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ORIGINAL STUDY

The surgical treatment of developmental dislocation of the hip in older children : A comparative study

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The aim of this retrospective study was to compare simultaneous open reduction and Salter innominate osteotomy versus one-stage combined surgical treatment including femoral shortening.

A total of 24 patients were studied. Group 1 included 16 hips in 14 patients treated by simultaneous open reduction and Salter innominate osteotomy ; Group 2 included 13 hips in 10 patients treated by one-stage open reduction, Salter innominate osteotomy and femoral shortening.

The average age at the time of operation was 4.1 years (range : 3.3 to 5.1). Average follow-up was 5.3 years (range : 2.7 to 9.0). Clinical and radiological assessment at final follow-up showed that the outcome was not significantly different between the two groups. The duration of operation, however, was significant different between the groups.

Patients with DDH between 3 and 5 years of age were treated successfully with either simultaneous open reduction and Salter innominate osteotomy or a one-stage combined surgical procedure including femoral shortening. Clinical and radiological outcomes were similar. Nevertheless, after this follow-up period, the rate of avascular necrosis was slightly higher in Group 1 ; on the other hand, one-stage combined surgical treatment including femoral shortening significantly prolonged the operative time.

Key words : developmental dislocation of the hip ; older children ; surgical treatment.

INTRODUCTION

The goals of treatment in developmental dislocation of the hip (DDH) include achieving and maintaining concentric reduction, thus providing an optimal environment for the development of the femoral head and acetabulum (*6, 22, 23*).

If the diagnosis is made in early life, conservative treatment such as Pavlik's harness or other abduction devices may be successful (*22, 23, 27*). The normal development of the hip joint (femoral head and acetabulum) is jeopardised when the diagnosis is delayed.

The treatment of DDH is a challenge in older children. Those patients have high displacement of the hip, contracted soft tissues, insufficiency of the acetabulum, and increased anteversion of the femoral head (*5, 15*). The problems lie in reducing the femoral head into the acetabulum, maintaining the concentric reduction and obtaining a satisfactory functional hip joint (*8*).

Ombredanne (*24*) reported an operation that included open reduction with femoral shortening in

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1932. Combined operation of open reduction with femoral shortening, iliac osteotomy, reorientation of the femoral head and neck, and medial transposition of the iliopsoas muscle have been used since 1963 (*18*).

Many studies suggested that the treatment of choice in older children was a one-stage combined surgical treatment with femoral shortening (*1, 4, 5, 7, 12, 15, 18, 19, 24, 31, 34, 36*). Some authors preferred one-stage combined surgical treatment with femoral shortening in the patients who were between 3-5 years of age (*1, 5-7, 15, 23, 31, 36*), whereas others performed open reduction and Salter innominate osteotomy in the same age group (*8-10, 16, 28*).

The aim of the present study was to compare simultaneous open reduction and Salter innominate osteotomy versus one-stage combined surgical treatment including femoral shortening.

PATIENTS AND METHODS

Twenty nine hips in 24 patients treated surgically for complete DDH were analysed retrospectively (table I). Inclusion criteria were : age between 3 and 5 years, combined surgery, and a minimal follow-up of 2 years. Combined surgery consisted of simultaneous open reduction and Salter innominate osteotomy (Group I : 16 hips) , or an one-stage simultaneous open reduction and Salter innominate osteotomy combined with femoral shortening (Group II : 13 hips). Children with neuromuscular disease, those who had preoperative traction and those not available for follow-up were excluded from the study (in total, 21 children).

The average age of the children at the time of surgery was 4.1 ± 0.6 years (range : 3.3 to 5.1). Average follow-up was 5.3 ± 2.0 years (range : 2.7 to 9.0). There were 21 girls and 3 boys. Sixteen hips underwent simultaneous Salter osteotomy and open reduction (Group 1). Thirteen hips underwent one-stage combined surgical treatment including femoral shortening (Group 2).

