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Early results of treatment for developmental dysplasia of the hip in children of walking age (1-4 years)

Yürüme çağındaki (1-4 yaş) gelişimsel kalça displazili olgularda erken dönem tedavi sonuçlarımız

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Amaç: Gelişimsel kalça displazisi nedeniyle 1-4 yaşlarındaki olgularda uyguladığımız tedavinin erken dönem sonuçları incelendi.

Çalışma planı: Yirmi dört hasta ilk tedavi sırasındaki yaşlarına göre retrospektif olarak iki gruba (2 yaş altı ve üstü) ayrıldı. Grup I'de 13 hasta (20 kalça; ort. yaş 19.1 ay; dağılım 14-24 ay), grup II'de 11 hasta (15 kalça; ort. yaş 32.6 ay; dağılım 26-50 ay) vardı. Başlangıç tedavisi olarak grup I'de 12 kalçaya kapalı ya da açık redüksiyon, sekiz kalçaya açık redüksiyon ve femoral ve/veya pelvik osteotomisi uygulandı. Grup II'deki tüm kalçalarda açık redüksiyon ve femoral ve/veya pelvik osteotomisi yapıldı. Ameliyat sonrası klinik değerlendirmede modifiye McKay ölçütleri, radyografik değerlendirmede Severin sınıflandırması kullanıldı. Ortalama izlem süresi grup I'de 29.1 ay (dağılım 12-60 ay), grup II'de 37.3 ay (dağılım 12-66 ay) idi.

Sonuçlar: Grup I'de dokuz kalçada, grup II'de iki kalçada ek tedavi olarak kemik girişimi yapıldı ($p<0.05$). Avasküler nekroz grup I'de altı kalçada (%30) görülürken, grup II'de görülmedi ($p<0.05$). Grup I'de radyolojik olarak %85, klinik olarak %90; grup II'de radyolojik olarak %86, klinik olarak %100 çok iyi ve iyi sonuç elde edildi.

Çıkarımlar: Yürüme çağındaki olguların gelişimsel kalça displazisinde açık ya da kapalı redüksiyon ile birlikte pelvik ve/veya femoral osteotomilerin de gerekebileceği unutulmamalıdır.

Anahtar sözcükler: Çocuk; femur başı nekrozu/etiyoloji/komplikasyon; kalça çıkığı, doğuştan/cerrahi/komplikasyon/radyografi; kalça eklemi/radyografi; osteotomi/yöntem; ameliyat sonrası komplikasyon.

Objectives: We evaluated the early results of treatment for developmental dysplasia of the hip in children between the ages of one and four years.

Methods: Twenty-four patients were retrospectively divided into two groups according to whether they were below or above two years of age at the time of the initial treatment. Group I consisted of 13 patients (20 hips; mean age 19.1 months; range 14 to 24 months); 11 patients (15 hips; mean age 32.6 months; range 26 to 50 months) comprised group II. Initially, patients in group I were treated with closed or open reduction (12 hips) and open reduction with femoral and/or pelvic osteotomies (8 hips). Group II patients underwent open reduction with femoral and/or pelvic osteotomies. Clinical results were evaluated according to the modified McKay criteria, and radiographic results to the Severin classification. The mean follow-up periods were 29.1 months (range 12 to 60 months) and 37.3 months (range 12 to 66 months), respectively.

Results: Subsequent operations were performed in nine hips in group I, and in two hips in group II ($p<0.05$). Avascular necrosis of the femoral head was noted in six hips (30%) in group I and in none of the hips in group II ($p<0.05$). Excellent or good radiographic results accounted for 85% and 86%, and clinical results for 90% and 100% in groups I and II, respectively.

Conclusion: The need for pelvic and/or femoral osteotomies should be considered in conjunction with closed or open reduction in the treatment of developmental dysplasia of the hip in children between the ages of one and four years.

Key words: Child; Femur head necrosis/etiology/complications; hip dislocation, congenital/surgery/complications/radiography; hip joint/radiography; osteotomy/methods; postoperative complications.

