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Late-Presenting Developmental Dysplasia of the Hip Treated with the Modified Hoffmann-Daimler Functional Method

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Background: The general consensus is that nonoperative treatment of developmental dysplasia of the hip should not be attempted for patients in whom previous treatment of the disease has failed, those in whom the disease was neglected, or those in whom the disease presented late. In such cases, it is believed that the optimum period for hip remodeling has passed and that operative methods are preferable. The purpose of the present study was to report the efficacy of a modified form of the Hoffmann-Daimler method for the treatment of late-presenting developmental dysplasia of the hip.

Materials: We retrospectively reviewed the records of sixty-nine patients (ninety-five hips) with neglected developmental dysplasia of the hip who had been managed nonoperatively with a modification of the Hoffmann-Daimler method from 1971 to 2000. With this method, the patient wears a flexion harness (Phase A), during which time the femoral head is gradually reduced, followed by an abduction splint (Phase B), during which time the reduced hip remodels. We have modified the original method by introducing new treatment strategies. The study group included nine boys and sixty girls. The average age of the patients was sixteen months (range, six to forty-four months) at the start of treatment and 11.5 years (range, six to twenty-nine years) at the time of the latest follow-up. Radiographs were assessed to determine the acetabular index, the Severin classification, and the presence of evidence of osteonecrosis of the proximal femoral epiphysis. Hips that were rated as Severin class I or class II were classified as satisfactory, whereas those that were rated as Severin class III or class IV were classified as unsatisfactory.

Results: On the basis of the most recent follow-up radiographs, eighty-eight (93%) of the dislocated hips were classified as satisfactory (sixty-seven were rated as Severin class I and twenty-one were rated as Severin class II) and seven were classified as unsatisfactory (six were rated as Severin class III and one was rated as Severin class IV). No hip was rated as Severin class V or VI. The average acetabular index was $40^\circ \pm 7.4^\circ$ prior to the onset of treatment and $24^\circ \pm 5.7^\circ$ at the end of treatment. No redislocations or other complications were noted. Osteonecrosis was noted in six of the ninety-five hips.

Conclusions: Late-presenting or neglected developmental dysplasia of the hip can be successfully treated with use of a modified Hoffmann-Daimler method. The high rate of successful reduction, the low prevalence of osteonecrosis and residual dysplasia, and the limited complications may make this modified method a safe alternative to surgical treatment.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

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Although the rate of occurrence of developmental dysplasia of the hip has been substantially reduced as a result of better clinical assessment, especially with the availability of sonographic hip screening^{1,2}, there are still some cases that present in older patients as a result of late or missed diagnoses^{3,4}. The functional methods that have been applied to treat developmental dysplasia of the hip, such as the use of a Pavlik harness, have been successful, with a relatively low complication rate⁵. However, the general consensus is that they are not used after the age of six months. The rate of successful treatment of developmental dysplasia of the hip with use of the Pavlik harness after the age of six months decreases⁶, mainly because the size and strength of the child do not allow the lower extremities to be held efficiently in the preferred positions⁶⁻⁸. At this older age, it is believed that the optimum period of cartilage remodeling has passed, and closed reduction and/or surgical procedures are recommended^{9,10}.

In the present study, we reviewed the outcomes for children with late-presenting developmental dysplasia of the hip who had been managed nonoperatively with a modified Hoffmann-Daimler functional method. The purposes of the study were (1) to describe our modifications of this method, (2) to determine whether this modified method successfully reduces the hip and maintains the reduction, (3) to evaluate the prevalence of osteonecrosis of the femoral head, and (4) to identify any residual subluxation or dysplasia of the hip.

Materials and Methods

The medical records of 144 patients with the diagnosis of developmental dysplasia of the hip who had been managed with the modified Hoffmann-Daimler method between January 1971 and December 2000 were reviewed. Fifty-nine patients were excluded because their radiographs or medical records were inadequate or could not be located. We have not applied this method to children who were previously operated on, those who were managed with open reduction, or those in whom the dislocation of the hip was secondary to neuromuscular disease, arthrogyrosis, septic arthritis, or a teratological condition or was associated with a congenital anomaly or syndrome. Patients who had been previously managed unsuccessfully with a Pavlik or Freijka harness were included in this analysis. Eighty-one (85%) of ninety-five hips treated with the Hoffmann-Daimler method had had no previous treatment and were diagnosed for the first time at this late stage. Seven patients for whom other treatment had been selected were excluded. Nine children (thirteen dislocated hips) who had less than six years of follow-up and all children who were younger than six years of age at the time of the most recent follow-up were also excluded.

A total of sixty-nine patients with ninety-five dislocated hips were available for the study (Table I). The study group included nine boys and sixty girls. The average age of the patients was sixteen months (range, six to forty-four months) at the start of treatment and 11.5 years (range, six to twenty-nine

TABLE I Statistical Analysis of Measured Variables with Respect to Severin Classification at the Time of Follow-up

