Late-diagnosed DDH

A prospective 11-year follow-up of 71 consecutive patients (75 hips)

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ABSTRACT – I have prospectively studied 71 consecutive patients (75 hips) with late-diagnosed DDH (developmental dysplasia of the hip) treated uniformly with special reference to the development of the femoral head and the acetabulum. The age at the start of treatment was 10 (2–64) months. The follow-up time was 11 (6–18) years.

After tenotomy and traction, closed reduction failed in 7 hips. These cases were treated by open reduction with or without Salter innominate osteotomy—in 2 hips femoral osteotomy was also done (shortening, varus and derotation). 1 hip subluxated and 1 re-dislocated after closed reduction. Avascular necrosis occurred in 4 hips and additional surgery was required in 12 hips—11 Salter osteotomies, 1 varus femoral osteotomy.

In the first year after reduction, the acetabular angle improved rapidly—faster in the younger children. When treatment started between 12 and 22 months, the improvement was slower and the final outcome more unpredictable. The femoral head continued to grow irrespective of the age at reduction and became normal in almost all cases. Salter's innominate osteotomy stabilized hips after open reduction and gave excellent results in cases with an increasing acetabular angle.

At the last re-examination, all but 2 patients were asymptomatic. Radiographically, 65 hips were rated Severin group I, 9 group II and 1 group III.

■

Due to a well-functioning neonatal screening procedure, late-diagnosed DDH is rare in Sweden; in the whole country 1973–1976, 0.53 per thousand (Palmén 1984); in the city of Malmö 1956–1998, 0.16 per thousand (Danielsson 2000). Since the follow-up system of hips is well organized, late diagnosis is usually not very late; in Sweden, three-quarters of the cases were diagnosed before 7 months of age and 3% after 2 years (Palmén 1984). The cases are so rare that they are usually referred to a few centers.

In this homogeneous prospective study, I have followed all late-diagnosed cases of DDH and analyzed complications and radiographs. The radiographic variables were studied with special regard to age at the start of treatment.

Patients and methods

71 consecutive patients (64 girls), 75 hips (33 right-sided, 4 bilateral) from southern Sweden—some of immigrant origin—with late-diagnosed DDH during the period 1977–1991 were uniformly treated and prospectively studied, with special reference to the development of the femoral head and acetabulum. Teratological and neuromuscular cases were excluded.

DDH was defined as a radiographically definite dislocation or subluxation which clinically before and/or after traction was dislocated or dislocatable. All doubtful cases were excluded.

The mean age at the start of treatment was 10 (2–64) months. About half of the patients were younger than 7 months. For statistical calculations, the material was divided into 3 groups with regard to age at the start of treatment (36 children, 37 hips less than 6 months of age; 17 children, 17 hips 6–11 months and 15 children, 17 hips 12–22 months). The remaining 3 patients (4 hips) (cases 33, 50 and 71) were more heterogenic with regard to age (3–5 years) and treatment and were thus excluded from the comparison. There was no age-difference between the 3 groups at the last re-examination.

The initial treatment, in accordance with Morel (1975), included tenotomy of the long adductor and gracilis followed by skin traction for 3–4 weeks with gadually increasing weight, first longitudinally and then in abduction. The initial loading of traction was low. All but 7 hips were reduced under general anesthesia, and treated in a hip spica for 6 months, followed by a Pavlik harness for 3 months day and night and for another 3 months, during the night only. In 5 children (7 hips), closed reduction was unsuccessful and was therefore directly followed by open reduction. In 5 hips, a Salter innominate osteotomy (Salter 1961) was added to increase the stability and improve the acetabular angle. In 2 of these hips also, a 15–20 mm shortening—varus-derotation osteotomy of the femur was performed.

The children were repeatedly examined clinically and radiographically for 10.9 (5.5–17.5) years to a mean age of 11.7 (6.2–18.2) years. All children had a follow-up for at least 5 years after the primary treatment.

Leg length was measured on the physical examination from the anterior superior iliac spine to the medial malleolus and, after Salter innominate osteotomy, from the umbilicus to the medial malleolus.

For the diagnosis of avascular necrosis I followed the criteria of Salter et al. (1969) and Kalamchi and MacEwen (1980) to diagnose avascular necrosis and anteroposterior radiographs of the pelvis and both hips with legs parallel and in neutral position (Eklöf et al. 1988) for measurements. Only radiographs with an obturatorium index from 0.56 to 1.8, and—up to 5 years of age—a symphysis-os ischium angle within border-lines (Tönnis 1976) were used. The migration percentage (MP) (Heyman and Herndon 1950, Reimers 1980, Moberg and Hansson 1996) was calculated. MP > 20% was considered abnormal (Moberg and Hansson 1996). I calculated the acetabular angle according to Almby and Lönnerholm (1979), the CE-angle according to Wiberg (1939) and the spherical index according to Fredensborg (1976). An acetabular angle < 20° was considered normal (Harris 1976). Lempicki et al.'s (1990) suggestion that an angle 15–20° should be considered uncertain was taken into consideration. I used Severin's (1941) definition concerning the CE-angle: age 6–13 years > 19° normal, 15–19° uncertain; > 14 years > 25° normal, 20–25° uncertain. A spherical index < 35 was considered abnormal (Fredensborg 1976).