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Despite screening programs to detect developmental dysplasia of the hip (DDH) in the newborn period, a significant number of cases refer in the late phases of the disorder.[1] Major principles for treatment of DDH differ in walking age children as compared to newborns.[2] Contractures involving the periarticular muscles, tendons and capsular structures prevent reduction in children and the pressure that develops on the femoral head after reduction may cause ischaemic changes.[3,4]

There is no consensus concerning the treatment algorythm for DDH in the walking age group. High rates of dysplasia and subluxation have been reported in different series, where primary closed or open reduction were performed after 12 months, and these hips received femoral and pelvic osteotomies afterwards .[5-7] Primary open reduction combined with femoral and/or pelvic osteotomies are reported to have favorable results in patients older than 18 months .[1,2,4,8-10]

This study aims to evaluate the effects of different treament options, performed on patients younger than 24 months and older than 24 months and who are able to walk.

Patients and method

40 hips of 28 patients were treated in our department between July 1997 and November 2001, with the diagnosis of walking age DDH. Among these, 35 hips of 24 patients who could be followed up for at least one year were included in the study group.

Patients were retrospectively divided into two groups according to their age at initial evaluation. Group I included patients younger than 2 years, and group II patients older than 2 years. Subgroups were separately compared according to the initial treatment modality they received; namely, 12 hips which received closed reduction or soft tissue intervention as the initial treatment and 23 hips which received soft tissue and bony interventions.

Group I included 20 hips of 13 patients (7 bilateral, 2 left and 4 right hips; 18 female and 2 male hips) and Group II 15 hips of 11 patients (4 bilateral, 6 left and 1 right hip; 11 female and 4 male hips). None of these patients were previously treated for DDH. One patient also had osteogenesis imperfecta. Mean age at time of initial treatment was 19.1 months (range 14-24 months) in group I and 32.6 months (range 26-50 months) in group II. Mean follow-up period was 29.1 months (range 12-60 months) for group I and 37.3 months (range 12-66 months) for group II.

The following procedures were applied to both groups as the initial treatment modality: In group I, closed reduction 4 hips, adductor-iliopsoas tenotomy by the medial approach and closed reduction 3 hips, open reduction 5 hips, open reduction and pelvic osteotomy 5 hips, open reduction, femoral osteotomy and pelvic osteotomy 2 hips; group II, open reduction and pelvic osteotomy 1 hip, preoperative skeletal traction, open reduction and pelvic osteotomy 2 hips, open reduction and femoral osteotomy 3 hips, open reduction, femoral osteotomy and pelvic osteotomy 9 hips.

As additional procedures, 10 hips (50%) in group I needed surgical intervention and 11 procedures were performed on 9 of these (twice on 2 hips). In group II, three hips (20%) needed surgery and in two out of these three surgery was applied. Indication for an additional surgical procedure was subluxation accompanying acetabular dysplasia. A standing neutral pelvic radiograph demonstrating an increase in the distance between the proximal femur and the teardrop figure, breakage of the Shenton line and reduction in coverage of the femoral head under the acetabulum constituted the criteria for subluxation. The additional surgical procedure was performed within a mean interval of 15 months (range 3-48 months) in group I and 20 months (range 4-36 months) in group II, following the first intervention. The additional procedures performed were: in group I, 3 pelvic osteotomy, 2 open reduction, 2 open reduction and pelvic osteotomy, 1 open reduction and femoral osteotomy, 1 open reduction, femoral osteotomy and pelvic osteotomy, 1 femoral osteotomy and pelvic osteotomy, 1 femoral osteotomy; in group II 1 femoral osteotomy, 1 open reduction and pelvic osteotomy.

Four different types of skin incisions were used: iliofemoral and Watson Jones incision in 13 hips, bikini and lateral longitudinal incision in 7 hips, iliofemoral incision in 4 hips and bikini incision in 9 hips. Revision surgery was performed using the previous incision area.

The anterior approach was preferred for open reduction in all cases. Routinely, the ligamentum teres and pulvinar were excised, iliopsoas tenotomy was performed and the labrum was cut radially (the

labrum was left intact in 5 hips, partial labral excision were necessary in 3 hips where the labrum prevented reduction) and capsular plication was performed.