Variable	Severin Class I or II (Satisfactory)	Severin Class III or IV (Unsatisfactory)	P Value*
Gender (female/male) (<i>no. of hips</i>)	79/9	6/1	NS
Age at onset of treatment† (<i>mo</i>)	16 ± 9.3	21 ± 10.4	NS
Age-group at start of reduction (<i>no. of hips</i>)			<0.001
<12 months (n = 39)	39 (100%)	0 (0%)	
≥12 months (n = 56)	49 (87.5%)	7 (12.5%)	
Duration of Phase A† (<i>d</i>)	47 ± 28	41 ± 22	NS
Duration of Phase B† (<i>mo</i>)	13 ± 4.9	13 ± 5.4	NS
Severity of dislocation (<i>no. of hips</i>)			<0.001
Tönnis grade II (n = 45)	45 (100%)	0 (0%)	
Tönnis grade III (n = 23)	23 (100%)	0 (0%)	
Tönnis grade IV (n = 27)	20 (85%)	7 (15%)	
Acetabular index before treatment†	40 ± 7.3	46 ± 7.5	<0.05
Acetabular index after treatment†	23 ± 5.3	32 ± 3.5	<0.001
Post-treatment improvement in acetabular index†‡	16 ± 7.9	14 ± 5.2	NS
Ossific nucleus before treatment (<i>no. of hips</i>)			NS
Absent (n = 29)	28 (97%)	1 (3%)	
Present (n = 66)	60 (91%)	6 (9%)	
Unilateral or bilateral involvement (<i>no. of hips</i>)			NS
Unilateral (n = 43)	40 (93%)	3 (7%)	
Bilateral (n = 52)	48 (92%)	4 (8%)	

*NS = not significant. †The values are given as the mean and the standard deviation. ‡Calculated as the acetabular index before treatment minus the acetabular index after treatment.

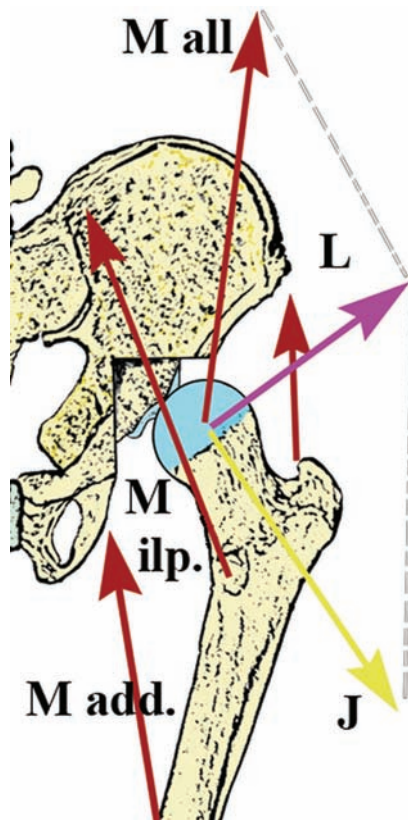


Fig. 1-A

In normal hips, in any position, hip joint reaction force (J) is equal in magnitude and opposite in direction to the force applied to the hip by muscles (M all). The L force, which is the vector sum of the hip joint reaction force (J) and the force applied to the hip by muscles (M all) is normally zero. The force applied to the hip by muscles (M all) is the sum of the vectors of the flexors (M ilp), adductors (M add), abductors, external rotators, and extensors. By placing the hip in adduction, the direction of force L progressively dislocates the femoral head.

years) at the time of the most recent follow-up. Forty-three patients had unilateral involvement (with twenty-five having involvement of the left hip and eighteen having involvement of the right hip), and twenty-six had bilateral involvement. For the patients who had bilateral involvement, each hip was considered separately in the statistical analysis. The duration of treatment in the Hoffmann-Daimler harness and splint was recorded for each phase.

The type and severity of subluxation and dislocation were classified on the basis of anteroposterior pelvic radiographs according to the system presented by Tönnis¹¹. All patients were monitored with serial anteroposterior radiographs of the pelvis and hips from the beginning of treatment with the modified Hoffmann-Daimler method to the end of treatment and then from the end of treatment to skeletal maturity. Mose templates¹² were used to measure the center-edge angle of Wiberg¹³. The lateral end of the sourcil¹⁴ was selected as the marking point indicating the lateral margin of the middle of the superior portion of the acetabulum for accurate measure-

ment of the acetabular index and the center-edge angle in cases in which the osseous landmarks were indistinct. Acetabular remodeling on radiographs was evaluated by observing the change in the acetabular index over time with use of serial measurements. We measured the acetabular index prior to treatment and again one year after the end of treatment, and we calculated the difference between these measurements as a quantitative indication of acetabular improvement.

The final results were evaluated according to the Severin classification system¹⁵. Although controversy^{16,17} has arisen lately about the reliability and reproducibility of the Severin system, in the present study, hip deformity was graded with use of this system at different ages by two independent observers (including one of the authors [T.B.]) who were experienced pediatric orthopaedic surgeons ($k > 0.87$).

Radiographs were evaluated for signs of osteonecrosis as described by Salter et al.¹⁸, and femoral head growth disturbances were classified according to the criteria described by Bucholz and Ogden¹⁹. The presence or absence of the ossific nucleus on the radiograph of the hip prior to the commencement of treatment was also recorded.