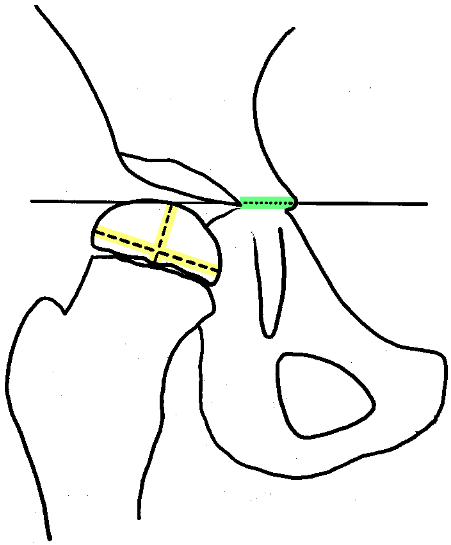


Figure 1. Maximum width and height of the calcified femoral head - - -. Thickness of the medial pelvic wall ....

The size of the femoral head was defined as the broadest epiphyseal distance of the head (maximum width) multiplied by the highest perpendicular epiphyseal head-distance (maximum height) on AP radiographs (Figure 1). The thickness of the medial pelvic wall was defined as that part of Hilgenreiner's line which covered the medial pelvic wall (Figure 1). The precision of the measurements was evaluated by duplicate examinations (random error < 0.5 mm, systematic error < 0.1 mm).

I studied the variables in relation to age at the start of treatment and at different intervals: at the start of treatment or the first time both femoral heads were calcified, 1 year after starting treatment, before additional surgery and at the last re-examination.

I classified the radiographic assessments of the results according to Severin (1941).

The Student's t-test, chi-square test and Wilcoxon's matched pairs were used for statistical analyses. P < 0.05 was considered significant.

Table 1a. Clinical and radiographic data in all 71 patients (75 hips)

