

## Posteromedial Limited Surgery in Developmental Dysplasia of the Hip

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**Abstract** We questioned whether our modified soft tissue surgical procedure can provide acceptable results with lower complication rates in developmental dysplasia of the hip (DDH). We retrospectively reviewed 143 patients (185 hips) with a mean age of 11.6 months at operation and a minimum followup of 5 years (mean, 7.5 years; range, 5–13 years). We used a posteromedial approach and sectioned the adductor longus and iliopsoas tendons. If we achieved an arthrographically documented anatomic reduction we closed the incisions; if not, we made an arthrotomy to obtain an anatomic reduction through the

same incision at the same session. A hip score indicating an acceptable outcome was obtained in 168 hips (90.8%). We identified osteonecrosis of the femoral head (ON) in 36 (19.5%) hips and redislocation in four (2.2%). Both the ossific nucleus and physis were affected in 10 of the 36 hips with ON. We performed secondary operations in 12 hips (6.5%). Hips of the infants after walking age and hips with higher preoperative dislocation grades, acetabular indices, and ON were more prone to having lower hip scores. Based on the data, we believe routine arthrotomy is not needed during posteromedial surgery in DDH and this modified procedure was safe and effective.

**Level of Evidence:** Level II, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

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### Introduction

Neonatal detection, gentle anatomic reduction of the hip, avoiding the complications of anesthesia during nonoperative or surgical treatment, and reducing hospitalization and inconvenience for the patient and parents are the universally accepted goals in the treatment of developmental dysplasia of the hip (DDH). For newborns through infants 6 to 9 months of age, an abduction orthosis (preferably a Pavlik harness) seems the preferred treatment method in DDH [21]. However, after 6 to 9 months of age or in a patient with failed abduction orthosis treatment, a closed or open reduction followed by a hip spica cast immobilization is often recommended up to 18 to 24 months of age [21].

In children younger than 24 months, there are several alternative surgical approaches (inguinal, anterior, antero-lateral, or medial) for the open reduction in DDH. There are two main variations of the medial approach:

anteromedial [7, 8] and posteromedial [4]. Proponents of the medial approach suggest it provides simple, direct, and nontraumatic access to all inferomedial obstacles to reduction in a bloodless field, is cosmetically preferable, and can treat both hips at the same session [20]. We have been using the posteromedial approach to open reduction in DDH for many years and two of the authors (YT, HÖ) previously reported their experiences with this procedure [9, 18, 19]. The rate of excellent and good radiographic outcomes using the Severin's criteria [14] ranged from 68% to 98% in these series, suggesting the posteromedial approach open reduction was safe and effective in DDH treatment under 1.5 years of age. In 1993, we modified our approach by avoiding routine hip arthrotomy, and rather performed it only if concentric reduction was not achieved after sectioning the adductor longus and iliopsoas tendons through the posteromedial incision. The short-term results of 137 hips treated by this limited surgical procedure were previously published [2]. This former study included only radiographic assessment of the acetabular slope at the latest followup and after a minimum of 2 years followup (mean, 4.2 years; range, 2–9 years), 82% of the hips were considered to have normal acetabular slope in the frontal plane, and osteonecrosis of the femoral head (ON), redislocation, and secondary operation occurred at a rate of 13%, 1%, and 2%, respectively [2]. We believe it is important to section adductor longus and iliopsoas tendons, the main extraarticular obstacles to reduction in unstable or unreducible hips of children younger than 18 months, but arthrotomy is not routinely needed at the same session and can be an unwarranted surgical step in many hips. Such a modification simplifies the procedure and shortens the operating time in some cases.

We hypothesized our easier procedure, which we consider between classical closed and open reductions, could provide an outcome as acceptable as the previously described classical procedures and with a tolerable complication rate. We have extended our radiographic followup to at least 5 years and analyzed in detail the preoperative, intraoperative, and latest radiographic status and the correlation between latest outcome and several factors such as preoperative dislocation grade, age, gender, laterality, need for arthrotomy, preoperative acetabular slope, and the occurrence of ON. In addition we evaluated the correlation between the previously mentioned factors and the rate of ON, redislocation, and secondary operation.