Hoffmann-Daimler Method and Modifications

Developmental dysplasia of the hip is a dynamic disorder, and malformations of the anatomic structures result from the gentle but persistent forces that are applied on the dislocated hip²⁰. When the hip is adducted²¹ and the knee is fully extended^{22,23}, the muscles around the hip (primarily the adductors, iliopsoas, and hamstrings) act to dislocate the hip²⁴. With the hip in adduction, the dysplastic acetabulum cannot balance the forces acting on the femoral head (Fig. 1-A). A dislocating force is produced, which drives the femoral head over the posterosuperior rim of the acetabulum, resulting in further ana-

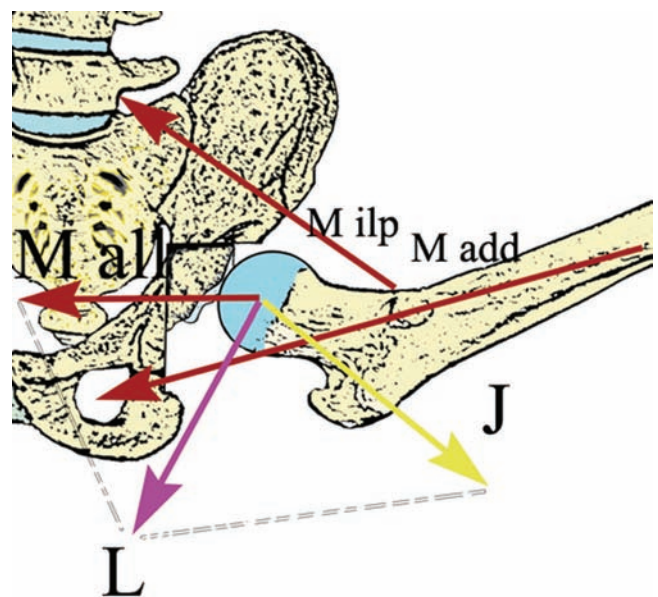


Fig. 1-B

By placing the dysplastic hip in flexion and abduction, the resultant force (L) is reoriented and the femoral head is gradually reduced.



Fig. 2-A

Figs. 2-A, 2-B, and 2-C Clinical photographs of a thirty-two-month-old child who was managed with the Hoffmann-Daimler harness because of bilateral Tönnis grade-IV hip dislocation. **Fig. 2-A** The left hip is still unreduced, as indicated by the internal rotation of the left foot (arrow). In comparison, the right hip is reduced, as indicated by the external rotation of the right foot.

tomic changes to the limbus, capsule, and acetabular rim and leading to a complete dislocation.

The treatment of developmental dysplasia of the hip with use of the Hoffmann-Daimler method involves placing the dislocated hip in flexion. The anatomic changes caused by the dislocation gradually reverse, allowing the femoral head to gradually move into the acetabulum by the redirected action of the adductor and flexor muscles of the hip

(Phase A) (Fig. 1-B). This principle is similar to that used in any functional method of treatment of developmental dysplasia of the hip. By abducting the reduced hip (Phase B), acetabular changes correct as a result of the mechanical forces placed on the acetabulum²⁵⁻²⁸.

As indicated earlier, there are two phases of treatment with the Hoffmann-Daimler method²⁹⁻³² (Figs. 2-A, 2-B, and 2-C). During the reduction phase (Phase A) a harness is used



Fig. 2-B

Fig. 2-B The flexion harness and the abduction splint are worn simultaneously. **Fig. 2-C** The Hoffmann-Daimler abduction splint. This device maintains abduction of the hips and it is suitable for children at the crawling and walking stages.



Fig. 2-C

with the hips fully flexed, whereas during the acetabular remodeling phase (Phase B) a splint is used to abduct the hips.

Phase A (Reduction Phase) for the Original Hoffmann-Daimler Method

In this phase, the Hoffmann-Daimler flexion harness is applied. If femoral head reduction is achieved initially or soon after harness placement, Phase B is begun. More commonly, femoral head reduction is achieved gradually, with the position of the femoral head being assessed on serial radiographs with use of four points: the high-riding dislocation position, the ischial tuberosity, the obturator foramen, and the acetabulum (Fig. 3).

Once the femoral head is at the ischial tuberosity, hip flexion is reduced to 110° in the harness. This subphase, when the femoral head moves over the ischial tuberosity to the obturator foramen, is the most difficult and lengthy part of the reduction phase. Sometimes, a posterior strap is added to the flexion harness to increase hip abduction or bilateral thigh skin traction in abduction is used to facilitate reduction. With the traditional Hoffmann-Daimler method, failure of the femoral head to reduce in three weeks from the time of reaching the ischial tuberosity position is an absolute indication for open reduction of the hip.

If the femoral head remains inferior to the acetabulum (point 3) for more than three weeks, hip flexion is further reduced to 100° and posterior abduction straps are used to facilitate femoral head reduction.

With the original method, the reduction phase (Phase A) should never exceed thirty days. If the femoral head is not reduced by this time, open reduction should be performed³³.

Modifications of Phase A Used in the Present Study

In our series, hip flexion in the harness did not exceed 120° and abduction was never forced with the use of posterior straps. We did not follow the Hoffmann-Daimler method guideline of open reduction or forced reduction by bilateral thigh traction or other means if the femoral head was not reduced within thirty days after the initiation of treatment. Instead, in our patients, open reduction was not done and the harness was used (for as long as 150 days) to allow the femoral head to gradually but spontaneously reduce (Figs. 4-A through 4-E). Furthermore, in cases in which the hip reduced easily in fifteen days or less, a hip spica cast, with the hip flexed 90° and abducted 70°, was used for six weeks before Phase B was begun.

Phase B (Acetabular Remodeling Phase) for the Original Hoffmann-Daimler Method

Once the femoral head is reduced, harness flexion is reduced to 90° while a Hoffmann-Daimler splint in 90° of abduction (Fig. 2-B) is also worn for one month. After one month, the harness is discontinued and the abduction splint is used full time (Fig. 2-C) (see Appendix). Once the child is walking well, the magnitude of abduction in the splint is decreased from about 90° to 45° for each hip. For more severe cases of acetabular dysplasia or for limited femoral head coverage, the decrease of the amount of hip abduction in the

Hoffmann-Daimler splint is delayed for three months.