A	B	C	D	E	F	G	H1	H2	I1	I2	J1	J2	K1	K2	L1	L2	M1	M2	N1	N2	O1	O2	P1	P2
1	2	1	7	10.7	1	.	42	23	28	26	11	11	4	50	165	165	18/46	18/45	50	51	35	35	2	5
2	2	2	4	11.3	1	.	38	23	15	12	10	10	20	28	117	130	23/45	23/45	51	51	28	28	9	9
3	2	1	7	7.8	1	.	41	27	23	20	10	10	12	35	91	117	15/38	15/38	39	39	24	24	11	11
4	2	2	2	10.6	1	.	33	27	12	12	10	10	60	80	64	81	18/43	18/43	44	44	40	40	3	3
5	2	1	13	12.2	1	1	38	19	35	20	4	5	10	15	18	23	19/48	19/48	44	44	45	35	-10	4
6	2	2	4	12.5	1	.	41	30	20	20	12	12	10	20	150	150	17/48	16/48	44	44	27	30	13	10
7	2	1	4	17.8	1	.	42	25	22	19	9	9	1	28	181	190	20/55	20/54	44	46	29	27	18	19
8	2	1	14	10.3	1	.	35	21	26	15	6	5	30	77	128	176	18/43	18/43	47	47	32	35	7	7
9	2	2	5	13.8	1	.	42	30	20	19	7	5	1	15	136	162	17/51	17/51	49	49	35	35	12	12
10	2	2	4	14.6	2	.	42	20	22	22	19	19	18	32	324	286	18/49	17/46	50	48	25	25	18	18
11	2	1	16	12.4	1	1	47	20	28	18	8	16	8	44	72	126	18/45	18/45	49	49	42	30	-2	12
12	2	1	3	16.3	1	6	42	30	19	17	13	12	12	35	91	117	-/50	19/50	44	48	30	30	14	12
13	2	1	6	11.0	1	.	40	20	22	20	10	10	16	40	160	187	19/47	19/47	40	40	27	29	5	5
14	2	1	3	11.0	1	.	40	30	20	22	12	12	10	18	112	120	19/47	19/47	45	45	30	30	6	6
15	2	1	4	12.3	1	.	45	28	28	28	11	10	5	4	64	160	17/46	19/48	48	50	35	35	11	11
16	2	1	11	16.0	1	1	35	18	20	18	9	8	6	50	128	170	18/45	18/45	53	56	29	26	13	13
17	2	1	7	14.9	1	1	30	18	10	10	5	6	35	176	154	165	18/48	19/48	44	46	38	36	4	9
18	2	2	4	10.1	1	.	32	22	14	12	13	13	1	6	105	185	20/44	20/44	45	45	30	30	9	7
19	2	2	4	14.6	1	.	45	40	25	25	8	8	6	7	154	154	24/61	24/61	48	48	40	40	6	6
20	2	2	7	13.7	1	.	40	21	20	18	13	13	20	60	70	108	18/48	18/48	48	48	27	27	18	18
21	2	1	4	13.2	1	.	40	30	17	17	10	10	21	42	48	54	20/50	20/50	48	48	31	31	12	12
22	2	2	6	7.9	1	3	38	23	24	19	10	12	40	104	60	108	16/34	16/32	41	41	32	25	0	6
23	2	1	6	12.0	1	.	40	23	20	16	5	5	32	28	140	130	18/47	18/47	45	45	40	40	2	2
24	1	1	7	10.1	1	.	34	18	19	18	5	5	30	54	220	209	20/45	20/45	44	44	35	35	7	7
25	2	2	3	10.9	1	.	34	22	16	15	10	10	8	15	55	66	19/46	20/45	44	43	26	26	16	16
26	2	2	15	11.2	1	.	37	25	18	14	9	10	18	66	96	126	14/38	15/37	42	43	30	33	8	3
27	2	1	17	14.3	1	6	35	18	16	13	10	10	63	104	96	231	13/52	19/47	40	42	29	29	17	15
28	2	2	9	8.5	1	.	36	27	20	18	9	9	35	84	135	144	15/38	15/38	39	39	28	32	8	5
29	1	2	5	14.1	1	6	40	20	28	21	12	11	10	84	36	84	14/52	18/52	42	46	27	25	17	15
30	2	2	3	9.3	1	.	46	32	19	20	14	14	15	28	112	150	15/37	15/37	43	43	30	30	11	11
31	2	2	2	11.7	1	.	40	22	19	19	10	10	6	8	7	9	20/44	20/44	48	48	40	40	5	5
32	2	1	16	12.2	1	.	32	18	12	12	12	11	54	140	210	273	21/45	23/47	44	45	28	28	11	11
33	2	2	36	17.5	1	2	45	24	35	22	18	11	13	17	210	230	14/50	12/53*	40	42	30	28	17	16
34	2	2	7	11.5	1	.	43	27	20	20	11	12	21	55	72	170	17/47	17/47	45	45	27	27	9	13
35	2	1	22	15.7	3	.	40	.	20	.	10	.	40	.	180	.	19/54	.	45	.	33	.	10	.
35	2	2	22	15.7	3	.	29	.	20	.	9	.	63	.	200	.	19/53	.	45	.	39	.	-9	.
36	2	2	5	8.9	1	1	36	25	25	25	11	13	1	18	77	104	15/37	15/37	41	41	30	24	11	17
37	2	1	4	9.9	1	.	40	20	16	14	10	10	15	24	77	96	18/42	18/42	43	43	30	30	5	5
38	2	2	19	11.2	1	.	47	32	25	13	11	10	50	136	17	20	17/42	18/42	48	48	27	29	-2	2
39	2	2	7	10.5	1	.	41	25	28	23	13	13	35	70	117	150	15/38	15/38	40	40	30	30	14	14
40	2	2	2	6.2	2	.	38	29	22	20	9	9	1	12	104	108	13/35	13/32	37	41	35	35	6	7
41	2	1	6	10.1	1	.	41	23	19	19	8	9	35	54	216	234	20/45	20/45	44	44	27	27	14	14
42	2	1	3	9.6	1	6	42	28	22	20	10	10	24	96	44	126	15/40	17/40	38	40	25	31	14	6
43	2	2	3	6.8	1	.	37	20	20	20	15	15	8	15	96	104	14/32	14/32	44	44	26	26	14	14
44	2	2	3	11.9	1	.	32	20	12	13	10	10	12	8	96	96	20/48	20/48	48	48	35	35	9	9
45	2	1	4	13.2	1	.	40	26	23	15	10	10	15	28	96	140	17/42	17/42	48	48	33	31	7	7
46	1	1	13	16.2	1	1	42	20	20	10	11	9	108	150	204	234	22/57	22/56	43	43	36	27	1	15
47	2	2	7	12.2	1	.	40	25	27	22	9	8	11	12	136	153	16/52	18/48	48	52	42	45	15	10
48	2	1	5	8.6	1	.	43	.	23	.	13	.	24	.	112	.	16/40	.	40	.	37	.	6	.
48	2	2	5	8.6	1	.	34	.	20	.	13	.	24	.	126	.	16/40	.	40	.	37	.	6	.
49	2	1	4	10.0	1	.	35	30	20	17	10	10	6	9	66	96	16/35	16/35	49	49	28	30	12	12
50	2	2	37	18.1	3	.	28	18	20	20	14	15	15	18	392	350	15/57	17/47	42	53	33	26	9	17
51	1	2	3	9.7	1	.	47	29	22	21	16	16	4	20	54	45	15/39	15/39	38	38	25	25	17	17
52	1	1	10	11.9	1	.	35	26	22	19	10	9	24	66	198	187	21/52	21/52	46	46	27	28	17	15
53	2	2	13	12.9	1	.	30	24	25	25	14	14	8	10	19	18	19/49	19/49	47	47	27	27	13	13
54	2	1	4	12.0	1	.	42	28	17	17	9	10	2	4	13	14	18/56	18/56	43	44	30	30	14	12
55	2	1	15	8.2	1	1	33	15	23	14	5	5	42	99	170	234	19/38	20/37	50	54	27	27	11	8
56	2	1	12	10.2	1	4	37	.	31	.	19	.	40	.	55	.	13/47	.	42	.	20	.	22	.
56	2	2	12	10.2	1	.	31	.	21	.	11	.	24	.	50	.	13/41	.	36	.	26	.	5	.
57	2	1	3	12.8	1	.	42	25	21	20	10	10	6	11	11	12	17/46	17/46	43	39	37	37	5	5
58	2	2	5	12.0	1	.	45	21	16	15	5	7	1	5	204	198	25/46	26/46	48	48	34	32	7	7
59	2	1	4	8.3	1	.	48	25	17	12	12	12	2	6	77	96	15/34	15/34	44	44	25	25	10	10
60	2	2	11	6.4	1	.	33	23	18	16	11	11	63	130	170	198	15/33	15/33	42	42	23	22	18	20
61	2	2	4	7.3	1	.	46	28	20	22	16	15	9	27	45	55	22/45	22/45	49	49	25	25	16	16
62	2	1	4	9.5	1	.	33	20	23	20	13	12	15	40	99	117	19/43	19/43	42	43	27	29	14	10
63	1	2	3	10.9	1	.	32	24	24	20	10	10	1	6	24	54	17/45	17/45	40	40	27	27	7	7
64	2	2	12	12.8	1	.	40	20	22	18	12	12	4	10	72	141	19/50	20/48	45	45	35	37	13	11
65	1	1	4	12.0	1	.	31	20	19	17	4	5	2	4	20	24	22/50	22/50	44	44	42	41	0	4
66	2	1	4	15.2	1	.	35	23	20	20	9	7	2	3	60	77	17/47	17/47	40	40	31	31	9	9
67	2	2	15	18.2	1	5	40	19	28	20	12	11	3	10	12	17	16/51	16/51	47	44	27	30	17	14
68	2	2	8	9.5	1	.	39	21	16	15	11	11	12	88	84	96	15/37	15/37	46	46	33	31	6	3
69	2	1	3	13.3	1	.	40	30	18	18	11	11	12	18	108	130	20/45	20/45	44	44	29	29	14	14
70	2	1	20	7.4	1	1	47	18	30	13	11	12	35	114	78	153	10/25	10/26	40	38	35	27	8	8
71	2	1	64	11.0	4	.	34	.	8	.	4	.	160	.	390	.	17/46	.	39	.	50	.	-2	.
71	2	2	64	11.0	4	.	26	.	9	.	3	.	187	.	429	.	17/50	.	35	.	50	.	-13	.

