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Should we try closed reduction and casting treatment first for cases with developmental dysplasia of the hip beyond 18 months of age?

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Abstract

This study aims to evaluate the clinical and radiological outcomes of closed reduction and casting in patients older than 18 months with developmental dysplasia of hip (DDH) and to assess the success of this technique. We retrospectively analyzed medical records of DDH patients treated between March 2011 and June 2014. A total of 20 hips from 13 patients (2 boys, 11 girls) aged 18 months or older were included. Among them, 4 had right unilateral involvement, 2 had left unilateral involvement, and 7 had bilateral involvement. The mean age at treatment initiation was 19.4 months. Radiographic evaluations included the acetabular index (AI) using the Hilgenreiner method, Wiberg's center-edge (CE) angle, acetabular angle (AA), and femoral neck-shaft angle. Hips were classified as normal, slightly dysplastic, or severely dysplastic based on Tönnis' acetabular index table. Stable reduction was achieved in 12 hips (60%) of 8 patients with closed reduction and casting. However, 8 hips (40%) of 5 patients required acetabular osteotomy due to persistent dysplasia. Our findings suggest that closed reduction and hip spica casting should be considered for DDH in patients older than 18 months based on radiographic outcomes. However, our study is limited by a short follow-up period and a relatively small sample size. Further studies with larger cohorts and long-term follow-ups are necessary for more definitive conclusions.

Keywords: developmental dysplasia of the hip, late-presenting DDH, closed reduction, hip spica cast

1. Introduction

Developmental dysplasia of the hip (DDH) is one of the most common orthopedic conditions, characterized by excessive laxity of the hip capsule and failure of concentric reduction of the femoral head and acetabulum (1). The incidence of DDH varies between 1 and 34 per 1000 live births, depending on diagnostic criteria and screening methods used in different populations (2). It is a neonatal condition, but it can remain undetected and manifest at later ages. The main purpose of DDH treatment is concentric reduction of the femoral head in the acetabulum and the prevention of possible degenerative hip-joint development. The regeneration potential of the hip joint is highest in the early stages of life, so it is recommended that treatment starts as early as possible, and the effectiveness of treatment decreases in delayed cases (3–6). The closed reduction procedure involves a dislocated or subluxated hip reduction under general anesthesia and a pelvipedal cast application. Traditionally, closed reduction and cast therapy are applied in an early period (7,8,9), but some have also tried it in selected cases in the post-walking period with no open reduction (10,11,12). This study aims to evaluate the efficacy of closed reduction and casting in DDH patients older than 18 months and assess radiological and clinical outcomes in this patient population.

2. Materials and Methods

Following approval from the local ethics committee under protocol number 10840098-604.01.01-E.15430, we retrospectively evaluated the medical records of patients with DDH between March 2011 and June 2014. Informed consent was obtained from all patients before undergoing treatment. We excluded patients if they were younger than 18 months of age, had undergone open reduction, had undergone prior closed reduction and casting treatment, or had cerebral palsy, myelomeningocele, hypoxic encephalopathy, muscular dystrophy, or leukoencephalopathy accompanying teratological hip dislocation. We included 20 hips of 13 patients (2 boys, 11 girls) who were 18 months and older. There were four patients who had right unilateral involvement, 2 patients with left unilateral involvement, and 7 patients with bilateral involvement (Table 1). The mean age at the start of treatment with a closed reduction and cast was 19.4 months

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(18-28 months).

We evaluated the acetabular index (AI) using the Hilgenreiner method, Wiberg's CE angle, acetabular angle (AA), and femoral neck-body angles in direct radiographs. Using Tönnis' acetabular index table for various age groups, the hips were classified as normal, slightly dysplastic, and severely dysplastic (13). Values between one and two standard deviations from the mean were considered mild dysplasia, and values of 2 standard deviations above the mean were considered severe dysplasia.

