Acta Orthop. Belg., 2013, **79**, 159-165

ORIGINAL STUDY

Clinical and radiological outcomes are correlated with the age of the child in single-stage surgical treatment of developmental dysplasia of the hip

Mehmet F. Yagmurlu, Ilhan A. Bayhan, Umit Tuhanioglu, Ahmet S. Kilinc, Eyup S. Karakas

From the Baltalimani Bone Diseases Educational and Research Hospital, Istanbul, Turkey

The principles of treatment of developmental dislocation of the hip (DDH) in an older child are different from those in a newborn. In the older child retraction of the muscles around the hip, associated with a marked acetabular dysplasia and elongation of the joint capsule explain the difficulty and instability of reduction and the frequency of complications. The aim of this study is to evaluate the effect of age on the results of a one-stage open reduction in developmental dislocation of the hip.

We present the results of 21 children (27 hips) with a mean age of 6 years and 10 months at time of operation, consisting of one- stage open reduction, femoral shortening and Salter or triple pelvic osteotomy. Two groups were formed : one older and one younger than 8 years of age. We evaluated the patients according to the Severin and Mc Kay classifications.

After an average follow-up of 49 months (24-84 months) 74% of patients showed a very good or good result according to Severin's radiological classification and 63% according to Mc Kay's clinical classification. When analyzed with regard to age, we found important differences in the clinical and radiological results between the children younger and older than 8 years.

Keywords : developmental dysplasia of the hip ; one-stage surgical reduction ; age at treatment.

INTRODUCTION

Late presenting developmental dislocation of the hip (DDH) is still a common problem in developing countries and among low socioeconomic groups (*7, 11,13,21*). When untreated, it results in soft tissue contractures, persistent dysplastic changes in the hip, pain, functional impairment, abnormal gait and finally osteoarthritis in early adulthood (*2,4,11, 12,13,16,20,23*).

Main problems in the treatment of late presenting DDH are high displacement of the femoral head, marked insufficiency of the acetabulum and soft tissue contractures around the hip (*1,10,18*). Reduction of DDH is challenging and complications are frequent (*9,11,23*). Inadequate soft tissue release may cause femoral head compression that may lead to transient and/or permanent ischaemia (*5,8,23,24,26*). Although preoperative skeletal traction has been used to prevent this complication for many years, femoral shortening has been shown to be more effective in preventing complications (*13,17,23*).

■ Mehmet F. Yagmurlu, Associate Professor of Orthopaedics and Traumatology, Clinical chief.
■ Eyup S. Karakas, Professor of Orthopaedics and Traumatology, Clinical chief.
■ Ilhan A. Bayhan, Orthopaedic surgeon.
■ Umit Tuhanıoglu, Orthopaedic surgeon.
■ Ahmet S. Kılınc, Orthopaedic surgeon.
Baltalimani Bone Diseases Educational and Research Hospital, Istanbul, Turkey.
Correspondence : Avni İlhan Bayhan, MD, Metin Sabanci Baltalimanı Bone Disease Education and Research Hospital, Baltalimanı 34470, Istanbul, Turkey.
E-mail : ilhanbayhan@gmail.com

No benefits or funds were received in support of this study. The authors report no conflict of interests.

Marked acetabular dysplasia is another important problem in late presenting DDH. Due to lack of a stimulating effect of the femoral head, the acetabulum is dysplastic and shallow in these patients. Closed or open reduction without osseous realignment has been associated with residual dysplasia due to decrease in growth capacity of the acetabulum with age (*1,3,6,15,21*). Pelvic osteotomies are required in order to increase the coverage of the femoral head, establish stability and prevent residual dysplasia (*9,11,12,13,14*).

Avascular necrosis is frequently due to increased pressure on the developing femoral head by contractures around the hip during and/or after reduction (*8,23,26*).

The single stage surgical treatment of DDH consists of open reduction, femoral shortening and pelvic osteotomy. The procedure is technically demanding and requires experience, especially when performed in patients over 4 years of age.

The aim of this study is to evaluate and identify the factors influencing the results of one- stage open reduction in DDH.