Table 1 b. Total material before additional Salter pelvic osteotomy and at the last re-examination

A	D	R	E	G	Acetabular angle				CE-angle				Migration percentage			
					Before		J1	J2	Before		O1	O2	Before		P1	P2
					a	b	a	b	a	b	a	b	a	b	a	b
5	13	4.5	12.2	1	28	12	4	5	14	32	45	35	28	8	–10	4
11	16	5.1	12.4	1	30	20	8	16	15	24	42	30	29	15	–2	12
16	11	13.0	16.0	1	20	9	9	8	10	30	29	26	34	13	13	13
17	7	11.5	14.9	1	14	11	5	6	18	37	38	36	26	7	4	9
22	6	1.8	7.9	3	24	19	10	12	–10	23	32	25	70	9	0	6
33	36	5.9	17.5	2	33	20	18	11	0	15	30	28	41	29	17	16
36	5	5.8	8.9	1	17	16	11	13	15	20	30	24	30	19	11	17
46	13	8.9	16.2	1	27	14	11	9	20	26	36	27	24	13	1	15
55	15	3.8	8.2	1	24	14	5	5	18	25	27	27	29	9	11	8
56	12	6.0	10.2	4	22	11	19	11	2	20	20	26	40	10	22	5
70	20	2.7	7.4	1	30	13	11	12	15	35	35	27	23	–13	8	8