## Materials and Methods

We retrospectively reviewed 228 developmentally dysplastic hips of 175 patients operated on between December 1993 and November 2001 using the posteromedial limited

surgery we introduced in 1993 [2]. The patients came from four centers. Among these patients, 143 (185 hips) had at least 5 years of complete followup. The main reason for a loss to followup of at least 5 years in the other 32 patients was their having moved to a new location. Mean age at operation was  $11.6 \pm 4.4$  months (range, 3–18 months); all patients between 3 and 6 months of age had a history of failed nonoperative treatment. The patients were divided into two age groups, 3 to 10 months (nonwalking group) and 11 to 18 months (walking group), to assess the effect of age on the latest outcome and occurrence of complications. One hundred and twenty-seven of the patients were girls (166 hips) and 16 were boys (19 hips). The affected side was bilateral in 42 patients and unilateral in 101 (50 right hips, 51 left hips). The minimum followup was 5 years (mean,  $7.4 \pm 2.3$ ; range, 5–13 years).

We followed patients and obtained radiographs at regular intervals of 3, 6, 12, 18, and 24 months postoperatively, then once a year and finally once every 2 years from 6 to 7 years of age to at least skeletal maturity. All plain radiographs were obtained while the patient was supine and both patellae were pointing straight upwards. The film-focus distance was 110 cm in all cases. All postoperative and followup plain radiographs were evaluated by the same author (HÖ) using the same goniometer.

One author (HÖ) assessed preoperative dislocation grade and the author who performed the operation assessed intraoperative arthrographic reduction grade using Tönnis' two discrete classification systems [17]. Preoperative grades 1 and 2 indicate the lateral displacement of the proximal femoral epiphysis without superior displacement and it is medial and lateral to the Perkins' line in grades 1 and 2, respectively. Preoperative grades 3 and 4 indicate that there are both superior and lateral displacements of the proximal femoral epiphysis and it is level with the superior acetabular rim in grade 3 and above the superior acetabular rim in grade 4. Grade 2 dislocation was rated as "low dislocation" and grades 3 and 4 as "high dislocation". Preoperative acetabular slope was measured by the acetabular index angle of Hilgenreiner [16]. (AI), and the end of the superior acetabular notch was used as the index point for the lateral edge of the acetabular roof [17]. Preoperative AI was divided into two subgroups, less than or equal to  $45^\circ$  and greater than  $45^\circ$ , to assess the effect of preoperative AI on the latest outcome and occurrence of complications. ON was assessed using the classification system of Kalamchi and MacEwen [6]. Type 1 ON was rated as mild and types 2, 3, and 4 were rated as severe ON while assessing the effects of several factors on the type of ON. Radiographic assessment of the hips at the latest followup was made using a recently defined objective classification system [12] (Table 1). This system includes three quantitative parameters evaluating the lateral coverage of the femoral head

**Table 1.** The radiographic classification system for the assessment of the results [12]

Radiographic parameters	2 Points	1 Point	0 Points
CE angle of Wiberg [22] (°)	$\geq 15^*$	0–14*	$< 0^*$
	$\geq 20^{**}$	5–19**	$< 5^{**}$
Acetabular angle of Sharp [15] (°)	$\leq 49^*$	50–55*	$> 55^*$
	$\leq 43^{**}$	44–49**	$> 49^{**}$
Center trochanter distance [11] (mm)	from 0 to +10*	from –1 to –5 and from +11 to +15*	$< -5$ and $> +15^*$
	from –11 to +1**	from –12 to –17 and from +2 to +7**	$< -17$ and $> +7^{**}$

\* Skeletally immature hip (one or more than of the following items are still visible on the plain radiograph: triradiate cartilage, proximal femoral physis, greater trochanteric physis); \*\*Skeletally mature hip (all of the following items are not visible on the plain radiograph: triradiate cartilage, proximal femoral physis, greater trochanteric physis).

(Reprinted with permission of Lippincott Williams and Wilkins from Omeroglu H, Ucar DH, Tumer Y. A new, objective radiographic classification system for the assessment of treatment results in developmental dysplasia of the hip. *J Pediatr Orthop B.* 2006;15:77–82, Figs. 1, 2 and 3.).

#### Corrective Items (– 1 Point for each)

- Existence of an acetabulum in which there is a considerable distance between the most lateral point of subchondral sclerosis and the most lateral point of the acetabular roof and the subchondral sclerosis is ill defined and irregular.
- Secondary procedures (closed reduction, soft tissue and/or bony surgery).
- Early redislocation or resubluxation.

#### Total Points

6 = Excellent; 5 = Good; 4 = Fair-Plus; 3 = Fair-Minus;  $< 3$  = Poor; 5–6 = Satisfactory;  $\leq 4$  = Unsatisfactory.

