group than in the younger age group (p = 0.0131) (Table 1).

TABLE 1: Comparison of initial radiological findings and outcomes of gradual reduction using overhead traction between DDH diagnosed under and over 18 months of age

Variables	Under 18 months of age (41 patients, 42 hips)	Over 18 months of age (39 patients, 43 hips)	*P* value*
Radiological findings at diagnosis			
Acetabular index	40° (32 to 50°)	41° (30 to 56°)	0.4966
Distance *a*	1 mm (-8 to 9 mm)	-2 mm (-14 to 6 mm)	0.0131†
Appearance of femoral epiphyseal ossification nucleus	42 (100%)	43 (100%)	1
Outcomes			
Successful reduction	41 (98%)	42 (98%)	1
Re-dislocation	2 (5%)	1 (2%)	0.616
AVN	0 (0%)	0 (0%)	1
Follow-up without further treatment beyond 5 years of age			
Number of hips	32	36	
Acetabular index	30° (17 to 40°)	32° (22 to 42°)	0.151
Center-edge angle of Wiberg	3° (-9 to 19°)	2° (-11 to 14°)	0.4863
Residual acetabular dysplasia	23 (72%)	28 (78%)	0.5894
Residual subluxation	0 (0%)	1 (3%)	1
Secondary surgery for residual acetabular dysplasia/subluxation	22 (69%)	25 (69%)	1
Severin classification[8] at final visits			
Number of hips	33	36	
Group I	26 (79%)	26 (72%)	0.8133
Group II	4 (12%)	6 (17%)	
Group III	3 (9%)	4 (11%)	

AVN, avascular necrosis of the femoral head; DDH, developmental dysplasia of the hip.
*Categorical variables were examined with the Fisher exact test or the chi-squared test, and continuous variables were examined with the Mann-Whitney U test.
†Statistically significant, P < 0.05.

Discussion

The treatment strategy for untreated DDH after walking age remains controversial. Some investigators have preferred one-stage surgical procedures such as open reduction combined with femoral and/or pelvic osteotomies in an earlier age [8, 9]. Conversely, there is also a concept to expect acetabular remodeling after reduction during growing period. Salter and Dubos [20] stated that the acetabular remodeling cannot be ensured in hips over 18 months of age. Lindstrom et al. [21], however, described that acetabular remodeling can continue until 6 years after reduction even in the hips reduced after 24 months of age. Zionts and MacEwen [6], reviewing 51 hips treated with closed reduction from 1 to 3 years of age, recommended initial conservative treatment because acetabular development after concentric reduction was often sufficient in this age group. We previously demonstrated spontaneous disappearance of soft-tissue interposition after GR using OHT, which could provide favorable effects on acetabular development [12]. In the present study, we observed satisfactory acetabular development even in some patients diagnosed over 18 months of age. Concentric reduction after the OHT treatment could lead to a favorable acetabular remodeling in this age group. Hence, we no longer recommend one-stage surgical procedures in an earlier age for DDH from 1 to 3 years of age.

AVN of the femoral head is the most serious complication in DDH treated with closed or open reduction, with an incidence of 2-24% from 1 to 3 years of age (Table 2) [6, 7, 8, 10] An interruption of the blood supply to the femoral head may result from excessive mechanical pressure on the head by acute closed reduction or direct injury to the vessels by open reduction [22]. Rampal et al. [3], using GR by traction named the Petit-Morel method, reported an AVN incidence of 2.1% in 47 hips from 1 to 5 years of age. AVN has never observed in DDH after walking age by GR using OHT in the present study. Extremely lower AVN rates by GR using traction technique may be due to gradual stretching of soft tissues around the hip and decrease in intra-articular pressure during reduction.

Disadvantage of open reduction includes joint infection and articular chondrocyte death induced by exposure to air [23], which may lead to coxa magna and early-onset degenerative change even in hips with concentric reduction [24].