A high dislocation was observed in fourteen hips (group I 3 hips, group II, 11 hips). Twelve of these were treated with femoral shortening osteotomy; two of whom also received skeletal traction for two weeks before the operation and thus femoral shortening was not performed. The amount of shortening was decided upon by preoperative radiographic assessment and peroperative clinical examination.[11] 18 hips received 19 femoral derotation osteotomies (group I 6 hips, group II 12 hips; one hip was operated twice). Clinical examination during the operation was the decision making procedure for femoral derotation.[11] A total of three hips from group I and II were treated with femoral varization. Femoral osteotomy site was the subtrochanteric area and angulated plates were used for fixation.

The final decision was whether to perform pelvic osteotomy. A total of 26 hips (13 hips from each group) received 27 pelvic osteotomy operations (Salter osteotomy in 22 hips, Pemberton osteotomy in 5 hips). Acetabular index measured from the preoperative radiograph was taken into consideration when the decision was made for pelvic osteotomy; however, in cases with previous open reduction it was based upon the peroperative examination.[11] Pemberton osteotomy was preferred when the iliac wing was thin and the width of acetabulum were adequate (5 Pemberton procedures were performed in group I hips). In other circumstances, the Salter osteotomy was preferred. Bone grafts were taken from the iliac wing for the Pemberton osteotomy and no other fixation materials were used. For the Salter osteotomy, bone grafts were again taken from the iliac wing and two K-wires were used for fixation.

Table 1. Clinical evaluation according to modified McKay criteria

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

In bilateral cases, soft tissue procedures were carried out simultaneously. For bilateral cases necessitating osseous intervention, one hip was operated three weeks before the other one and the second operation was performed after the casts were removed. Only in two cases (group I), pelvic osteotomy was performed within the same operation.

Mean immobilization period in a hip spica cast was 6.6 weeks (range 6-18 weeks). After a pelvic osteotomy, no weight-bearing was allowed for the first 20 days following removal of the hip spica cast and all patients were advised to practice active range of motion exercises. The Frejka pillow was used fol-

Table 2. Radiological classification by Severin

Degree		Radiological appearance	Center-edge angle	Age
Ia	Very good	Normal	>19°	6-13 years
			>25°	≥14 years
Ib	Good	Normal	15-19°	6-13 years
			20-25°	≥14 years
II	Good	Mild deformity in the femoral head, neck or acetabulum	Same values as degree Ia-Ib	
III	Moderate	Not dysplastic or subluxated	<15°	6-13 years
			<20°	≥14 years
IV	Bad	Subluxated		
V	Bad	Femoral head articulating with the neoacetabulum superior to the true acetabulum		
VI	Bad	Redislocated		

lowing closed reduction, in two patients (group I) for two months after removal of the cast. No other type of orthesis was used in other patients. Follow-up examinations consisted of clinical examination and pelvic radiographs and were carried out two months after the cast was removed, and every 6 months. In most cases, the K-wires and the angulated plate were removed at the postoperative sixth month.

Both pre and postoperative radiological evaluation involved standing neutral pelvic radiographs. The acetabular index was measured on a preoperative radiograph, while Wiberg's center-edge angle and acetabular index were evaluated on a postoperative one.[12] Modified McKay criteria[8] (Table 1) were used for postoperative clinical assessment, and Severin classification [13,14] (Table 2) for radiological evalutation.

Diagnosis for avascular necrosis was made according to Salter criteria[15] postoperatively, where absence of the ossification center one year after reduction, failure of growth in a preexisting ossification center or widening of the femoral neck, fragmentation of the femoral head after density increase and development of deformity in the femoral head after ossification is complete were all evaluated as avascular necrosis. Development of avascular necrosis was classified according to the Bucholz-Ogden system[16].

Statistical evaluation was carried out using *x*-square and Student's *t* tests.

Results

Group I and II were statistically comparable in terms of gender distribution and age ($p>0.05$).