Radiographic evaluation is done every two months, with measurement of the center-edge angle and the acetabular index. Once these measurements are normal, the splint is discontinued. The duration of Phase B is usually about one year.

Modifications of Phase B Used in the Present Study

The Hoffmann-Daimler abduction splint was worn with the hips being forced not to maximum abduction but rather to the abduction that was possible. The degree of abduction remained the same for as long as was needed for the acetabular obliquity to be restored radiographically. After that, abduction was gradually reduced monthly to the level of 45° for each hip. Toward the end of treatment, hip abduction in the splint was gradually decreased in order to avoid difficulty in walking after the end of treatment.

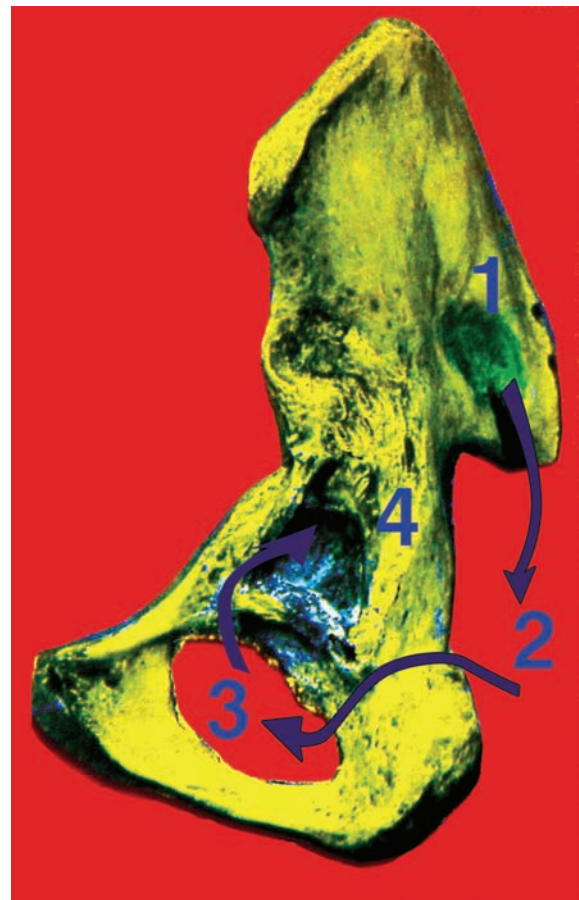


Fig. 3

Phase A is divided in three subphases: subphase 1-2, when the femoral head travels caudally from the dislocated position (point 1) and arrives at the ischial tuberosity (point 2); subphase 2-3, when the femoral head rides over the ischial tuberosity to the obturator foramen (point 3); and subphase 3-4, when the femoral head leaves the obturator foramen and reduces into the acetabulum (point 4) over its inferior rim (acetabular notch).



Fig. 4-A
Anteroposterior radiograph of the pelvis of a twenty-two-month-old girl with bilateral Tönnis grade-IV hip dislocation.



Fig. 4-B
Arthrographic studies of both hips reveal a constricted hip capsule. The hips were irreducible.

Statistical Analysis

The data were analyzed with use of the nonparametric Mann-Whitney test. The level of significance was set at $p < 0.05$. All analyzed variables showed a nonparametric distribution. The chi-square test was used for qualitative data. The Spearman correlation coefficient was used to examine correlations be-

tween multiple factors. Statistical analysis was performed with use of SPSS software (version 10.0; SPSS, Chicago, Illinois).

Results (see Appendix)

Before treatment, radiographic assessment of the severity of dislocation with use of the Tönnis classification system



Fig. 4-C

Phase A. Anteroposterior radiograph of the pelvis, made after 120 days of harness use with bilateral successful reduction of the femoral head.



Fig. 4-D

Phase B. Anteroposterior radiograph, made after twenty-one months, showing that the acetabulum has remodeled completely and the femoral head is spherical and concentric.



Fig. 4-E

Anteroposterior radiograph of the pelvis, demonstrating an excellent radiographic result twenty-seven years later.

demonstrated that forty-five hips (47%) were grade II, twenty-three (24%) were grade III, and twenty-seven (28%) were grade IV. The Hoffmann-Daimler method was not used for grade-I hips.

The mean duration of the reduction phase (Phase A) was forty-seven days (range, fifteen to 150 days), and the mean duration of the remodeling phase (Phase B) was thirteen months (range, three to thirty months). On the basis of the most recent follow-up radiographs that were made after treatment, eighty-eight (93%) of the dislocated hips were rated as satisfactory (sixty-seven were rated as Severin class I and twenty-one were rated as Severin class II) and seven were rated as unsatisfactory (six were rated as Severin class III and one was rated as Severin class IV). No hip was rated as Severin class V or VI. Table I lists the variables that were evaluated. With the numbers available, gender, the side of involvement, bilateral involvement, the presence or absence of the ossific nucleus, and the durations of Phases A and B were not found to have a significant correlation with the final Severin grade. All seven patients who were classified as having a Severin class-III or IV hip at the time of the most recent follow-up had started treatment when they were more than twelve months old, and all of these hips initially had been classified as Tönnis grade IV.