MATERIAL AND METHODS

Twenty-seven hips in 21 patients were prospectively evaluated between 1996 and 2004. All cases were diagnosed late, were not associated with muscular or chromosomal disorders and did not have any prior treatment. The average age at operation was 6 years and 10 months (4-14 years) with an average follow-up of 49 months (range : 24 to 84 months). Four patients were male and 17 were female. Six of the patients had bilateral DDH. Patients were divided in two groups according to their age (8 years and older- younger than 8 years).

All the children were operated by the senior author. Preliminary skeletal traction was not used. The hip joint was approached by the Smith-Petersen technique extended with a long lateral incision starting at the greater trochanter. In 24 hips a Salter osteotomy and in 3 hips a Steel osteotomy were added to reshape the acetabulum. Shortening and derotation of the femur without varisation was accomplished at the level of the intertrochanteric region. The amounts of femoral shortening and derotation were decided intraoperatively. This was performed by reduction of the femoral head in the acetabulum after osteotomy and excision of the overlapping femoral segment. The acetabular osteotomy was done before the femoral osteotomy in order to optimize the amount of shortening.The mean amount of shortening was 1.7cm (range : 1 to 3 cm). Derotation was added if a residual anterior instability was present after reduction of the femoral head into the reoriented acetabulum. Seven hips required derotation between 10 to 20 degrees to achieve adequate stabilisation. Capsule plication was not performed in any of the cases.

After surgery patients were immobilized for 6 weeks in a half spica cast with the hip in 20 to 60° of flexion, 30 to 60° of abduction and neutral to 15° of internal rotation. Range of motion exercises started after removal of the cast and weight bearing was allowed when tolerated. Additional braces or devices were not used. Plates and screws were not removed before 7 months.

Patients were evaluated clinically and radiologically. The preoperative, immediate postoperative and last follow-up radiographs were evaluated by an independent orthopaedic surgeon who was not involved in the study. Radiographs prior to surgical treatment were evaluated for the degree of dislocation using the Tönnis system (*26*). Preoperative acetabular indices and continuity of the Shenton line were recorded. Final radiographs were graded according to the radiological criteria of Severin (*25*) (Table I). Postoperative acetabular index, center-edge angle of Wiberg and continuity of the Shenton lines were recorded . Radiographs were also assessed for the presence of avascular necrosis of the femoral head and if present they were classified according to Bucholz-Ogden (*5*).

At last follow-up, patients were evaluated clinically. Hip range of motion, Trendelenburg sign, pain, and clinical leg length discrepancy were recorded. Clinical evaluation was carried out in accordance with the Mc Kay scoring system (*17*) (Table II).

Statistical Method

Statistical calculations were performed with the NCSS 2007 program for Windows. Besides standard descriptive statistical calculations (mean and standard deviation), an unpaired test-test was used for the comparison of two groups, a paired t-test in the assessment of pre- and post-treatment values, and Chi square and Mc Nemar's tests for the evaluation of the qualitative data. Statistical significance level was set at $p < 0.05$.

RESULTS

According to the Tönnis grading system, 6 hips were class III and 21 were class IV. The Shenton

Table I. — Radiological classification according to Severin (25)

Degree	Radiological	Appearance	CEA	Age
Ia	Very good	Normal	> 19°	6-13 years
			> 25°	≥ 14 years
Ib	Good	Normal	15-19°	6-13 years
II	Good	Mild deformity in the femoral head, neck or acetabulum	Same values as degree Ia-Ib	
III	Moderate	Dysplasia without subluxation	< 15°	6-13 years
			< 20°	≥ 14 years
IV	Bad	Subluxated		
V	Bad	Articulation of the femoral head with false acetabulum		
VI	Bad	Redislocated		

CEA : Center-Edge Angle.