The acetabular index was reduced by 18.9±10.7 degrees in group I (preoperative 39±7.3°, postoperative 20.1±8.7°; $p<0.05$) and 22.3±8.9 degrees in group II (preoperative 37.5±5.7°, postoperative 15.3±6.7°; $p<0.05$). At the final follow-up examination, the center-edge angle was 29.4±13.4 degrees in group I and 33.3±12.7 degrees in group II.

Osseous intervention was performed on 8 hips (40%) in group I and 15 hips (100%) in group II is the initial treatment ($p<0.05$). Additional treatment was necessary for 10 hips (50%) and was performed on 9 in group I, while it was necessary for three hips (20%) and performed on two hips in group II ($p<0.05$).

In group I, acetabular dysplasia and subluxation was detected at long-term in 7 of 12 hips (58%), who received only closed or open reduction. They were all treated with bony interventions. Additional treatment was necessary for 3 hips among 8 (37%), which received bony interventions initially, two of which were reoperated. Finally, among the 20 hips in group I, 2 had closed reduction, 3 open reduction and 15 closed or open reduction with bony intervention, of which 9 were pelvic osteotomy, four combined pelvic and femoral osteotomies and two femoral osteotomy.

All patients in group II were treated with open reduction and bony intervention. Finally, 10 hips had received kombined pelvic and femoral osteotomies, 3 pelvic and 2 femoral osteotomy.

When both groups are evaluated together, all of the 12 hips treated with closed reduction and soft tissue operation initially were in group I and 7 of these (%58) additionally needed and received bony procedures. Only 6 out of 23 hips (%26) needed bony procedures in addition to initial soft tissue operation and bony procedures and four of these were operated on($p<0.05$).

Avascular necrosis occurred in 6 hips in group I

Figure 1. Postoperative radiograph of a girl with DDH, 19 months after the procedure. There is avascular necrosis of the right hip. Open reduction was performed when she was 18 months old, and received open reduction and femoral derotation osteotomy three months after the first operation due to subluxation. The result was radiographically and clinically good.

(30%), but in none of the hips in group II ($p<0.05$). All hips with avascular necrosis were treated with open reduction, four of these necessitated additional surgical procedures, one of which was a repeat open reduction (Figure 1).

Primary femoral shortening osteotomy was performed on 12 of 14 hips with high dislocations. Only one out of these hips suffered avascular necrosis (8%). Avascular necrosis did not occur in two hips who have received skeletal traction before surgery (group II).

According to the radiological criteria of Severin[13], the hips in group I were classified as follows: 12 hips degree Ia (60%), 5 hips (25%) degree II, one hip (5%) degree III, two hips (10%) degree IV (the sum of very good and good results was 85%). In group II, 13 hips (86%) were degree Ia, two hips (14%) degree III (with good and very good results adding up to 86%). Clinical evaluation results by modified McKay criteria revealed the following: 16 hips (80%) degree I, two hips (10%) degree II, two hips (10%) degree IV in group I (sum of very good and good results being 90%); 13 hips (86%) degree I, two hips (14%) degree II (very good and good esults being 100%) in group II (Figure 2).

A complication in one hip (group II) was extreme femoral derotation, causing impairment during walking, and thus correction was accomplished with a derotation osteotomy. The same patient had suffered femoral nerve paralysis after the first operation; which was corrected in another center, through secondary nerve repair after one year of inadequate self repair. The patient with osteogenesis imperfecta was twice complicated with subtrachanteric fractures distal to the plate (group II), and union was achieved using a posterior splint with pelvic support. Only 3 cases had a limb length shortening of 2 cm (group I, 1 hip; group II, 2 hips).

Discussion

The most important objective in the treatment of childhood DDH is to achieve stable reduction.[1,2,17] Treating DDH in children of walking age and older is a challenge and closed or open reduction by themselves alone may not be efficient as single step procedures. Many studies emphasize that, most cases who receive a closed or open reduction attempt alone, necessitate additional procedures like pelvic or femoral osteotomies due to dysplasia or subluxation.[5-7] Kerry and Simonds,[5] report that in a group of children aged 9-36 months, they have observed residual dysplasia in 12 out of 31 hips after traction and closed reduction and that 8 had femoral and four had pelvic osteotomies later on. Zionts and MacEwen,[7] treated 51 hips of children younger than 4 years using closed or open reduction techniques and they had to perform femoral and pelvic osteotomies in 33 hips due to subluxation. Kershaw et al.[6] had to perform open reduction, pelvic and femoral