The prevalence of osteonecrosis was 6% (six of ninety-five hips). One hip had type-I osteonecrosis, two had type-II osteonecrosis, and three had type-III osteonecrosis. When type-I changes were excluded, the prevalence of osteonecrosis (types II, III, and IV) was only 5% (five of ninety-five hips). One patient with type-III osteonecrosis and two with type-II

osteonecrosis had been managed elsewhere with a Freijka or a Pavlik harness before starting treatment with the modified Hoffmann-Daimler method. With the numbers available, the side of involvement, bilateral involvement, the presence or absence of the ossific nucleus, the age at the onset of treatment, the durations of Phases A and B, and the degree of displacement of the femoral head (Tönnis grade) were not significantly associated with the appearance of osteonecrosis.

The average acetabular index was $40^{\circ} \pm 7.4^{\circ}$ (range, 25° to 57°) prior to the onset of treatment and $24^{\circ} \pm 5.7^{\circ}$ (range, 11° to 40°) following the end of treatment. The mean improvement in the acetabular index was $16^{\circ} \pm 7.8^{\circ}$ (range, 1° to 42°).

Seven hips redislocated during the first months of treatment with the Hoffmann-Daimler method. In two cases, the flexion harness was removed mistakenly by the parents, in two cases the femoral ring was accidentally removed, and in three cases the reduction had been achieved in less than a week.

The flexion harness was immediately reinstated in all cases in which successful re-reduction was achieved. The next step was to apply a hip spica cast with the hip held in flexion and abduction for six weeks, after which time Phase B was begun.

Nine hips reduced during Phase A after less than fifteen days of treatment. All of these hips were considered to be very unstable and were treated with a hip spica cast for six weeks before Phase B was begun. There were no observed redislocations following this treatment plan.

No other well-documented complications such as infection, osteochondritis dissecans, chondrolysis, trochanteric over-

growth, limb-length discrepancy, subluxation or dislocation of the hip, coxa valga or coxa vara, coxa magna, or deformity of the femoral head were observed following the treatment of developmental dysplasia of the hip in our patients.

Complications that occurred in association with the Hoffmann-Daimler flexion harness and splint included contact dermatitis, especially at the flexor surfaces of hips in very obese children, and diaper rash in the region where the skin was continuously moistened by urine. We also saw ulceration of the skin in the spine area (resulting from pressure exerted by continuous contact of the straps) and at the thighs (caused by the plastic segment of the femoral rings). All of these complications were minor and resolved uneventfully.

Discussion

For patients with developmental dysplasia of the hip, functional treatments, such as the Pavlik method, have been used with remarkable success as the femoral head descends gradually into the acetabulum^{34,35}. However, functional treatment of developmental dysplasia of the hip is not currently considered appropriate for patients over the age of six months. As the patient with developmental dysplasia of the hip becomes older, the anatomic changes that ensue become substantial obstacles to closed reduction (Fig. 4-B). The seemingly irreparable and irreversible anatomic changes of developmental dysplasia of the hip (inverted limbus, constriction and narrowing of the hip capsule), which can hinder reduction, gradually reverse (through hip remodeling) and allow the femoral head to find its anatomic position (Fig. 4-C). This occurred even in the oldest patient with complete (Tönnis grade-IV) subluxation in our series, something that seems to contradict the general belief that after six months the anatomic obstacles to reduction usually are insurmountable. Once concentric reduction is achieved, acetabular remodeling can be surprisingly good³⁶⁻³⁸.

The reported prevalence of redislocation after open reduction has ranged from 0% to 15%^{39,40} and in this group of patients the prevalence of osteonecrosis was as high as 44%⁴⁰. Mardam-Bey and MacEwen reported that 66% of children of walking age with developmental dysplasia of the hip who had undergone closed reduction required additional surgery⁴¹, and other investigators have noted a high prevalence of redislocation after open reduction^{9,42-44}. In younger children who have been managed with a Pavlik harness, the rate of redislocation has been reported to be 14%^{5,45}, which has been attributed mainly to an adduction contracture that limits hip abduction and prevents reduction of the femoral head. In our series, the hips that reduced easily were also prone to redislocate easily. Therefore, a hip spica cast was used for six weeks for hips that redislocated or hips that reduced in less than fifteen days. The modified Hoffmann-Daimler method described here is arguably more advantageous because the reduction of the femoral head was achieved in all cases and none of our patients required additional surgery.

Inadequate acetabular development may be a common problem after open reduction of the congenitally dislocated hip⁴⁶, and it can lead to early degenerative joint disease. Tucci

et al. reported that 20% of patients who had been managed successfully with the Pavlik method later had development of acetabular dysplasia⁴⁷. Acetabular development after closed reduction for the treatment of developmental dysplasia of the hip has been investigated by numerous authors, and it has been reported that the lower limit of acetabular remodeling is two years of age⁴⁸ and that the upper limit is eleven years of age⁴⁹. The acetabular remodeling potential continues even as long as eight years after reduction if the hip is reduced before the fourth year of age⁵⁰. In the present study, once a concentric reduction was achieved by placing the hips in the abduction splint, the acetabulum continued to remodel, even in children who were more than 3.5 years of age.

The mean acetabular improvement was greater in patients who started the treatment when they were more than eighteen months old, perhaps because of the fact that such children are able to walk⁵¹ while wearing the abduction splint. The redirected concentric compressive force on the acetabulum in the splint is generated by the action of the adductor muscles. When the child walks, weight-bearing is added and may further stimulate the process of acetabular remodeling.