(CE angle of Wiberg [22]), acetabular slope (acetabular angle of Sharp [15]) and proximal femoral anatomy (center-trochanter distance [11]), and three corrective items (shape of the acetabular subchondral density, secondary procedures and early resubluxation or redislocation) to avoid overestimation of the results. This system has been reported to have acceptable levels of intraobserver and interobserver agreements and evaluates both the adequacy of the initial treatment and the latest status of the hip [12].

We used no traction prior to surgery in any of the patients. The operation was performed with the patient supine. A 4- to 5-cm-long longitudinal skin incision was made in line with the posterior margin of the adductor longus tendon. After sectioning the adductor longus tendon, the lesser trochanter and the iliopsoas tendon were exposed through the plane between the adductor brevis and adductor magnus muscles as defined by Ferguson [4]. After sectioning the iliopsoas tendon at the level of lesser trochanter, 1.5 to 2 cc of water-soluble contrast agent was injected in the hip joint. We avoided forceful reduction and instead the hip was allowed to reduce spontaneously while being abducted and flexed without lifting the femoral head to the acetabulum by the fingers located on the greater trochanter. If a Grade 1 arthrographic reduction (anatomic reduction) was obtained, the operation was ended. In cases of Grade 2 (somewhat lateralized femoral head) or Grade 3 (femoral head is outside the acetabulum) arthrographic reductions, the inferomedial hip capsule was opened, ligamentum teres was excised, and transverse acetabular ligament was sectioned to obtain an anatomic reduction

through the same incision at the same session. The same previously mentioned gentle reduction maneuver was made after completion of the arthrotomy procedure. Bilaterally affected hips were operated on at the same session. Operative time including the closure of the wound did not exceed 20 minutes when an open reduction was not performed and 45 minutes when an arthrotomy was made in any of the hips. No intraoperative or postoperative blood transfusion was needed in any of the patients. Following the tenotomies, Grade 1 arthrographic reduction was obtained in 89 hips (48.1%), Grade 2 in 75 (40.5%), and Grade 3 in 21 (11.4%). Thus, the rate of arthrotomy or open reduction was 51.9% according to the previously described surgical technique.

Postoperatively, the hips were immobilized in a bilateral hip spica cast in “human position” [5] leaving both ankles and feet free for 3 months, and then a full-time abduction brace holding both hips in 90° to 100° flexion and 40° to 50° abduction was applied for an additional 3 months [2].

Clinical examination was made at all regular followups and hip pain (no pain and mild, moderate, or severe pain as judged by the clinician) and limping (no limping, slight limping, or positive Trendelenburg sign) were the clinical parameters assessed at the regular and latest followups by one of the authors (AB, HA, HÖ or YT), whomever was the primary surgeon of the patient.

We used the t-test for independent samples to compare the mean hip scores [12] regarding gender, laterality, age, preoperative dislocation grade, preoperative AI, need for open reduction, occurrence of ON, and type of ON. We

used the chi square and Fisher's exact tests to assess the correlation between gender, laterality, age, preoperative dislocation grade, preoperative AI, need for open reduction, and the rates of ON, redislocation, and secondary operation.

## Results

The triradiate cartilage was not visible in 11 hips, and both the triradiate cartilage and greater trochanteric physis were not visible in 16 hips due to physiologic completion of the skeletal growth at these sites, therefore, nearly 15% of the hips were almost skeletally mature at the latest followup. In one hip, in addition to the physiologic closure of the triradiate cartilage, early closure of the proximal femoral physis due to Type 4 ON and closure of the trochanteric apophysis due to apophysiodesis operation were seen.

Mean preoperative AI [16] and mean hip score [12], center-edge angle of Wiberg [22], acetabular angle of Sharp [15], center trochanter distance [11] at the latest followup were  $45.7^\circ \pm 4.3^\circ$  (range,  $36^\circ$ – $56^\circ$ ) and  $5.42 \pm 0.94$  (range, 1–6),  $22.8^\circ \pm 6.9^\circ$  (range,  $-20^\circ$ – $38^\circ$ ),  $47.5^\circ \pm 3.4^\circ$  (range,  $34^\circ$ – $59^\circ$ ),  $4.5 \pm 4.3$  mm (range,  $-15$  mm– $19$  mm), respectively. Latest hip score was 6/6 (excellent outcome) in 111 hips (60%) (Fig. 1A, B), 5/6 (good outcome) in 57 hips (30.8%) (Fig. 2A, B), 4/6 (fair-plus outcome) in eight hips (4.3%), 3/6 (fair-minus outcome) in five hips (2.7%) (Fig. 3A, B) and 1&2/6 (poor outcome) in four hips (2.2%), thus indicating an acceptable radiographic outcome in nearly 91% of the hips.