The surgical approach was a Smith-Petersen approach in Group I and a Klisic approach or a lateral femoral proximal approach in Group II. The patients in Group I underwent psoas tendon release, open reduction, followed by Salter innominate osteotomy. Patients in Group II underwent psoas tendon release, open reduction, Salter innominate osteotomy followed by femoral varus derotation osteotomy with shortening. The amount of correction in femoral varus derotation and shortening was decided intraoperatively. The amount of shortening ranged from 1 to 3 cm. The average derotation angle was 27° (range 10-56°). The average varus angulation at the subtrochanteric osteotomy was 12°. The osteotomy was fixed with a paediatric blade plate or a small DCP plate. Capsular repair was performed in all patients as described by Wenger *et al* (*16*). After operation, a spica cast was applied with the hip flexed 30°, abducted 30° and in neutral rotation. The cast was changed 6 weeks after surgery, and an abduction brace or cast was used for an additional 6 weeks.

Clinical assessment followed McKay's criteria (*21*) as modified by Barrett *et al* (*2*), including pain symptoms, gait pattern, status of Trendelenburg sign, and the range of hip joint motion (table II). Excellent and good results were considered as satisfactory, fair and poor as unsatisfactory. Sharp's acetabular angle (*31*) and Wiberg's center-edge (CE) angle (*36*) were measured on radiographs taken preoperatively, immediately after surgery and at follow-up. Radiographic assessment was performed using the method of Severin (*30*) (table III). The presence of avascular necrosis of the femoral head was graded by the criteria of Kalamchi and MacEwen : group I, changes affecting the ossific nucleus ; group II, lateral physeal damage ; group III, central physeal damage ; group IV, total damage to the femoral head and physis (*14*).

Statistical analysis was performed using the unpaired t test, and Mann-Whitney test from the MedCalc statistical software (MedCalc Software, Mariakerke, Belgium). A p value less than 0.05 was considered significant.

RESULTS

In Group I, the average operation time was 141 ± 25 minutes (range : 110 to 180) and in Group II, 224 ± 37 minutes (range : 130 to 270). There was a significant difference between the two groups with respect to operation time.

Excellent clinical results were obtained in 8 hips (27.5%), good results in 13 hips (44.8%), fair results in 6 hips (20.6%), whereas 2 hips (6.8%) ended up with poor results. Radiological results were excellent in 22 hips (75.8%), good in 6 hips (20.6%), and poor in 1 hip (3.4%).

In Group I, clinical results were excellent in 5 hips (31.2%), good in 7 hips (43.7%), fair in 3 hips (18.7%) and poor in 1 hip (6.2%) (table IV). In Group II, 3 hips (23.0%) were rated excellent,

Table I. — Data of the patients

Case*	Gender	Age at op. (yr)	Follow-up duration (yr)	Sharp's acetabular index (deg) Preop.	Sharp's acetabular index (deg) FU.	Final CE angles (deg)	Kalamchi-MacEwen's criteria of AVN	McKay's criteria for clinical evaluation	Severin's radiographic criteria	Complications
G 1										
1	F	5	8.4	48	38	11		Poor	IV	Subluxation
(2)	F	5.1	8.3	41	28	44		Excellent	IA	
3	M	3.3	6.2	39	15	44		Excellent	IA	
4	F	3.5	3.4	40	15	50		Good	IA	
5	F	3.6	5.6	32	23	37		Good	IA	
6	F	3.4	3.2	36	21	38		Good	IA	
7	F	4.9	6.0	41	18	18		Fair	II	Coxa vara
8	F	3.8	2.7	36	17	20		Good	II	
9	F	4.9	6.0	41	18	18		Fair	II	Coxa vara
10	F	3.6	4.0	46	21	30		Good	IA	
11	M	4	3.2	37	20	30		Excellent	IA	
12	F	3.5	3.6	34	20	25	I	Good	IA	
(13)	F	3.6	3.5	33	20	25		Excellent	IA	
14	F	4.9	4.1	33	10	45		Fair	IA	
15	F	4.4	3.5	40	25	45		Excellent	IA	
16	F	3.6	6.6	50	23	38	I	Good	IA	
G 2										
17	M	5.0	9.0	32	10	40		Fair	II	
18	F	3.3	5.2	38	20	40		Good	IA	
(19)	F	4.3	4.2	38	30	53	III	Fair	II	Femur length discrepancy
20	F	4.2	7.4	41	18	38		Good	IA	
21	F	3.9	5.5	43	12	40		Excellent	IA	
(22)	F	5.0	4.7	41	12	40		Good	IA	
23	F	4.3	8.3	35	18	40		Good	IA	
24	F	4.9	4.0	38	15	50		Excellent	IA	
25	F	3.5	3.8	50	35	15		Poor	II	
(26)	F	4.5	2.8	50	35	20		Fair	IA	
27	F	3.7	9.0	42	18	38		Good	IA	
28	F	4.9	7.8	38	10	38		Excellent	IA	
29	F	4.8	5,6	32	18	28		Good	IA	