On the basis of unpublished data, Hoffmann-Daimler reported that at the outset of applying the method, one child had development of femoral artery thrombosis due to the extreme flexion of the thighs associated with the use of the flexion harness. Neither in the international literature nor in our study did we find femoral artery thrombosis as a complication of the harness or splint. Femoral nerve palsy also has been reported as a complication of the Pavlik harness^{6,52}, but we did not observe this complication in association with the Hoffmann-Daimler harness in our study. No other well-documented complications resulting from the treatment of developmental dysplasia of the hip were observed in our patients.

The reported prevalence of osteonecrosis has ranged from 2.38% to 16% for infants managed with a Pavlik harness^{5,53} and from 0% to 67% for patients managed operatively for late-presenting developmental dysplasia of the hip⁵⁴⁻⁵⁹. When closed reduction is used, forceful traction and prolonged immobilization in forced abduction may lead to osteonecrosis rates of as high as 28%⁶⁰ secondary to high intra-articular pressure^{9,42}, a condition that is avoided with our modified method. A high prevalence (30% to 65%) of osteonecrosis was also initially reported in association with the original Hoffmann-Daimler method⁶¹⁻⁶³; the previously reported lowest rate associated with the Hoffmann-Daimler method was 12.7%⁶⁴. It was thought that this high rate was due to forced maximum abduction⁶³. In the present study, the prevalence of osteonecrosis was 6% and was not related to the degree of dislocation of the hip or the absence of an ossific nucleus at the time of reduction.

The general consensus is that hip dislocation in patients who are more than eighteen months old should be treated primarily surgically. In this age-group, the highest reported rate of success of operative treatment (as defined as a Severin class of I or II) has been 75%⁶⁵, but the rate of avascular necrosis has been reported to be 20% to 40% in Tönnis grade-III and IV

hips^{60,66}. In the present series, twenty Tönnis grade-III and IV hips in patients who were more than eighteen months old were treated with the modified method of Hoffmann-Daimler; in this group, the rate of success was 90% and the prevalence of avascular necrosis was 0%.


We believe that the extreme flexion in the reduction phase (Phase A), the forcing of the hip into increasing abduction either with use of a posterior strap or even with the application of lateral traction, the forced maximum abduction by the abduction splint, and the premature reduction of abduction during Phase B of the original Hoffmann-Daimler method were perhaps contributing factors to the high reported prevalence of osteonecrosis. We believe that an appropriate amount of time during therapy should be allowed for the soft-tissue structures, the acetabulum, and the femoral head to accommodate gradually.

The modified Hoffmann-Daimler method does not require in-hospital treatment. In cases in which the social setting is poor, we prefer to see the patient every week. In cases in which the parents are not reliable and cannot comply, especially during the first critical days of reduction, we prefer in-hospital treatment for better surveillance. Poor applications of the harness, inadequate supervision, or lack of compliance by the parents are factors that can lead to failure. Poor harness construction or fit is easily addressed by careful evaluation of the harness. We minimized poor compliance over the long duration of treatment by providing better parent education regarding developmental dysplasia of the hip and use of the harness.

There is general agreement that the best results are

achieved if the treatment of developmental dysplasia of the hip is initiated during the neonatal period. Patients in whom previous treatment of the disease has failed, those in whom the disease has been neglected, and those in whom the disease presented late are thought to be too old for management with functional methods. The modified Hoffmann-Daimler method, however, appears to achieve a safe and lasting reduction with a low prevalence of osteonecrosis and residual acetabular dysplasia.

Appendix

 A table showing details of all of the patients and a video demonstrating the application of the brace are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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References