Table 1. Demographic features of dysplastic hips

	Unilateral Right	Unilateral Left	Bilateral	Total
Male	1	0	1	3
Female	3	2	6	17
Total	4	2	7	20

2.1. Closed reduction and pelvipedal casting procedure

Under general anesthesia, a gentle closed reduction was attempted for each patient. In cases of adductor tightness, an adductor tenotomy was performed. The adequacy of the reduction was assessed based on Ramsey's safe zone criteria (10). In arthrographies performed with a sub-adductor approach, we evaluated the reduction achieved in hips with contrast material pooling of 2 mm or less as good, and reduction with pooling over 7 mm and soft tissue interposition was considered poor (Figs. 1A, 1B).

After confirming reduction under fluoroscopy, a pelvipedal cast was applied. Rolled cotton was placed over the abdomen to allow breathing space, and additional padding was applied in a figure-eight configuration through the groin and around the lower extremities. The hips were positioned in 90–110° flexion and 45–60° abduction.

Patients underwent closed reduction and pelvipedal cast application after arthrography up to three times at eight-week intervals. After the first eight weeks of this procedure, we removed the cast under anesthesia and examined the hip-joint stability. If the hip was stable, we did not force dislocation and performed a second cast in the human position. We removed the cast again under anesthesia and examined the hip stability after a second eight-week period. Then, we applied a third cast in the Ferguson position with less hip flexion and abduction (10-20 degrees of flexion, 30 degrees of abduction). We confirmed the perioperative reduction by intra-articular injection of contrast medium (Omnipaque, GE Healthcare, Ireland) in casting procedures under fluoroscopy (Ziehm Vision R, Ziehm Imaging GmbH, Nürnberg, Deutschland). We did not apply traction to any of the patients before reduction. We evaluated the efficacy of the therapy with anteroposterior (AP) radiographs of the pelvis after the end of the casting treatment.

Fig. 1. (A) Sub-adductor arthrography procedure. In sub-adductor approach for arthrography of the hip that extravasated contrast material runs through the adductor space and is not superimposed on the hip joint.

Fig. 1. (B) Scope view of sub-adductor arthography procedure. Arthrography is used to confirm reduction after closed reduction under anesthesia and help identify possible blocks to reduction. The reduction in scope view was evaluated contrast material pooling of 2 mm or less as good, and reduction with pooling over 7 mm and soft tissue interposition was considered poor.

2.2. Statistical analysis

We formed two different groups comprising those who benefited from closed reduction and cast treatment and those who needed osteotomy despite these treatments. We analyzed the data and treatment efficacy of hips in both groups. Fisher's exact test was used to analyze data such as gender, side, and tenotomy, and the Mann-Whitney test was used for age, follow-up time, number of castings, acetabular index, acetabular angle, femoral neck-body angle, and Tönnis criteria. We evaluated the results with the software SPSS (Statistical Package for the Social Sciences) (IBM SPSS Statistics for Windows, version 22.0, IBM Corp., Armonk, NY, USA). Significance was determined using $p < 0.05$, and the 95% confidence intervals were calculated.

3. Results

The mean follow-up period for the patients was 41.5 months (7-90 months). The mean age at the time of the first pelvic cast treatment was 19.4 months (18-28 months). Eight of the patients were 18 months old, three were 20 months old, one

was 21 months old, and the eldest was 28 months old.

Two of the 20 hips were Tönnis 1, six were Tönnis 2, seven were Tönnis 3, and five were Tönnis 4 in pre-reduction pelvic AP radiographs corresponding to the Tönnis displacement criterion. We detected adductor contracture in six hips of five patients and performed an adductor tenotomy. Two of the patients who underwent adductor tenotomy were 18 months old, two were 20 months old, one was 28 months old, and all were female (Table 2).