Legends for Table 1 a and b

A Case no. Bilateral cases: right/left
B Sex
  1 male
  2 female
C Side
  1 right
  2 left
D Age, months at the start of treatment
E Age, years at the final re-examination
F Primary treatment
  1 tenotomy + traction + closed reduction + hip spica
  2 tenotomy + traction + open reduction + hip spica
  3 tenotomy + traction + open reduction + Salter osteotomy + hip spica
  4 tenotomy + traction + open reduction + Salter osteotomy + shortening-varus-derotation osteotomy + hip spica)
G Complications and additional surgery
  1 Salter osteotomy
  2 Salter osteotomy + subtrochanteric varus-derotation osteotomy
  3 open reduction + Salter osteotomy
  4 repeated open reduction + subtrochanteric varus-derotation osteotomy + Salter osteotomy
  5 intertrochanteric varus osteotomy
  6 avascular necrosis
H 1 Acetabular angle (°) on dislocated side (if bilateral, right side first) at the start of treatment
H 2 Acetabular angle (°) on contralateral side at the start of treatment
I 1 Acetabular angle (°) on dislocated side (if bilateral, right side first) 1 year after the start of treatment
I 2 Acetabular angle (°) on contralateral side 1 year after the start of treatment
J 1 Acetabular angle (°) on dislocated side (if bilateral, right side first) at the last re-examination
J 2 Acetabular angle (°) on contralateral side at the same time as above
K 1 Size of calcified femoral head (mm) on dislocated side (if bilateral, right side first) at the start of treatment or when the heads were first visible
K 2 Size of calcified femoral head (mm) on contralateral side at the same time as above
L 1 Size of calcified femoral head (mm) on dislocated side (if bilateral, right side first) 1 year after the start of treatment
L 2 Size of calcified femoral head (mm) on contralateral side 1 year after the start of treatment
M 1 Height/width of calcified femoral head (mm) on dislocated side (if bilateral, right side first) at the last re-examination
M 2 Height/width of calcified femoral head (mm) on contralateral side at the same time as above
N 1 Spherical index on dislocated side (if bilateral, right side first) at the last re-examination
N 2 Spherical index on contralateral side at the same time as above
O 1 CE-angle (°) on dislocated side (if bilateral, right side first) at the last re-examination
O 2 CE-angle (°) on contralateral side at the same time as above
P 1 Migration percentage on dislocated side (if bilateral, right side first) at the last re-examination
P 2 Migration percentage on contralateral side at the same time as above
R Age (years) at the Salter osteotomy
* Avascular necrosis on the contralateral side before treatment
a Dislocated side
b Contralateral side

Figure 2. Case 56, girl aged 10 years with bilateral DDH, operated on with closed reduction at 1 year of age. See Results of history. Re-examination: no symptoms, normal hip motion, right leg +1 cm. Acetabular angle: right 19°, left 11°. Migration percentage: right 22, left 5. Femoral head quotient: 1.15.

Figure 3. Case 22, girl aged 7.9 years with a left-sided DDH, operated on with closed reduction at 6 months of age. The hip gradually subluxed and at age 1 year 10 months, open reduction and a Salter osteotomy were performed. Re-examination: no symptoms, normal physical examination. Acetabular angle: right 12°, left 10°. Migration percentage: right 6, left 0. Femoral head quotient: dislocated/normal side 1.06.

Results

Complications and additional surgery

A child with severe joint laxity (case 56) (Figure 2) had bilateral DDH, was operated on with closed reduction at age 1 year. 1 month later, the right hip was still dislocated and an open reduction (medial approach) was done. After another month, the hip was again dislocated and closed reduction and a hip spica were tried. At age 1 year 10 months, the right hip was still subluxated and very unstable. Therefore an open reduction (anterior approach) was done, followed by a varus-derotation osteotomy 1 month later. Due to increasing femoral neck length and subluxation, a Salter osteotomy was performed at age 6 years.

Another hip (case 22) (Figure 3) subjected to closed reduction at age 7 months, gradually subluxed and at age 1 year 10 months was treated with open reduction (anterior approach) and a Salter osteotomy. At surgery, I found that a strangulating iliopsoas tendon and an elongated ligamentum teres had prevented a proper reduction. Re-evaluation of the radiograms after closed reduction showed that the hip had not been immobilized in a fully reduced position.

Avascular necrosis occurred in 4 hips, 1 in age group 1 and 3 in group 2 (Figure 4).

Additional surgery was performed in 12 more hips due to an increasing acetabular angle and in 1 hip also due to hip pain. A Salter osteotomy was performed at age 6.8 (3.8–13) years in 11 hips (Table 1b) and a varus-derotation osteotomy at age 13 years in a child with pain (case 67).

Clinical evaluation

All but 2 patients had no symptoms; both (cases 33 and 67) sometimes had pain in the hip region and they later avoided some physical activities.

All but 2 had normal range of hip motion. Case 71 (Figure 5) had bilateral hip flexion 0–120°, abduction 45°, and total rotation 45°; case 67 had a decreased abduction of 15° and rotation of 15°.

I found leg shortening of 0.5 cm in 5 children

Figure 4. Case 12, girl aged 16 years with a right-sided DDH, operated on with closed reduction at 3 months of age. Avascular necrosis type II. Re-examination: no symptoms, right leg –1.5 cm, normal range of hip motion. Right femoral neck short. Acetabular angle: right 13°, left 12°. Migration percentage: right 14, left 12.