- Graf R, Tschauner C. [Sonography of the infant hip. Sources of error, progress and current clinical relevance]. *Radiologe*. 1994;34:30-8. German.
- Sharpe P, Mulpuri K, Chan A, Cundy PJ. Differences in risk factors between early and late diagnosed developmental dysplasia of the hip. *Arch Dis Child Fetal Neonatal Ed*. 2006;91:F158-62.
- Gul R, Coffey JC, Khayat G, McGuinness AJ. Late presentation of developmental dysplasia of the hip. *Ir J Med Sci*. 2002;171:139-40.
- Yngve D, Gross R. Late diagnosis of hip dislocation in infants. *J Pediatr Orthop*. 1990;10:777-9.
- Grill F, Bensaheh H, Canadell J, Dungi P, Matasovic T, Vizkelety T. The Pavlik harness in the treatment of congenital dislocating hip: report on a multicenter study of the European Paediatric Orthopaedic Society. *J Pediatr Orthop*. 1988;8:1-8.
- Mubarak S, Garfin S, Vance R, McKinnon B, Sutherland D. Pitfalls in the use of the Pavlik harness for treatment of congenital dysplasia, subluxation, and dislocation of the hip. *J Bone Joint Surg Am*. 1981;63:1239-48.
- Viere RG, Birch JG, Herring JA, Roach JW, Johnston CE. Use of the Pavlik harness in congenital dislocation of the hip. An analysis of failures of treatment. *J Bone Joint Surg Am*. 1990;72:238-44.
- Harris IE, Dickens R, Menelaus MB. Use of the Pavlik harness for hip displacements. When to abandon treatment. *Clin Orthop Relat Res*. 1992;281:29-33.
- 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.
- Suzuki S. Reduction of CDH by the Pavlik harness. Spontaneous reduction observed by ultrasound. *J Bone Joint Surg Br*. 1994;76:460-2.
- Tönnis D. Normal values of the hip joint for the evaluation of X-rays in children and adults. *Clin Orthop Relat Res*. 1976;119:39-47.
- Mose K. Methods of measuring in Legg-Calve-Perthes disease with special regard to the prognosis. *Clin Orthop Relat Res*. 1980;50:103-9.
- Ogata S, Moriya H, Tsuchiya K, Akita T, Kamegaya M, Someya M. Acetabular cover in congenital dislocation of the hip. *J Bone Joint Surg Br*. 1990;72:190-6.
- Kim HT, Kim JI, Yoo CI. Diagnosing childhood acetabular dysplasia using the lateral margin of the sourcil. *J Pediatr Orthop*. 2000;20:709-17.
- 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):37.
- Ali AM, Angliss R, Fujii G, Smith DM, Benson MK. Reliability of the Severin classification in the assessment of developmental dysplasia of the hip. *J Pediatr Orthop B*. 2001;10:293-7.
- Ward WT, Vogt M, Grudziak JS, Tumer Y, Cook PC, Fitch RD. Severin classification system for evaluation of the results of operative treatment of congenital dislocation of the hip. A study of intraobserver and interobserver reliability. *J Bone Joint Surg Am*. 1997;79:656-63.
- 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.
- 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 Open Scientific Meeting of the Hip Society*. St. Louis: CV Mosby; 1978. p 43-63.
- Dunn PM. The anatomy and pathology of congenital dislocation of the hip. *Clin Orthop Relat Res*. 1976;119:23-7.
- Carter CO, Wilkinson JA. Genetic and environmental factors in the etiology of congenital dislocation of the hip. *Clin Orthop Relat Res*. 1964;33:119-28.
- Michelsson JE, Langenskiöld A. Dislocation or subluxation of the hip. Regular sequels of immobilization of the knee in extension of young rabbits. *J Bone Joint Surg Am*. 1972;54:1177-86.
- Suzuki S, Yamamoto T. The mechanical cause of congenital dislocation of the hip joint. Dynamic ultrasound study of 5 cases. *Acta Orthop Scand*. 1993;64:303-4.