Table II. — Clinical evaluation according to modified Mc Kay criteria (17)

Degree		Findings
I	Very good	Stable, no pain, no limp, trendelenburg negative, full range of motion
II	Good	Stable, no pain, small limp, mild limitation of ROM
III	Fair	Stable, no pain, limp, Trendelenburg positive, limited range of motion or a combination of these
IV	Poor	Unstable, or painful, or both, Trendelenburg pasitive

lines which were broken in all of the hips preoperatively were restored in 17 hips (63%) after surgery (Table III).There was however no statistically significant difference in the improvement of the Shenton line between the children younger or older than 8 years of age (Table IIIb). The overall average preoperative acetabular index of 37.8° (25-52) improved to 21.2° (10-32) postoperatively. The average improvement of the acetabular index was 16.6°. Children aged 8 years and older showed 38.36% improvement of the acetabular index , from an average preoperative index of 41.1° to 25.44° postoperatively. In children under 8 years of age, the average preoperative acetabular index of 36.17° decreased to 19° postoperatively , an improvement of 47.4%, showing a statistically significant difference with the older age group ($p = 0.013$, Table IVa) .The postoperative CE Wiberg angle was also significantly better in the younger age group ($p = 0.049$, Table IVa).

Postoperatively, according to the Severin grading system, 9 hips (33.3%) were class 1a, 3 hips (11.1%) class1b, 8 hips (29.6%) class 2, 6 hips (22.2%) class3 and 1 (3.7%) hip class 4 , showing an overall satisfactory result of 74% (Table III).

When the radiological results (Severin grading) were analyzed with respect to the child's age it was found that radiological grades decreased significantly as the child was older ($r\ (27) = 0.60$, $p < .001$). In other words, results were better in children who were younger. We further analyzed age-related differences via chi-square statistics. When the cut-off point was taken at 8 years of age , the difference was significant. Chi-square statistics indicated that the rates for satisfactory results in children who were younger than 8 years of age (85.7%) were significantly higher compared to those in children 8 years and older (33.3%), ($x^2\ (1) = 6.67, p < .01$).

At latest follow-up all but one of the patients were free of pain. According to the Mc Kay hip score, 6 hips (22.2%) were excellent, 11 (40.7%) hips good, 8 (29.6%) hips fair and 2 hips (7.4%) poor. Sixty-three percent of patients declared excel-

Table III. — Data at last follow-up and applied surgical method

Children aged 8 years or older

Gender	Age At Op.	Affected Side	Pain	Limb length discrep. (cm)	Shenton-Menard. line	Severin class.	McKay hip score	Surgical technique
male	13	right (bilateral)	-	-	intact	clas3	fair	triple
male	14	left (bilateral)	-	-	broken	clas3	poor	triple
female	11	left	-	3	broken	clas4	poor	salter
female	11	left	-	2	broken	clas3	fair	triple
female	8	left (bilateral)	-	-	intact	clas1a	excellent	salter
female	8	right (bilateral)	-	2	broken	clas2	fair	salter
male	9	right (bilateral)	-	-	intact	clas1b	good	triple
male	10	left (bilateral)	-	-	broken	clas2	fair	triple
male	8	right	-	1	intact	clas1a	good	salter

Children aged less than 8 years

Gender	Age At Op.	Affected Side	Pain	Limb length discrep. (cm)	Shenton-Menard. line	Severin class	McKay hip score	Surgical technique
female	5	right	-	-	intact	clas1a	good	salter
female	6	left	-	-	broken	clas2	fair	salter
female	4	left	-	-	intact	clas1a	excellent	salter
female	5	left	-	-	intact	clas2	good	dega
female	4	left	-	-	intact	clas1a	good	salter
female	6	right (bilateral)	-	-	broken	clas3	fair	salter
female	6	left (bilateral)	-	-	intact	clas2	good	salter
female	4	left	-	1	intact	clas1a	good	salter
female	7	left (bilateral)	-	2	broken	clas3	fair	salter
female	7	right (bilateral)	-	-	intact	clas2	good	salter
male	6	left	-	-	intact	clas1b	good	salter
female	4	right	-	-	intact	clas1a	excellent	salter
female	4	right	-	-	intact	clas2	excellent	salter
female	4	left	-	1	broken	clas1b	good	salter
female	6	right	-	2	broken	clas3	fair	salter
female	7	left	-	-	intact	clas1a	excellent	salter
female	4	left (bilateral)	-	-	intact	clas2	good	salter
female	4	right (bilateral)	-	-	intact	clas1a	excellent	salter

lent and good results (Table IV). Clinical findings in children, younger than 8 years of age (9 good and 5 excellent) were better when compared to the children 8 years and older (2 good and 1 excellent), but without statistically significant difference ($p = 0.76$, Table IIIb).