Table 2. Demographic features of patients who underwent adductor tenotomy

	18 Months	20 Months	28 Months	Total
Right	1	2	0	3
Left	1	1	1	3
Total	2	3	1	6

There was no distinction between the groups in terms of gender, side, and need for tenotomy because of adductor tension (Fischer's exact test, p=1.000). We could not find a significant distinction between the groups when age, follow-up period, number of casts, acetabular index value at first admission, acetabular angle, femoral neck-stem angle and Tonnis displacement criteria (Mann-Whitney Test) were compared (Tables 3, 4).

We detected mild dysplasia in one hip and severe dysplasia in three hips according to the Tönnis grading performed on X-rays after a closed reduction and cast treatment. The three patients who underwent Dega osteotomy were girls and first had casts at 18, 20, and 21 months. We performed Salter's osteotomy in two other patients who were normal in follow-ups but unstable after the removal of the third cast (Table 5).

Table 3. Results of patients requiring and not requiring osteotomy according to the Mann-Whitney test

Patients		Age (Month)	Follow-up Time (Months)	Casting Period	AI (Right)	AI (Left)	AA (Right)	AA (Left)	FBCA (Right)	FBCA (Left)	Tonnis (Right)	Tonnis (Left)
Only closed reduction	Standard Deviation	3.197	13.284	0.467	7.270	8.226	5.574	4.650	8.426	4.413	0.924	0.924
Osteotomy	Standard Deviation	2.702	12.818	0.548	10.714	9.423	6.164	5.899	14.241	15.620	1.342	1.414

Table 4. Significance of differences between the groups according to the Mann-Whitney test

	Age (Month)	Follow-up Time (Months)	Casting Period	AI (Right)	AI (Left)	AA (Right)	AA (Left)	FBCA (Right)	FBCA (Left)	Tonnis (Right)	Tonnis (Left)
p	0.270	0.450	0.225	0.819	0.362	0.646	0.954	0.909	0.955	0.952	0.209

Among the hips of patients who underwent closed reduction and pelvipedal casting, which was evaluated as reduced, one was Tönnis stage 4, three were Tönnis stage 3, five were Tönnis stage 2, and one was Tönnis stage 1. We evaluated 10 hips as normal, and one patient with Tönnis stage 3 developed mild dysplasia, but we performed osteotomy in one patient with Tönnis stage 3 who developed severe dysplasia. Dysplasia did not develop in two patients with Tönnis stage 2 and stage 3 who underwent Salter osteotomy, while in three patients who underwent Dega osteotomy, we noted severe dysplasia in one hip with Tönnis stage 3, and the other hips were normal. We did not find a significant relationship between the Tönnis staging and need for osteotomy (right hip: p=0.952; left hip: p=0.209).

We calculated the mean age of the patients who underwent osteotomy because of dysplasia in the follow-up period as 23.4 months. The youngest was 18 months old, while the oldest was 28 months old. The interval between performing the surgical procedure after the closed reduction and pelvic plaster was 5.2 months (4-6 months).