Table 2. Acetabular angle (°) dislocated and normal side classified according to age at the start of treatment and to different time intervals after the start of treatment (primary Salter osteotomies excluded). n = number of hips, (SD)

Age at the start of treatment	Acetabular angle: at the start of treatment				after 1 year		at the last re-examination	
	n	Dislocated	n	Normal	Dislocated	Normal	Dislocated	Normal
Group 1: < 6 months	37	39 (4.8)	35	26 (4.6)	20 (3.8)	19 (3.9)	11 (2.9)	11 (2.9)
P-value		–		0.03	–	–	–	–
Group 2: 6–11 months	17	38 (3.6)	17	23 (3.1)	21 (4.5)	19 (3.5)	9 (2.5)	10 (2.5)
P-value		–		–	–	–	–	–
Group 3: 12–22 months	15	38 (5.8)	15	20 (4.3)	24 (6.0)	16 (4.2)	10 (3.7)	10 (3.4)
P-value (Group 1 vs 3)		–		< 0.001	0.01	–	–	–

(cases 29, 33, 42, 47 and 67), of 1 cm in 1 child (case 50) and of 1.5 cm in 1 child (case 12) (Figure 4). 1 child (case 56) had an increased leg length of 1 cm and 1 (case 44) of 2 cm on the dislocated side. The latter also had an increased foot length of 1.5 cm—the discrepancy was not assumed to be secondary to DDH.

Radiographic evaluation

Acetabular angle (Table 2). At the start of treatment, the acetabular angle was greater on the dislocated side than on the normal one in all the patients. On the previously dislocated side, it did not differ between the various age groups at the start of treatment, but on the normal side, it did ($p < 0.001$).

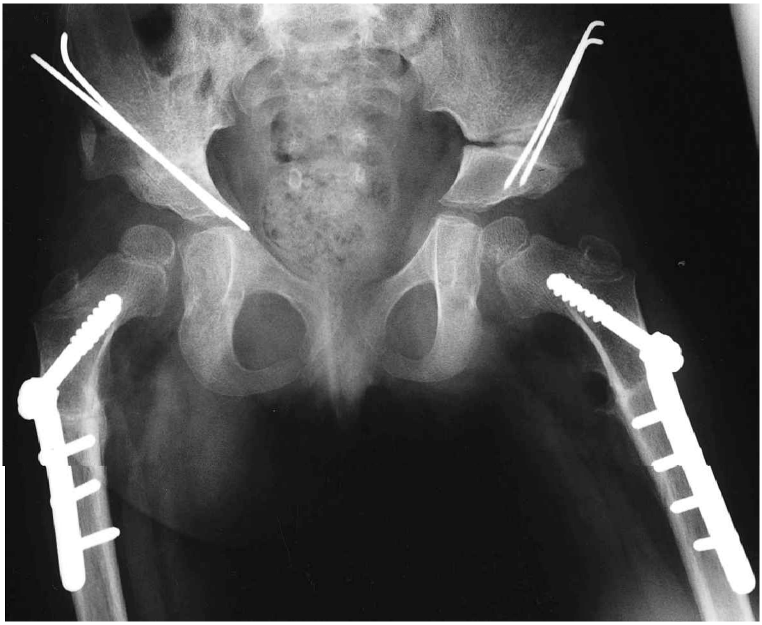
During the first year after the start of treatment, the acetabular angle improved considerably in all age groups, more on the dislocated than on the normal side. The acetabular angle in dislocated hips also improved more in the 2 youngest groups than in the oldest one. 1 year after treatment, there was no significant difference between the previously dislocated and the normal side in groups 1 and 2, but still a difference ($p = 0.004$) in group 3.

Later on, although further improvements in the angle occurred, no difference was noted between the age groups, and the acetabular index on the previously dislocated side followed that of the normal side (in group 3, however, the changes were unpredictable). Before additional surgery, the acetabular index of the previously dislocated side was therefore greater in group 3 than in group 1 ($p = 0.03$). At the last re-examination after additional surgery, the acetabular angle improved to the same values in age group 3 as in groups 1 and 2, and did not differ from normal.

The ratio between the acetabular angle on the dislocated and normal sides in unilateral cases differed between groups 1 and 3 at the start of treatment. 1 year later, as well as before additional surgery, the ratios in groups 1 and 2 were still lower than in group 3. After additional surgery, the ratios in all groups were 1.00.

Figure 5. Case 71, girl aged 11 years with a bilateral DDH, operated on at age 5 years 4 months with open reduction, Salter osteotomy and shortening varus—derotation osteotomy on the right side and 2 weeks later on the left side.

Preoperative radiographs



Radiographs 6 weeks after the last operation.

At age 9 years of age: no symptoms. Acetabular angle: right 4°, left 3°. Migration percentage: right –2, left –13.

Table 3. Size of the femoral head. Ratio dislocated/normal side (SD) in unilateral cases classified according to at the start of treatment and to different age-intervals after the start of treatment (primary Salter osteotomies excluded). n = number of ratios

Age at the start of treatment	n	Ratio at the start of treatment[a]	Ratio after 1 year	Ratio at the last re-examination	P-value for trend
Group 1: < 6 months	35	0.51 (0.33)	0.82 (0.19)	0.99 (0.07)	< 0.001
Group 2: 6–11 months	17	0.43 (0.27)	0.86 (0.16)	1.00 (0.02)	< 0.001
Group 3: 12–22 months	13	0.63 (0.52)	0.76 (0.21)	0.96 (0.07)	< 0.001
P-value (Group 1 vs 3)		–	–	–	

[a] At the start of treatment or when both femoral heads first became calcified

According to Harris (1976), the acetabular angle was normal in all hips at the last re-examination. However, 6 previously dislocated hips and 5 contralateral ones had an acetabular angle of 15–19° and, according to Lempicki et al. (1990), should be considered uncertain. Of these, at least case 33 and case 56 and probably also case 10 must be considered abnormal.