At last follow-up , except for two children who had a leg length discrepancy of 2 cm, all leg lengths in patients with bilateral DDH were equal. Among 15 unilateral DDH cases, 6 had an average leg length discrepancy of 1.7 cm, ranging between 1.0 and 3.0 cm (Table IV).

Table IVa. — Pre- and postoperative acetabular index (AI) and final CE angle of Wiberg according to age groups

	Age < 8 years (n : 18)	Age ≥ 8 years (n : 9)	p
AI preoperative	36.17 ± 8.41	41.11 ± 6.75	0.156
AI postoperative	19.00 ± 5.14	25.44 ± 5.57	0.009
AI improvement %	47.40 ± 9.67	38.36 ± 8.21	0.013
CE Wiberg	27.39 ± 8.80	19.78 ± 8.66	0.049

Table IVb. — Statistical evaluation of Shenton line and McKay score

		< 8 years		> 8 years		
Postop Shenton Line	Intact	13	72.2%	4	44.4%	χ^2 : 1.98
	Broken	5	27.8%	5	55.6%	p = 0.159
McKay Hip Score	Poor	0	0.0%	2	22.2%	
	Fair	4	22.2%	4	44.4%	
	Good	9	50.0%	2	22.2%	χ^2 : 6.88
	Excellent	5	27.8%	1	11.1%	p = 0.76

Avascular necrosis of the femoral head was observed in 4 (14%) hips. According to the Bucholz and Ogden Classification, 2 were type 1, one type 2 and onewas type 3. All type 1 patients had satisfactory clinical results.

There were no redislocations, no infections, no fractures at the osteotomy site nor implant failure or wound problems.

DISCUSSION

The goals of treatment of DDH are to provide a painless stable hip without functional limitations and gait abnormalities and to prevent early osteoarthritis. This can only be achieved with a concentrically reduced hip. Good results become harder to achieve with advancing age (*9,10,11,12,20*).

Isolated open reduction bears the disadvantages of residual acetabular dysplasia, and increased risk of avascular necrosis in older children. Femoral shortening appeared to facilitate reduction in children who were more than three years old (*1,4,20*). In addition, it was concluded that a one-stage operation consisting of open reduction, femoral shortening and correction of an acetabular deficiency with the appropriate pelvic osteotomy does not increase the risk of osteonecrosis in older children (*9,11,20*).

A high-riding femoral head with contracture of the musculature and soft tissues has been a major problem to overcome in late presenting cases with DDH. Though for many years preoperative skeletal traction has been the most popular way to solve this problem, the study of Schoenecker and Strecker has shown that femoral shortening is more effective in decreasing the risk of avascular necrosis of the femoral head (*23*). Femoral shortening relaxes the muscles crossing the hip joint. This facilitates reduction of the femoral head into the acetabulum and by decreasing the pressure on the reduced femoral head decreases the risk of avascular necrosis (*13,23*).

Femoral shortening also allows rotational realignment of the femoral head, increasing the stability of the reduction.

It has been shown in prior reported series as well as in our study, that femoral shortening has little effect on leg length difference. This may be explained by the relative overgrowth of the femur after the osteotomy and the transiliac lengthening effect of the iliac osteotomy (*11*). The leg length discrepancies occurring in this series did not seem to have caused any functional impairment.

İn our series we performed the femoral osteotomy after the acetabular osteotomy. This makes it possible to tune the femoral shortening and derotation according to the new orientation of the acetabulum. This is especially important to avoid excessive retroversion of the femoral head, which may deteriorate the results especially when combined with

Salter osteotomy which causes posterior insufficiency of the acetabulum (*1,7,9*).