Table 5. Demographic features of patients who underwent osteotomy

Osteotomy	Dega	Salter
Casting Period	3	2
Mean Osteotomy Time (Months)	23	21,5

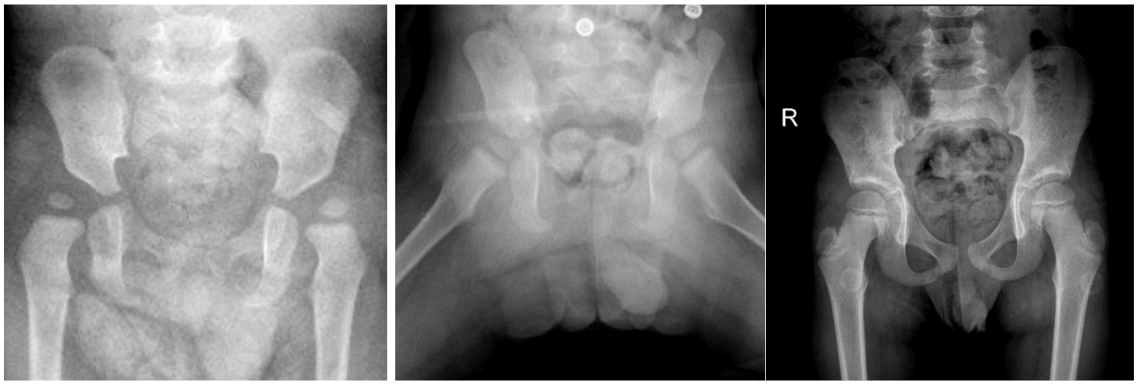
The mean AI of the right hips of patients treated with closed reduction and pelvipedal casting was 35.5 degrees before reduction, while the mean AI value at the time of the last cast removal was 18.2 degrees. The mean AI of the left hips before reduction was 33.4 degrees, but we calculated the mean AI value at the time of the last cast removal as 21.2 degrees. In patients who required surgery because of dysplasia, the mean

AI value of the right hip before closed reduction was 34.5 degrees, while the mean AI value after the last cast removal was 23.5 degrees. Thus, the left hip mean AI value decreased from 40.5 degrees to 24 degrees (Table 6).

In this study, the mean CE angles of the right and left hips of the patients treated with closed reduction and pelvipedal casting on the last pelvic AP radiographs were 18.4 (min 7 - max 32, SD 8.46) and 19.2 (min 9 - max 28, SD 5.87), respectively. Those of patients who underwent osteotomy were 18.25 (min 12 - max 26, SD 5.22) and 15.5 (min 14 - max 25, SD 7.23), respectively. In the 20-month-old patient treated with closed reduction and pelvipedal cast, dysplasia regressed in follow-up radiographs at 96 months (Figs. 2A–C).

Table 6. Pre-reduction and last mean AI values of patients who underwent closed reduction and osteotomy

AI	RIGHT	LEFT
The mean AI values before closed reduction	35.5° (20 - 42°)	33.4° (21 - 44°)
The mean AI values since the last cast removal	18.2° (12 - 24°)	21.2° (12 - 29°)
The mean AI values before closed reduction in osteotomy patients	34.5° (20 - 42°)	40.5° (21 - 46°)
The mean AI values of the patients who underwent osteotomy after the last cast removal	23.5° (16 - 29°)	24.0° (15 - 30°)



A **B** **C**

Fig. 2. (A) Pre-reduction pelvic AP radiograph (20th month), **(B)** Post-reduction pelvic AP radiograph (24th month), **(C)** Post-reduction pelvic AP radiograph (96th month). A single AP radiograph is the most appropriate examination in children with DDH where femoral head ossification has occurred. And the frog leg lateral view is a special radiograph of the pelvis to evaluate the hip to reduce exposure and maintain high diagnostic accuracy.

4. Discussion

In this study, we aimed to find the efficacy and success-related criteria of closed reduction and cast therapy as the first treatment for patients with DDH aged 18 months and older. We achieved stable reduction with closed reduction and casting treatment in 12 hips (60%) of 8 patients, while we performed acetabular osteotomy on 8 hips (40%) of 5 patients because of the development of dysplasia. We may consider closed reduction and cast therapy in patients with low dysplasia at the beginning of treatment, and we found no evidence that delaying osteotomy in patients with severe dysplasia might be a waste of time.

Closed reduction and cast treatment are sufficient for DDH treatment up to 18 months of age, while open reduction is performed after 18 months of age (14–18). Avascular necrosis, joint stiffness, and re-dislocation rates are high with closed reduction therapy in patients older than 18 months (19,20). The guidelines recommend direct open reduction in cases older than 24 months (12,13,21,22), although some authors suggest that closed reduction may be sufficient as the first-line treatment for patients older than 18 months (10–12,23–27).