CE-angle. Before additional surgery, the CE-angle in dislocated hips was higher in group 1 than in group 3 ($p = 0.03$). At the last re-examination after additional surgery, the CE-angle in dislocated hips had increased ($p = 0.005$) in group 3 and there was no difference between the 3 age groups. In the whole material, the CE-angle at the last re-examination was 32 (20–50)° in the previously dislocated hips and 30 (22–45)° in normal hips. The CE-angle at the last re-examination was normal in all cases but 1 (case 10), where both hips (previously dislocated as well as normal) had a CE-angle of 25°. Even when normal according to the definition, case 56 with a CE-angle of 20° on the right side and case 60 with a CE-angle of 23° on the previously dislocated side and 22° on the contra-lateral side must be classified as uncertain.

Spherical index. The spherical index did not vary between age groups. On the last re-examination, it was 45 (37–53) in the previously dislocated hips and 45 (38–56) in the normal hips. The spherical index was normal in all hips at the last re-examination.

If the spherical index was calculated using the height of the physis (Figure 1) and < 35 was considered abnormal, 10 of the previously dislocated hips had an abnormal spherical index. 4 of these had the same or nearly the same value on the normal side and could probably be considered normal. 3 of them, however, had been diagnosed as avascular necrosis and 3 were operated on.

Migration percentage (MP). Before additional surgery, MP in dislocated hips was lower in group 1 than in group 3 ($p = 0.005$). At the last re-examination, MP had decreased ($p = 0.02$) in group 3. In the whole material, MP at the last re-examination was 9 (-10–27)% in previously dislocated hips and 10 (-9–20)% in normal hips. MP according to definition was abnormal in 1 previously dislocated hip (22% in case 56) and in 1 contra-lateral hip (20% in case 60).

Femoral head (Table 3). There was no difference between the 3 age groups concerning the initial femoral head size ratio (dislocated/normal side) in unilateral cases. The ratio increased with age, especially during the first year after the start of treatment. The improvement was faster during the first year after the start of treatment in the 2 youngest groups than in the oldest group, but it continued in all groups. Thus, the ratio came close to 1 in all groups at the last re-examination before, as well as after, additional surgery.

At the last re-examination, the difference between maximum width and/or maximum height on the right and left hips (Fredensborg 1976) differed by 1 mm in 16 cases, 2 mm in 3 cases and more than 2 mm in 7 cases (2 bilateral).

Medial pelvic wall. Altogether 33 unilateral cases had an increased thickness of the medial pelvic wall as compared to the normal side. The mean difference was 0.9 mm—in no case was the opposite observed. The difference in the operated group was 1.8 ± 1.4 mm and higher ($p = 0.002$) than in the unoperated group (0.6 ± 1.0 mm).

Radiographic classification. Using Severin's method (1941), 65 hips were rated group I, 9

Table 4. Results before and after additional Salter osteotomy

	Number of hips	Acetabular angle (°)		Size of the femoral head (mm^2)		Spherical index		CE-angle (°)		Migration percentage	
		A	B	A	B	A	B	A	B	A	B
Operated side	11	24	14	407	730	42	44	11	33	34	7
Contralateral side	11	11	10	428	722	43	45	26	28	11	10

A Before surgery, B At re-examination

group II, 1 group III and none group IV or V.

Additional surgery

The improvement in values after additional surgery was most obvious in group 3 where 7/13 hips were operated on as compared to 3/17 in group 2 and 1/37 in group 1.

An additional Salter osteotomy greatly improved ($p < 0.001$) the acetabular angle, the CE-angle and the migration percentage (Tables 1b and 4). The result was the same in hips initially operated on with Salter osteotomy. The mean values at re-examination thus were 8°, 41° and –1°, respectively. The lesser trochanter was partly atrophic in all cases operated on with a Salter osteotomy and tenotomy of the iliopsoas.

Discussion

Migration percentage is much more reliable than the CE-angle in small children and in deformed hips and should be used. However, a large normal material representative of all age groups is not available. In this study, I considered a migration percentage of > 20 abnormal (Moberg and Hansson 1996).

The spherical index (Fredensborg 1976) is not always reliable because of difficulties in measuring the height. Using the physis or the rest of it as a reference provides a more reliable "height". However, in older patients and, sometimes after avascular necrosis, the rest of the physis has disappeared and this method cannot be used.

Redislocation after closed reduction occurred in 2 cases. In at least 1 case, the hip had not been immobilized in a fully reduced position. In the other case, redislocation could have been caused by extreme joint laxity. The hip thus also redislocated after open reduction (medial approach) (Ferguson 1973). In both cases, however, the orthopedic surgeon was inexperienced. The anterior approach (Scaglietti and Calandriello 1962), used in all other cases, gives excellent visualization of the hip without complications.