The literature on treatment of DHH reports a wide range of incidences of avascular necrosis of the femoral head. Ours is comparable with other studies in the same age group and using the same method (*8,10,11*). Our follow-up time is not sufficient to evaluate the late presenting Bucholz-Ogden type 2 osteonecrosis, so there is a slight risk for an increased incidence of avascular necrosis with longer follow-up.

One-stage treatment of DDH with various methods, has been reported by many authors. Salter and Dubos performed an innominate osteotomy with open reduction in children over 4 years of age and reported 57% satisfactory radiological results (*22*). Roth *et al* reported 46% good or excellent radiological results in an older age group with DDH (*20*). Barrett *et al* reported 63% clinical and 75% radiological satisfactory results in a group of children with a mean age of 5 years (*1*).

Galpin *et al* operated 32 hips (21 hips had femoral shortening) in 25 patients with a mean age of 4 years and 2 months (the oldest was 8 years and 2 months) ; there were 75% satisfactory results according to the Severin classification. The authors reported 3 cases of type IV avascular necrosis (*9*).

Williamson *et al* in a study with long-term follow-up reported that femoral osteotomy combined with pelvic osteotomy yielded better results for DDH patients over 3 years of age. They also mentioned that at last follow-up the radiological results in this group were better than the 5 year follow-up of femoral osteotomy alone (*27*).

Klisic and Jancovic treated 61 hips in 47 children whose ages ranged between 5 to 15 with a one-stage operation combining open reduction, femoral shortening, iliac osteotomy and reorientation of the proximal femur and reported 63% good and excellent combined radiological and clinical results (*13*).

The age limit to successfully treat a dislocated hip by reduction is not clear. Williamson *et al* found no correlation between the age at presentation and the end result but in their series there was only 1 patient older than 6 years of age (*27*). Klisic *et al* reported that 7- to 8-year-old patients do better than the older ones (*14*). Karakas *et al* stated that children younger than 8 years of age show better radiologic and clinical results (*11*).

Our study has shown 63% clinical and 74% radiological satisfactory results respectively. These results are comparable with those reported previously in this age group with similar treatment methods and they reflect the difficulties in treating late-presenting DDH, especially in the older age group. We have found that correcting the acetabulum is harder over 8 years of age, which can be explained by the increased stiffness of the symphysis pubis which may have to be overcome with additional osteotomies to this site. The CE angle at last follow-up is also higher in patients operated before 8 years of age. Our radiological evaluation showed better results in children operated before 8 years of age. The analysis of the clinical results shows the same tendency.

Our follow-up time is not sufficient to conclude about long-term results. Klisic *et al* found no significant differences in results relating to the follow-up time (*13*). Long-term follow-up may provide valuable data including late-presenting types of avascular necrosis and degenerative changes. We believe that it is reasonable to expect good long-term results especially in patients with satisfactory radiological results.

In light of our findings we think that one-stage treatment including open reduction, pelvic osteotomy and femoral shortening is an effective method in the treatment of children with late DDH, especially for those younger than 8 years of age.

REFERENCES

1. **Barrett WP, Staheli LT Chew DE.** The effectiveness of the Salter innominate osteotomy in the treatment of congenital dislocation of the hip. *J Bone Joint Surg* 1987 ; 68-A : 79-87.
2. **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* 1984 ; 66-A : 412-420.
3. **Bohm 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* 2002 ; 84-A :178-186 .