Tachdjian applied closed reduction and casting treatment up to 30 months of age, depending on the case (11,12). Ponseti achieved successful results with closed reduction and cast treatment in patients treated after walking age and suggested an open reduction in patients under the age of 3 years (11). In this patient series, we noted that children with DDH older than 18 months benefited from closed reduction and cast treatment before osteotomy, independent of dysplasia. According to Murray et al., closed reduction and casting treatment fails in up to 30% of advanced-age patients (28). Other studies show that 66% of patients treated with closed reduction and cast plaster may need surgical procedures (29,30). Cases of residual dysplasia have a chance of spontaneous recovery without surgery (31,32). In our study, only 40% of the patients required osteotomy because of residual dysplasia.

The mean time before osteotomy was 5.2 months, which is

acceptable according to the literature, demonstrating the feasibility of closed reduction and cast treatment in patients with DDH older than 18 months. In our study, we performed acetabular osteotomy 23.8 months after closed reduction and pelvipedal cast treatment in five patients aged between 18 and 21 months after the detection of dysplasia because of inadequate treatment. There was no distinction in age at presentation between patients treated with closed reduction and cast treatment and those requiring osteotomy (p=0.270).

There are two different opinions on the adequacy of closed reduction and cast treatment. Absolute anatomical reduction is prominent in the first opinion (12). In the second classical opinion if the hip is immobilized in a stable and unforced position, there will not be negative effect on the results from the soft tissue interposition between the femoral head and the medial wall of the acetabulum and the femoral head not being in full contact with the acetabular medial wall oriented towards the triradiate cartilage (23–25). If the inverted labrum is not large or fibrotic, it can be resorbed (33).

Hattori et al. reported that the prominent soft tissue interposition seen in arthrography disappears in 71% of cases over time, and the long-term follow-up results of these hips were the same as those of hips with anatomical concentric reduction (34). Another MRI study found similar results and reported that pulvinar could be resorbed if concentric reduction is achieved (35). As we practiced in our patients, we think that an acceptable non-absolute reduction is sufficiently provided by arthrographic closed reduction with confirmation under fluoroscopy.

The CE angle is most often used for examining hip-joint development in direct radiographs. Values less than 15 degrees are abnormal in children (36). We noted that the mean CE angles of the hips that underwent osteotomy were low as we evaluated the radiographs of the hips that underwent osteotomy after closed reduction because of acetabular dysplasia and the last radiographs of the hips that underwent closed reduction and pelvipedal cast. However, this result was not significant.

Avascular necrosis (AVN) is the most significant complication leading to joint deformity, length inequality, and late osteoarthritis in the long term after treatment (32). Thomas et al. found a 2.5-fold increase in the probability of developing AVN after open reduction compared with closed reduction (37). In our study, the mean follow-up period was 41.5 months (7-90 months), and we did not recognize AVN or joint stiffness in any patient during this period.

Our study has several limitations. First, the follow-up period was short, and we only had early results. We could not discuss our mid- and long-term results. Second, we had a limited number of cases. More precise data could be obtained with further case series and long-term follow-ups.

We consider closed reduction and cast treatment as a first-line treatment in selected DDH cases with ages between 18 and 30 months because it is less invasive and it can give the patient a chance of recovery before open surgery. When closed reduction and casting treatment is unsuccessful, we think that a delay in treatment can be acceptable according to the current literature. Before starting treatment, parents should be warned that closed reduction and cast treatment may be insufficient and that osteotomy may be required.

Conflict of interest

The authors declared no conflict of interest.

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None to declare.

Authors' contributions

Concept: Ö.K., Design: Ö.K., Data Collection or Processing: N.D., Analysis or Interpretation: Ö.K., H.H.C., Literature Search: Ş.S., Writing: Ş.S., N.D., Ö.K., H.H.C., C.S.

Ethical Statement

The study protocol was approved by the Clinical Research Ethics Committee of Medipol University (Date: 21.05.2020, Protocol number: 10840098-604.01.01-E.15430).

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