* For patients who had a bilateral dislocation, the second side is indicated by parentheses.
G = Group ; op = operation ; preop = preoperatively ; FU = follow-up.

6 hips (46.1%) good, 3 hips (23.0%) fair and 1 hip (7.6%) poor (table V). Twelve hips (74.9%) in Group I and 9 hips (69.1%) in Group II yielded satisfactory results, whereas 4 hips (24.9%) in Group I and 4 hips (30.6%) in Group II yielded unsatisfactory results. There was no significant difference between the two groups according to McKay's clinical criteria at final follow-up.

Radiological results in Group I were excellent in 12 hips (75.0%), good in 3 hips (18.7%) and poor in 1 hip (6.2%). Ten hips (76.9%) were rated excellent and 3 hips (23.0%) good in Group II. Fifteen hips (93.7%) in Group I and 13 hips (100%) in Group II yielded satisfactory results, whereas 1 hip (6.2%) in Group I and no hip (0.0%) in Group II yielded unsatisfactory results. There was no

Table II. — McKay's criteria for clinical evaluation (24, 25)

Grade	Criteria
Excellent	Stable, painless hip ; no limp ; negative Trendelenburg sign ; full range of motion
Good	Stable, painless hip ; slight limp ; slight decrease in range of motion
Fair	Stable, painless hip ; limp ; positive Trendelenburg sign ; and limited range of motion, or a combination of these
Poor	Unstable or painful hip or both ; positive Trendelenburg sign.

Table III. — Severin's radiographic criteria (28)

Grade		Criteria
Excellent	IA	CE angle > 19°, age 6-13 years ; CE angle > 25°, age > 14 years
Good	IB	CE angle 15-19°, age 6-13 years ; CE angle 20-25°, age > 14 years
	II	Moderate deformity of femoral head, femoral neck, or acetabulum, but otherwise the same as grade IA or IB
Fair	III	Dysplastic hip, no subluxation ; CE angle < 15°, age 6-13 years ; CE angle < 20°, age > 14 years
Poor	IV	Subluxation
	V	Femoral head in false acetabulum
	VI	Redislocation

Table IV. — Results of Group 1

	Clinical	Radiological
Excellent	5 (31.2%)	12 (75.0%)
Good	7 (43.7%)	3 (18.7%)
Fair	3 (18.7%)	0 (0.0%)
Poor	1 (6.2%)	1 (6.2%)
Satisfactory	12 (74.9%)	15 (93.7%)
Unsatisfactory	4 (24.9%)	1 (6.2%)

Table V. — Results of Group 2

	Clinical	Radiological
Excellent	3 (23.0%)	10 (76.9%)
Good	6 (46.1%)	3 (23.0%)
Fair	3 (23.0%)	0 (0.0%)
Poor	1 (7.6%)	0 (0.0%)
Satisfactory	9 (69.1%)	13 (100%)
Unsatisfactory	4 (30.6%)	0 (0.0%)

significant difference between the two groups according to Severin's radiographic criteria at final follow-up (figs 1, 2).

The average Sharp acetabular angle preoperatively and at follow-up was 39.1° ± 5.3° / 20.7° ± 6.2° and the average CE angle at follow-up was 32.3° ± 11.9° in Group I, and in Group II, the average Sharp acetabular angle preoperatively and at follow-up was 39.8° ± 5.6° / 19.3° ± 8.7°, and the average CE angle at follow-up was 36.9° ± 10.5°.

In all patients, the Sharp acetabular angle and CE angle improved at the latest follow-up. There were no statistical differences between two groups regarding the preoperative and follow-up Sharp acetabular angle and follow-up CE angle.