Figure 2. 4 year-old girl with bilateral high DDH. **(a)** preoperative radiograph. **(b)** Postoperative radiograph after 20 months. Bilateral open reduction, Salter type and femoral shortening-derotation osteotomies were performed. The end-result is perfect both clinically and radiographically.

osteotomies during the long-term follow-up after an initial primary open reduction because of loss of reduction in 33 patients aged 6-60 months. In our study, the 12 hips which received open or closed reduction as initial treatment comprised group I; 7 of these 12 hips (58%) needed additional bony procedures after acetabular dysplasia and suluxation were detected. However, only 6 of 23 hips (26%) treated initially with soft tissue operations and bony procedures demonstrated acetabular dysplasia and subluxation, and bony procedures as additional interventions were performed on four hips ($p<0.05$).

In DDH patients aged 12 months and older, a high rate of very good and good results are reported when pelvic or femoral osteotomies are combined with closed or open reduction separately or in combination.[1,2,4,8] Berkeley et al.[2] performed anterior open reduction after failed closed reduction in patients 1-3 years old. During the procedure, they combined a Pemberton type osteotomy (55%) when the anterolateral coverage of the femoral head was inadequate peroperatively, femoral derotation in 85% and femoral shortening in 4% of cases, obtaining perfect and very good results radiologically in 95% and clinically in 100% of the patients. Galpin et al.[4] performed femoral osteotomy together with open reduction in 33 hips of 25 older children, they also added pelvic osteotomy to stabilize reduction in 21 hips. Radiologically 73% and clinically 77% very good and good results were obtained in their study, and they concluded that open reduction, femoral and pelvic osteotomies may give good results in children older than 2 years.[4] Barrett et al[8] reported to have 85% very good and good results after open reduction and Salter type pelvic osteotomy in patients aged between 18 months and 6 years. Williamson et al[1] obtained very good and good results in all 11 hips in whom combined femoral and pelvic osteotomies were performed as initial treatment in patients 3 years and older. In our study, we performed open reduction together with femoral and/or pelvic osteotomy on 8 hips in group I and 15 hips in group II as an initial treatment. Three hips in each group also needed additional surgery; 37% in group I and 20% in group II. These values are smaller as compared to hips which receive either open or closed reduction as an initial treatment. Finally, 15 hips in group I (75%) and all hips in group II (100%) had received bony procedures and 85% very good and good results were obtained in both groups radiologically and clinically. Results of the aforementioned studies and ours show that when closed or open reduction alone is applied to treat DDH in walking age children, dysplasia and subluxation may develop in the long term and pelvic or femoral osteotomies are generally needed as additional surgical interventions. The appropriate bony procedures chosen during initial surgery reduce the rate of additional surgery.

There are different opinions about when and what kind of a bony procedure is to be performed, at which age, or when. Inappropriate acetabular development is a complication observed after closed or open reduction in developmental dysplasia of the hip. Williamson et al[1] indicate that they have treated DDH patients older than 3 years with closed or open reduction after skeletal traction and femoral derotation after 6 weeks, and that 14 out of 34 hips developed progressive subluxation and thus they had to perform additional pelvic osteotomy. In the long term follow-up of DDH patients between 1-3 years of age whom they have treated with open reduction, Gibson and Benson[18] detected inappropriate acetabular development in more than 50% of their patients. When an anatomically normal configuration is achieved in a dysplastic hip, the rate of perfect and good results increase at long term.[19] The key feature in DDH is to correct the acetabular dysplasia and this is most easily achieved with pelvic osteotomy.[20] Pelvic osteotomy may be performed after the age of sixteen months.[2,8,19] Acetabular dysplasia and subluxation were present in all hips in group I necessitating additional surgery, and pelvic osteotomy was performed in 7 out of 9 hips. When initial and additional treatments are evaluated, in group I, 9 of 15 hips (60%) which needed bony procedures received pelvic osteotomy alone, while in group II, out of all 15, three hips received pelvic osteotomy alone and 10 hips (67%) combined pelvic and femoral osteotomies. Finally, clinical and radiological results were successful in both groups. For a successful treatment in walking age DDH, bony procedures should always be considered. Especially in patients younger than 24 months, when a bony procedure is necessary, a pelvic osteotomy by itself would generally be adequate. After 24 months combined pelvic and femoral osteotomies are frequently required.