Salter's innominate pelvic osteotomy was useful for stabilizing openly reduced hips. In cases with an increased acetabular angle, abnormal CE-angle and abnormal migration percentage, the Salter osteotomy gave excellent results. In 1 hip (case 56), a varus-derotation osteotomy stimulated growth of the femoral neck and increasing subluxation developed. A Salter osteotomy later improved the situation. Open reduction, without shortening osteotomy, was performed in 1 case at age 3 years 2 months which was probably too late.

The overall results of this study were better than those reported by Bjerkreim (1988), where 49 hips were rated Severin group I, 11 group II, 11 group III and 6 group IV. Bjerkreim's patients, however, were older (mean age 19 months) at diagnosis and additional surgery was performed in several cases (46 femoral and 13 pelvic osteotomies in 79 hips). This can be partly ascribed to the higher age at the start of treatment. Bjerkreim's indications for femoral osteotomies (65 operations, of these 19 on the contralateral side) were also wider than in the present study.

However, I wish to emphasize that the results are only medium-term and not final. Therefore both clinical and radiographic deterioration can be expected in the long run.

The results of Salter osteotomy were far better than Hansson et al. (1990) reported from all of Sweden 1963–1977, with 16 excellent, 18 good, 19 fair and 13 failures. The explanation is probably that 26 surgeons were involved. In my study, I performed all operations except 1 (which postoperatively dislocated).

A further improvement of the end-results is thus possible if all surgery for DDH is centralized and all late-diagnosed cases are followed up to skeletal maturity. The golden rule is that the first surgical procedure must be successful and that repeated surgery may lead to disaster (Hansson et al. 1990).

Most children with late-diagnosed DDH born in Sweden will be treated successfully by traction, tenotomies and closed reduction. The need for tenotomy has been questioned. Thus Bjerkreim (1988) did not have a single case of avascular necrosis in a similar material treated in a similar way, but without tenotomies. In a few cases, open reduction with or without a Salter osteotomy is necessary and sometimes a Salter osteotomy with closed reduction must be added later to improve the acetabular angle, the CE-angle and the MP.

In a review of the literature, the incidence of avascular necrosis varied from 0 to 73% (Salter et al. 1969) and from 0 to 98% (Lempicki et al. 1990). In my series, the incidence was 5%. Differences in definition as well as variations in treatment and age at the start of treatment are the obvious reasons for differences in incidence figures. Unfortunately, the percentage of avascular necrosis in late-diagnosed DDH cases in large series of cases will probably never reach 0, even if all known prophylactic measures are used.

According to Salter et al. (1969), increased size of the head (coxa magna) in DDH is a sign of avascular necrosis. In my material, I commonly found an increased size in hips operated on with open reduction, with or without osteotomy. Repeated operations gave the highest values. Operated cases also had an increased thickness of the medial pelvic wall with increased length of the neck and size of the head. Danielsson and Pettersson (1980) have shown that in operated cases of supracondylar fractures of the elbow, not only the distal end of the humerus, but also the proximal end of the radius and the ulna at re-examination were larger than in the normal elbow. In operated DDH cases, increased size of the head, without reduced height, is therefore probably due to growth stimulation secondary to the operation and not to avascular necrosis.

Opinions differ about the upper age-limit for normalization of the acetabular angle after reduction of late-diagnosed DDH. Schwartz (1965) found that 20 months was probably the upper limit for definitely successful treatment of DDH with closed reduction only. He also stated that the maximal development of the acetabulum (as judged by the acetabular angle) was reached within 2 years after reduction, regardless of the patient's age at the time of reduction. Almby et al. (1979) found that, after reduction, the acetabular angle on the dislocated side improved faster than on the normal side before the age of 14–16 months. After that age, the improvements on both the retarded and the normal side were slower. Visser (1984) claimed that the progressive improvements in the acetabular angle ceased at about age 3, Harris (1976) about age 4, Lindstrom et al. (1979) about age 5, whereas Lempicki et al. (1990) considered 10 years to be the upper age limit for further remodeling of the acetabulum.

In my study, it was obvious that the younger the child was at reduction, the faster and better the acetabular angle improved. The angle on the previously dislocated side also improved faster after reduction than on the normal side, at least during the first year. In the group reduced before 6 months, the angle was nearly normal 1 year after reduction and had totally normalized at the last re-examination. When treatment started between 12 and 18 months, the angle was not normalized either 1 year after reduction or at the last re-examination. In this and older age groups, the angle was still improving 1 year after reduction, but in the individual case the end-result was unpredictable and the angle could deteriorate as well as improve with age. My study thus gives strong support to Schwartz' (1965) and Almby et al.'s (1979) conclusions about the growth potential of the acetabulum.

Unlike the acetabulum, the femoral head continued to grow independently of the age at reduction and it normalized spontaneously with age.

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