The results and complications are listed in table I. Leg length discrepancy was noted in one hip (Case 19). Avascular necrosis of the femoral head (AVN) was detected in 3 hips (Case 12, 16, 19) ; two hips (12.5%) were in Group I, one hip (7.6%) was in Group II. Two of them had Kalamchi and MacEwen grade I AVN, whereas one had Kalamchi and MacEwen grade III AVN. No patient with AVN had further surgery. The use of different incisions was not relevant to the results. None of the patients had any complications such as infection, and graft displacement.

DISCUSSION

There are many studies in which the treatment of DDH in older children is combined surgical management that includes open reduction, pelvic osteotomy or acetabuloplasty, and femoral shortening

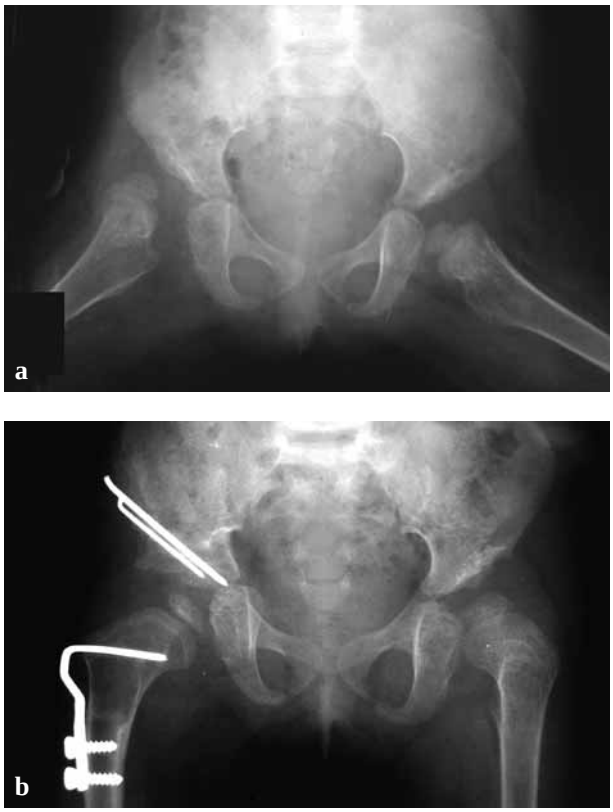

Fig. 1. — **a)** Preoperative radiograph of a 3-year-old child with developmental dislocation of the right hip ; **b)** Five months after combined surgical treatment was performed ; **c)** Eight years after operation, the implants had not been yet removed because of parents' neglect. Clinical result was excellent.

associated with derotation osteotomy and, when necessary, with varus osteotomy (*1, 4, 5, 7, 12, 15, 18, 19, 31*). On the other hand, there is a number of studies in which the treatment in children who range from 1.5 to 7 years of age is combined open reduction and pelvic osteotomy without femoral shortening (*8-10, 16, 28*).

AVN is a serious complication in the treatment of DDH (*3, 6, 11, 35*). The two major causes of AVN are excessive pressure on the cartilaginous femoral head, and occlusion of vessels of the femoral head (*6*). Particularly in older children, the presence of high displacement of the hip, contracted soft tissues and increased anteversion of the femoral head may complicate the reduction and encourage AVN of the femoral head (*1, 4, 12, 13, 14, 25, 31*). Schoenecker and Strecker (*28*) found 54% AVN rate in patients in whom open reduction was performed without femoral shortening. Femoral shortening allows easy reduction, reduces excessive pressure on the femoral head, and minimises necrosis of the cartilage and bone (*1, 17, 28, 31*). Tönnis (*33*) noted that the rate of ischaemic necrosis in open reductions was 8.2% for anterolateral approaches and only 5.5% when shortening osteotomy was combined with open reduction ; a simultaneous Salter osteotomy or acetabuloplasty increased the rate to 10.3% and a concomitant varus osteotomy to 22.2%. In the present study, the AVN rate was 12.5% in the patients who had simultaneous open reduction and Salter innominate, versus 7.6% in the patients who had one-stage combined operation including femoral shortening.