Salter and Dubos[21] indicate that bilateral pelvic osteotomy performed within the same session are contraindicated; while some authors recommend simultaneous bilateral pelvic osteotomy.[22] In patients with bilateral DDH, a unilateral pelvic osteotomy was applied initially, the other side was operated three weeks after the cast was removed. We preferred to treat them separately since most cases needed a femoral osteotomy as well as a pelvic osteotomy and since the operation time would otherwise be longer. In two patients bilateral pelvic osteotomy was applied in one session without any complications. One of these received bilateral Salter osteotomy, while the other one received bilateral open reduction and Pemberton osteotomy.

The rate of avascular necrosis is reported to be 6%[8], 7%[9] and 10%[4] in various studies. In our study, 6 hips in group I (30%) had avascular necrosis and none in group II. The 6 avascular necrosis cases in group I had received open reduction, four had additional surgery and one hip received open reduction twice. Böhm and Brzuske[19] emphasized that open reduction rather than an osteotomy was responsible for the increase in the rate of avascular necrosis. Kerry and Simonds[5] did not observe any avascular necrosis in 31 hips they have treated without performing open reduction. We believe that additional surgery, especially open reduction, was responsible for the high rate of avascular necrosis observed in group I. The high dislocation cases in group II were in the risk group for avascular necrosis; 9 of the 11 hips received primary femoral shortening and two hips preoperative traction but none had avascular necrosis. In group I, three high dislocetion cases were treated with primary femoral shortening osteotomy and one hip demonstrated avascular necrosis. In conclusion, only one hip with primary femoral sportening osteotomy had avascular necrosis (8%). The most important factor reducing the risk of avascular necrosis is protecting the femoral head from excessive pressure; for that purpose, preoperative traction, soft tissue release and femoral shortening may be performed.[8,23] Schoenecker and Strecker[3] applied preoperative skeletal traction in a group of patients older than 3 years and primary femoral shortening in another group. 54% avascular necrosis was observed in the traction group; while none of the patients in the shortening group had necrosis. We believe that primary femoral shortening is a safe treatment option for high dislocations.

Femoral derotatian osteotomy was performed on 6 hips in group I and 12 hips in group II (total of 18 hips and 19 procedures). In one hip, a corrective derotation osteotomy had to be performed due to excessive femoral derotation. Excessive derotation of the femur should be avoided when femoral derotation osteotomies are combined with pelvic osteotomies, since posterior instability and dislocation may occur.[4,11] Corrective osteotomy was applied to correct excessive derotation by Galpin et al[4] in two hips and by Karakaş et al[9] in one hip. Herring[11] states that truly increased anteversion is rare in DDH and that femoral derotation surgery is not necessary. In our study, we generally did not choose to perform femoral derotation osteotomy in children younger than 24 months.

Herring[11] states that femoral valgus osteotomy is not indicated since excessive valgus is generally not observed in the proximal femur. We did not prefer to perform femoral varus osteotomy in most of our cases. Femoral varization osteotomy was applied to one hip as an initial treatment modality and in two hips as additional surgery.

In conclusion, successful results are difficult to obtain using closed reduction and soft tissue operations alone in DDH patients younger than 24 months and who are able to walk. In this age group, revisions and additional surgical procedures like pelvic osteotomies become necessary when an initial bony procedure has not been performed. Patients older than 24 months generally need combined additional bony procedures (pelvic and femoral osteotomies) after open reduction. Special attention should be paid to children of walking age who are younger than 24 months, since the surgeon might wrongly prefer non-bony procedures and believe that conservative measures would give better results. Despite a short follow-up period, the results of our study indicate that whatever the age of the patient is, bony procedures should be kept in mind in DDH patients of walking age.

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