4. **Browne RS.** The management of late diagnosed congenital dislocation and subluxation of the hip. *J Bone Joint Surg* 1979 ; 61-B : 7-12.
5. **Bucholz RW, Ogden JA.** Patterns of ischemic necrosis of the proximal femur in nonoperatively treated congenital hip disease. In : *The hip. Proceedings of the sixth scientific meeting of the Hip Society*. St. Louis : C.V. Mosby ; 1978, pp 43-67.
6. **Chen IH, Kuo KN, Lubicky JP.** Prognosticating factors in acetabular development following reduction of developmental dysplasia of the hip. *J Pediat Orthop* 1994 ; 14 : 3-8.
7. **Coleman SS.** *Congenital Dysplasia and Dislocation of the Hip*, Mosby, St. Louis, C. V. 1978, pp. 98-125.
8. **Gage JR, Winter RB.** Avascular necrosis of the capital femoral epiphysis as a complication of closed reduction of congenital dislocation of the hip. a critical review of twenty years' experience at Gillette Children's Hospital. *J Bone Joint Surg* 1972 ; 54-A : 373-388.
9. **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* 1989 ; 71-A : 734-741
10. **Herring JA.** *Tachdjian's Paediatric Orthopaedics*. Vol 1. 3rd ed. Saunders, Philadelphia, 2000, p 568-654.
11. **Karakas ES, Baktir A, Argün M, Türk CY.** One-stage treatment of congenital dislocation of the hip in older children. *J Pediatr Orthop 1995 ;* 15 : 330-336.
12. **King HA, Coleman SS.** Open reduction and femoral shortening in congenital dislocation of the hip. *Orthop Trans* 1980 *; 4 :* 302-303.
13. **Klisic P, Jankoviç LJ.** Combined procedure of open reduction and femoral shortening of the femur in treatment of congenital dislocation of the hip in older children. *Clin orthop Relat Res* 1976 ; 119 : 60-69.
14. **Klisic P, Jankovic LJ, Basara V.** Open reduction with pelvic osteotomy and femoral shortening. *Acta Orthop Belg* 1990 ; 56 : 269–274.
15. **Lindstrom JR, Ponseti IV, Wenger DR.** Acetabular development after reduction in congenital dislocation of the hip. *J. Bone Joint Surg* 1979 ; 61-A : 112-118.
16. **Malvitz TA, Weinstein SL**. Closed reduction for congenital dysplasia of the hip. Functional and radiographic results after an average of thirty years. *J. Bone Joint Surg 1994 ;* 76-A : 1777-1792
17. **McKay DW.** A comparison of the innominate and pericapsular osteotomy in the treatment of congenital dislocation of the hip. *Clin Orthop Relat Res* 1974 ; 98 : 124-132.
18. **Omeroglu H, Bicimoglu A, Agus H, Tumer Y.** Measurement of center-edge angle in developmental dysplasia of the hip : a comparison of two methods in patients under 20 years of age. *Skeletal Radiol* 2002 ; 31 : 25-29.
19. **Race C, Herring JA.** Congenital dislocation of the hip : an evaluation of closed reduction. *J Pediatr Orthop* 1983 ; 3 : 166-172.
20. **Roth A, Gibson DA, Hall JE.** The experience of five orthopedic surgeons with innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. *Clin Orthop Relat Res* 1974 ; 98 : 178-182.
21. **Ryan MG, Johnson LO, Quanbeck DS, Minkowitz B.** One-stage treatment of CDH in children 3 to 10 years old. Functional and radiographic results. *J Bone Joint Surg* 1998 ; 80-A : 336–344.
22. **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.
23. **Schoenecker PL, Strecker WB.** Congenital dislocation of the hip in children. Comparison of the effects of femoral shortening and of skeletal traction in treatment. *J Bone Joint Surg 1984 ;* 66-A : 21-27.
24. **Segal LS, Boal DK, Borthwick L *et al.*** Avascular necrosis after treatment of DDH : the protective influence of the ossific nucleus. *J Pediatr Orthop* 1999 ; 19 : 177-184.
25. **Severin E.** Contribution to the knowledge of congenital dislocation of the hip joint. Late results of closed reduction and arthrographic studies of recent cases. *Acta Chir Scand* 1941 ; 84 (Suppl 63) : 1-16.
26. **Tönnis D.** *Congenital Hip Dislocation*. Thieme-Stratton, New York, 1982
27. **Williamson DM, Glover SD, Benson MK.** Congenital dislocation of the hip presenting after the age of three years.A long-term review.*J Bone Joint Surg* 1989 ; 71-B : 745-751.