Gabuzda and Renshaw (*6*) advocated that open reduction with femoral shortening was preferred in patients more than three years old. Karakas *et al* (*15*) noted that their study included children who were between 4 and 17 years of age in whom one-stage combined treatment with femoral shortening and varus derotation osteotomy was performed. Galpin *et al* (*7*) performed the same procedure in children as young as 2 years of age. Dimitriou and

Fig. 2. — ***a***) Preoperative radiograph of a 2-year-old child with bilateral developmental dislocation of the hip ; **b**) One year after simultaneous open reduction and Salter innominate osteotomy on the right hip. The operation was done when she was 3 years old, because the parents were reluctant to surgery. Note avascular necrosis of the right hip ; **c)** Two years after operation, good clinical result.

Cavadias (*5*) suggested combined surgical treatment with femoral shortening in children older than 3 years. In the study of Williamson *et al* (*36*), the minimum age was 3 years. Schoenecker and Strecker (*28*) reported better results after one-stage treatment in children older than 3 years of age than after open reduction alone. Ashley *et al* (*1*) reserved this operation for children older than 3 years old, but included patients with cerebral palsy as well. Shih and Shih (*31*) suggested that children who were from 2.7 to 11 years of age could be treated with one-stage combined surgical management. King and Coleman (*19*) noted that after the age of 4 years an open reduction combined with femoral shortening is often necessary to achieve optimum results. Nakamura *et al* (*23*) performed a combination of open reduction and femoral derotation varus osteotomy with shortening in children with DDH, at an average age of 2 years and 1 month. They concluded that a stable reduction as well as sufficient decompression of the femoral head achieved by femoral derotation varus osteotomy and shortening osteotomy, have played an important role in preventing the femoral head from developing necrosis. AVN rates in one-stage combined surgical treatment including femoral shortening have ranged from 0% to 11% in different studies : Ashley *et al* (*1*) 0%, Dimitriou and Cavadias (*5*) 2.9%, Shih and Shih (*31*) 5%, Karakas *et al* (*15*) 7.2%, Schoenecker and Strecker (*28*) 7.6%, Galpin *et al* (*7*) 9%, Williamson *et al* (*36*) 11%. The age at the time of operation ranged from 2 to 17 years.

On the contrary, Gür and Sarlak (*9*) stated that open reduction and Salter innominate osteotomy had been used routinely in their department for children from 18 months to 6 years of age. Gulman *et al* (*8*) found late radiographic signs of type 2, 3 and 4 avascular necrosis in 34.6% after open reduction and Salter innominate osteotomy. Salter *et al* (*27*) found an AVN rate of 30% between 1952 and 1957, versus 15% between 1957 and 1962. Haidar *et al* (*10*) with simultaneous open reduction and

Salter innominate osteotomy performed at an average age of 7.5 years, reported 97.3% clinical and 83.8% radiological good or excellent results, with 8% AVN. Schoenecker and Strecker (*28*) performed open reduction after preoperative traction in patients whose ages ranged from 3.0 to 7.8 years. AVN rates of combined open reduction and pelvic osteotomy (or acetabuloplasty) ranged from 7.8% to 53.0% in different studies : Gür and Sarlak (*9*) 7.8%, Haidar *et al* (*10*) 8.0%, Salter *et al* (*27*) 15.0% and 30.0%, Gulman *et al* (*8*) 34.6%, Schoenecker and Strecker (*28*) 53.0% ; the age at the time of operation ranged from 1.5 to 8.0 years.

Summarising the literature regarding the two treatment modalities (combined surgical treatment with or without femoral shortening), we found that most authors achieved satisfactory results in children who were 3-5 years of age.

In the present study, analysing retrospectively two small groups of patients after either simultaneous open reduction and Salter innominate osteotomy, or one-stage combined operation including femoral shortening, in a uniform age group of children between 3 and 5 years of age, we found no difference between the two groups, neither clinically nor radiologically. Our radiological results in both groups were definitely better than our clinical results. On the other hand, one-stage combined surgical treatment including femoral shortening significantly prolonged the operation time. There is no doubt that these patients should be further followed, to find out whether degenerative arthritis or additional AVN will develop.The definitive number of AVN in this small series remains uncertain, owing to the relatively short follow-up, considering that AVN may become apparent after as long as 10 years.

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