- 24.** Suzuki S, Yamamuro T. Correlation of fetal posture and congenital dislocation of the hip. *Acta Orthop Scand.* 1986;57:81-4.
- 25.** Ono T. [Bone dynamics of the acetabulum in experimental subluxation of the hip joint and its repair process]. *Nippon Seikeigeka Gakkai Zasshi.* 1987; 61:205-15. Japanese.
- 26.** Ishii Y, Weinstein SL, Ponseti IV. Correlation between arthrograms and operative findings in congenital dislocation of the hip. *Clin Orthop Relat Res.* 1980; 153:138-45.
- 27.** Hoffmann-Daimler S. [The influence of mechanical forces on developmental cartilage ossification]. *Z Orthop Ihre Grenzgeb.* 1969;106:782-90. German.
- 28.** Shefelbine SJ, Carter DR. Mechanobiological predictions of growth front morphology in developmental hip dysplasia. *J Orthop Res.* 2004;22:346-52.
- 29.** Hoffmann-Daimler S. [Preliminary report on a functional method for the treatment of so-called congenital hip luxation]. *Z Orthop Ihre Grenzgeb.* 1964;98:447-70. German.
- 30.** Hoffmann-Daimler S. [Indication, contraindication and technic of the functional management of so-called congenital hip dislocations in captions]. *Beitr Orthop Traumatol.* 1967;14:497-505. German.
- 31.** Hoffmann-Daimler S. [First results and consequences of functional methods of treating the so-called congenital hip dislocation]. *Z Orthop Ihre Grenzgeb.* 1967;102:569-84. German.
- 32.** Hoffmann-Daimler S. [Femur head reconstruction of the so-called congenital hip dislocation from the viewpoint of functional reposition and retention]. *Arch Orthop Unfallchir.* 1967;61:289-96. German.
- 33.** Hoffmann-Daimler S. ["Centering deficit" in the hip-joint (author's transl)]. *Z Orthop Ihre Grenzgeb.* 1974;112:502-6. German.
- 34.** Ponseti IV. Morphology of the acetabulum in congenital dislocation of the hip. Gross, histological and roentgenographic studies. *J Bone Joint Surg Am.* 1978;60:586-99.
- 35.** Ponseti IV. Growth and development of the acetabulum in the normal child. Anatomical, histological, and roentgenographic studies. *J Bone Joint Surg Am.* 1978;60:575-85.
- 36.** Harris NH. Acetabular growth potential in congenital dislocation of the hip and some factors upon which it may depend. *Clin Orthop Relat Res.* 1976;119:99-106.
- 37.** Benson MKD, Fixsen JA, Macnicol MF. Children's orthopaedics and fractures. Edinburgh; New York: Churchill Livingstone; 1994. p 415-43.
- 38.** Gotoh E, Ando M. The pathogenesis of femoral head deformity in congenital dislocation of the hip. Experimental study of the effects of articular interpositions in pigs. *Clin Orthop Relat Res.* 1993;288:303-9.
- 39.** Hsieh SM, Huang SC. Treatment of developmental dysplasia of the hip after failed open reduction. *J Formos Med Assoc.* 1998;97:763-9.
- 40.** McCluskey WP, Bassett GS, Mora-Garcia G, MacEwen GD. Treatment of failed open reduction for congenital dislocation of the hip. *J Pediatr Orthop.* 1989;9:633-9.
- 41.** Mardam-Bey TH, MacEwen GD. Congenital hip dislocation after walking age. *J Pediatr Orthop.* 1982;2:478-86.
- 42.** Olney B, Latz K, Asher M. Treatment of hip dysplasia in older children with a combined one-stage procedure. *Clin Orthop Relat Res.* 1998;347:215-23.
- 43.** Klisic P, Jankovic L, Basara V. Long-term results of combined operative reduction of the hip in older children. *J Pediatr Orthop.* 1988;8:532-4.
- 44.** Morcuende JA, Meyer MD, Dolan LA, Weinstein SL. Long-term outcome after open reduction through an anteromedial approach for congenital dislocation of the hip. *J Bone Joint Surg Am.* 1997;79:810-7.
- 45.** Cashman JP, Round J, Taylor G, Clarke NM. The natural history of developmental dysplasia of the hip after early supervised treatment in the Pavlik harness. A prospective, longitudinal follow-up. *J Bone Joint Surg Br.* 2002;84: 418-25.
- 46.** 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.
- 47.** Tucci JJ, Kumar SJ, Guille JT, Rubbo ER. Late acetabular dysplasia following early successful Pavlik harness treatment of congenital dislocation of the hip. *J Pediatr Orthop.* 1991;11:502-5.
- 48.** Schwartz DR. Acetabular development after reduction of congenital dislocation of the hip. A follow-up study of fifty hips. *J Bone Joint Surg Am.* 1965;47: 705-14.
- 49.** Cherney DL, Westin GW. Acetabular development in the infant's dislocated hips. *Clin Orthop Relat Res.* 1989;242:98-103.
- 50.** Murphy SB, Ganz R, Muller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. *J Bone Joint Surg Am.* 1995;77:985-9.
- 51.** Kamath SU, Bennet GC. Does developmental dysplasia of the hip cause a delay in walking? *J Pediatr Orthop.* 2004;24:265.
- 52.** Kalamchi A, MacEwen GD. Avascular necrosis following treatment of congenital dislocation of the hip. *J Bone Joint Surg Am.* 1980;62:876-88.
- 53.** Suzuki S, Yamamuro T. Avascular necrosis in patients treated with the Pavlik harness for congenital dislocation of the hip. *J Bone Joint Surg Am.* 1990;72:1048-55.
- 54.** Cooperman DR, Wallensten R, Stulberg SD. Post-reduction avascular necrosis in congenital dislocation of the hip. *J Bone Joint Surg Am.* 1980;62: 247-58.
- 55.** Esteve R. Congenital dislocation of the hip. A review and assessment of results of treatment with special reference to frame reduction as compared with manipulative reduction. *J Bone Joint Surg Br.* 1960;42:253-63.
- 56.** Domzalski M, Synder M. Avascular necrosis after surgical treatment for developmental dysplasia of the hip. *Int Orthop.* 2004;28:65-8.
- 57.** 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 Am.* 1994;76:1777-92.
- 58.** Koizumi W, Moriya H, Tsuchiya K, Takeuchi T, Kamegaya M, Akita T. Ludloff's medial approach for open reduction of congenital dislocation of the hip. A 20-year follow-up. *J Bone Joint Surg Br.* 1996;78:924-9.
- 59.** 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.
- 60.** Tönnis D. [Statistical evaluations of femur head necrosis rate with conservative and additional surgical treatment of congenital hip dislocation]. *Z Orthop Ihre Grenzgeb.* 1977;115:653-8. German.
- 61.** Anders G, Tönnis D (Dietrich). Deutsche Gesellschaft für Orthopädie und Traumatologie. Arbeitskreis für Hüftdysplasie. Hüftluxation und Hüftkopfnekrose: die Hüftkopfnekrose bei verschiedenen konservativen und operativen Einrenkungsverfahren der angeborenen Hüftluxation: eine Sammelstatistik des Arbeitskreises für Hüftdysplasie der Deutschen Gesellschaft für Orthopädie und Traumatologie. Stuttgart: Enke, 1978.
- 62.** Tönnis D (Dietrich), Anders G. Deutsche Gesellschaft für Orthopädie und Traumatologie. Arbeitskreis für Hüftdysplasie. Congenital hip dislocation: avascular necrosis: necrosis of the femoral head as a complication of different conservative and operative methods of reduction in congenital dislocation of the hip: collective statistics. New York: Thieme-Stratton, 1982.
- 63.** Eulert J. [Repositing technic for the so-called congenital hip dislocation using the Hoffmann-Daimler method]. *Z Orthop Ihre Grenzgeb.* 1977;115:641. German.
- 64.** Weseloh G, Legal H, Schorr H, Probst KJ. [Frequency of necroses of the head of the femur in the treatment of the so-called congenital dislocation of the hip joint according to Hoffmann-Daimler (author's transl)]. *Z Orthop Ihre Grenzgeb.* 1978;116:877-84. German.
- 65.** 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.
- 66.** Tönnis D, Itoh K, Heinecke A, Behrens K. [The management of congenital hip luxation with arthrographic control, an individual risk-reducing and time-saving method. I. Choice of method and risk assessment based on arthrographic findings]. *Z Orthop Ihre Grenzgeb.* 1984;122:50-61. German.