Table 2: Comparison of literature reporting outcomes of the treatment for DDH from one to three years of age

Study	Number of hips	Treatment	Age at reduction (months)	Success of reduction (%)	AVN (%)	Re-dislocation /Subluxation (%)	Additional surgery* (%)	Mean duration of follow-up (years)
Zionts and MacEwen[6]	51	CR	13 to 36	75	6	29	75	12
		with/without PT						(range, 5 to 22)
Huang and Wang[10]	17	CR	13 to 17	94	24	35	59	7
		with/without PT						(range, 4 to 9)
	32	OR and PO	13 to 17	100	6	3	3	4
								(range, 2 to 6)
Berkeley et al[7]	51	OR	12 to 36	100	2	0	0	6
		with/without FSO or PO						(range, 2 to 12)
Galpin et al[8]	20	OR and FSO	28 to 46	100	5	20	20	3
		with/without PO						(range, 2 to 6)
Current study	85	GR using OHT	13 to 49	98	0	5	59	8
								(range, 1 to 21)

AVN, avascular necrosis of the femoral head; CR, closed reduction; DDH, developmental dysplasia of the hip; FSO, femoral shortening osteotomy; GR, gradual reduction; OHT, overhead traction; OR, open reduction; PO, pelvic osteotomy; PT, preliminary traction.
*Rate of surgery for failure of conservative treatment, re-dislocation, and residual acetabular dysplasia/subluxation.

(AI, distance *a*, and CEA) and of the determination of the Severin classification has not been tested. Third, the drawback of the OHT method is that the treatment duration is prolonged. Patient's emotional changes and parents' psychological stress should have been considered for evaluating effectiveness of the treatment. However, we had no available data of patient- or parent-reported outcomes during the treatment.

To avoid the issues, extra-articular acetabuloplasty would be preferable for reconstructive procedure. Several investigators have reported that Salter osteotomy is beneficial and provides favourable long-term results for residual acetabular dysplasia [17, 25, 26]. In the present study, 98% of the hips treated with Salter osteotomy showed favorable radiological outcome at final follow-up. We prefer two-stage treatment strategy for DDH after walking age, initial conservative reduction by GR using OHT and subsequent extra-articular acetabuloplasty by Salter osteotomy.

There are two major limitations in this study because of its retrospective nature. First, 69 patients (81%) did not reach skeletal maturity at final follow-up. A further observation is necessary to verify a long-term result of our treatment for DDH after walking age. Second, intraobserver and interobserver reliability of the radiological measurements

Conclusion

In conclusion, GR using OHT is a preferable initial treatment for DDH after walking age with a high reduction rate and a low incidence of complications. This technique is applicable even to high dislocations from 18 months to 3 years of age. Some hips in this age group can remodel favorably until preschool ages. Salter osteotomy during preschool ages can provide a satisfactory mid-term outcome for hips with residual acetabular dysplasia after GR using OHT.

References

1. *Dezateux C, Rosendahl K. Developmental dysplasia of the hip. Lancet 2007;369:1541-52.*

2. *Morin C, Wicart P, French Society of Pediatric Orthopaedics. Congenital dislocation of the hip, with late diagnosis after 1 year of age: Update and management. Orthop Traumatol Surg Res 2012;98:S154-8.*

3. *Rampal V, Sabourin M, Erdeneshoo E, Koureas G, Seringe R, Wicart P. Closed reduction with traction for developmental dysplasia of the hip in children aged between one and five years. J Bone Joint Surg Br 2008;90:858-63.*

4. *Schoenecker PL, Dollard PA, Sheridan JJ, Strecker WB. Closed reduction of developmental dislocation of the hip in children older than 18 months. J Pediatr Orthop 1995;15:763-7.*

5. *Vitale MG, Skaggs DL. Developmental dysplasia of the hip from six months to four years of age. J Am Acad Orthop Surg 2001;9:401-11.*

6. *Zionts LE, MacEwen GD. Treatment of congenital dislocation of the hip in children between the ages of one and three years. J Bone Joint Surg Am 1986;68:829-46.*

7. *Berkeley ME, Dickson JH, Cain TE, Donovan MM. Surgical therapy for congenital dislocation of the hip in patients who are twelve to thirty-six months old. J Bone Joint Surg Am 1984;66:412-20.*

8. *Galpin RD, Roach JW, Wenger DR, Herring JA, Birch JG. One-stage treatment of congenital dislocation of the hip in older children, including femoral shortening. J Bone Joint Surg Am 1989;71:734-41.*

9. *Ning B, Yuan Y, Yao J, Zhang S, Sun J. Analyses of outcomes of one-stage operation for treatment of late-diagnosed developmental dislocation of the hip: 864 hips followed for 3.2 to 8.9 years. BMC Musculoskelet Disord*

2014;15:401.

10. Huang SC, Wang JH. A comparative study of nonoperative versus operative treatment of developmental dysplasia of the hip in patients of walking age. J Pediatr Orthop 1997;17:181-8.

11. Kaneko H, Kitoh H, Mishima K, Matsushita M, Ishiguro N. Long-term outcome of gradual reduction using overhead traction for developmental dysplasia of the hip over 6 months of age. J Pediatr Orthop 2013;33:628-34.

12. Hattori T, Ono Y, Kitakoji T, Takashi S, Iwata H. Soft-tissue interposition after closed reduction in developmental dysplasia of the hip. The long-term effect on acetabular development and avascular necrosis. J Bone Joint Surg Br 1999;81:385-91.

13. Kitoh H, Kawasumi M, Ishiguro N. Predictive factors for unsuccessful treatment of developmental dysplasia of the hip by the Pavlik harness. J Pediatr Orthop 2009;29:552-7.

14. Salter RB, Kostuik J, Dallas S. Avascular necrosis of the femoral head as a complication of treatment for congenital dislocation of the hip in young children: A clinical and experimental investigation. Can J Surg 1969;12:44-61.

15. Kalamchi A, MacEwen GD. Avascular necrosis following treatment of congenital dislocation of the hip. J Bone Joint Surg Am 1980;62:876-88.

16. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint. With special reference to the complication of osteo-arthritis. Acta Chir Scand 1939;83:1-135.

17. Kaneko H, Kitoh H, Mishima K, Matsushita M, Kadono I, Ishiguro N, et al. Factors associated with an unfavourable outcome after Salter innominate osteotomy in patients with unilateral developmental dysplasia of the hip: Does occult dysplasia of the contralateral hip affect the outcome? Bone Joint J 2014;96:1419-23.

18. Severin E. Contribution to the knowledge of congenital dislocation of the hip joint. Late results of closed reduction and arthrographic studies of the hip joint. Late results of closed reduction and arthrographic studies of recent cases. Acta Chir Scand 1941;84:1-142.

19. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis 1957;16:494-502.

20. Salter RB, Dubos JP. The first fifteen year's personal experience with innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. Clin Orthop Relat Res 1974;98:72-103.

21. Lindstrom JR, Ponseti IV, Wenger DR. Acetabular development after reduction in congenital dislocation of the hip. J Bone Joint Surg Am 1979;61:112-8.

22. Roposch A, Ridout D, Protopapa E, Nicolaou N, Gelfer Y. Osteonecrosis complicating developmental dysplasia of the hip compromises subsequent acetabular remodeling. Clin Orthop Relat Res 2013;471:2318-26.

23. Pun SY, Teng MS, Kim HT. Periodic rewetting enhances the viability of chondrocytes in human articular cartilage exposed to air. J Bone Joint Surg Br 2006;88:1528-32.

24. Gibson PH, Benson MK. Congenital dislocation of the hip. Review at maturity of 147 hips treated by excision of the limbus and derotation osteotomy. J Bone Joint Surg Br 1982;64:169-75.

25. Böhm P, Brzuske A. Salter innominate osteotomy for the treatment of developmental dysplasia of the hip in children: Results of seventy-three consecutive osteotomies after twenty-six to thirty-five years of follow-up. J Bone Joint Surg Am 2002;84:178-86.

26. Ito H, Ooura H, Kobayashi M, Matsuno T. Middle-term results of Salter innominate osteotomy. Clin Orthop Relat Res 2001;387:156-64.

Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

Kaneko H, HKitoh H, Iwata K, Mishima K, Matsushita M, Hattori T | Gradual Reduction Using Overhead Traction for Developmental Dysplasia of The Hip After Walking Age: A 30-year Retrospective Study | International Journal of Paediatric Orthopaedics | May-August 2020; 6(1): 12-17.