Mean hip scores of the nonwalking group ( $p = 0.009$ ), low dislocation group ( $p = 0.004$ ), preoperative AI less than or equal to  $45^\circ$  group ( $p = 0.001$ ), no arthroscopy performed group ( $p = 0.032$ ), no ON seen group ( $p < 0.001$ ), and mild ON group ( $p < 0.001$ ) were higher than those of the walking group, high dislocation group, preoperative AI greater than  $45^\circ$  group, arthroscopy performed group, ON seen group, and severe ON group, respectively (Table 2). Mean hip scores of female and male patients, and right and left hips were similar ( $p > 0.05$ ) (Table 2).

ON was seen in 36 hips (19.5%). Among these 36 hips, 26 (72.2%) had mild ON (Type 1) and 10 (27.8%) had severe ON (Type 2 [five], Type 3 [three], and Type 4 [two]). Hips operated on between 3 and 10 months of age ( $p = 0.029$ ), having preoperative low dislocation ( $p = 0.006$ ), and preoperative AI less than or equal to  $45^\circ$  ( $p = 0.001$ ) had higher rates of ON than hips operated on between 11 and 18 months of age, having preoperative high dislocation, and preoperative AI greater than  $45^\circ$ , respectively (Table 3). We observed no correlation between gender, laterality, arthroscopy, and occurrence of



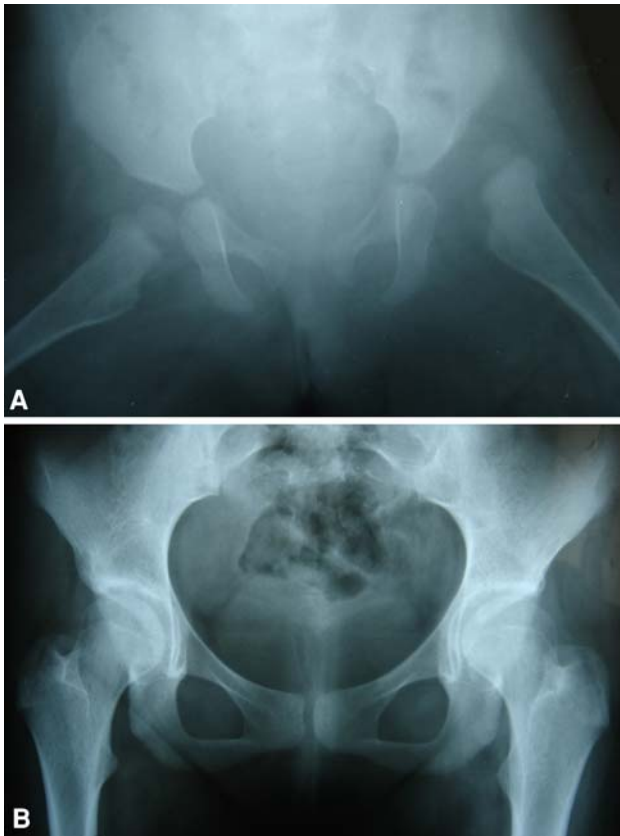
**Fig. 1A–B** (A) Preoperative and (B) 13-year postoperative followup radiographs of a female patient with bilateral DDH. She was 16 months old at the time of operation, and had bilateral Grade 3 dislocations. AI was measured as  $50^\circ$  and  $46^\circ$  in the right and left hips, respectively. Both hips were anatomically reduced following adductor longus and iliopsoas tenotomies without arthroscopy. At the latest followup both hips were rated as excellent.

ON ( $p > 0.05$ ) (Table 3). Similarly, no correlation was found between gender, laterality, age, preoperative dislocation grade, preoperative AI, need for open reduction, and the type of ON ( $p > 0.05$ ) (Table 3).

Early redislocation was seen in four hips (2.2%). All redislocations were diagnosed within the first 3 postoperative months and treated within the first 6 postoperative months. We performed a closed reduction on postoperative day 3, two posteromedial approach open reductions postoperatively at 1 and 3 months, and an open reduction with Salter innominate osteotomy and proximal femoral osteotomy postoperatively at 6 months. We observed no correlation between gender, laterality, age, preoperative dislocation grade, preoperative AI, need for open reduction, and occurrence of redislocation ( $p > 0.05$ ) (Table 4).

A secondary procedure to relocate the hip or to treat the residual acetabular dysplasia and/or proximal femoral deformity was performed in 12 hips (6.5%) (Table 5). We performed proximal femoral osteotomy (four hips); posteromedial open reduction (two hips); closed reduction





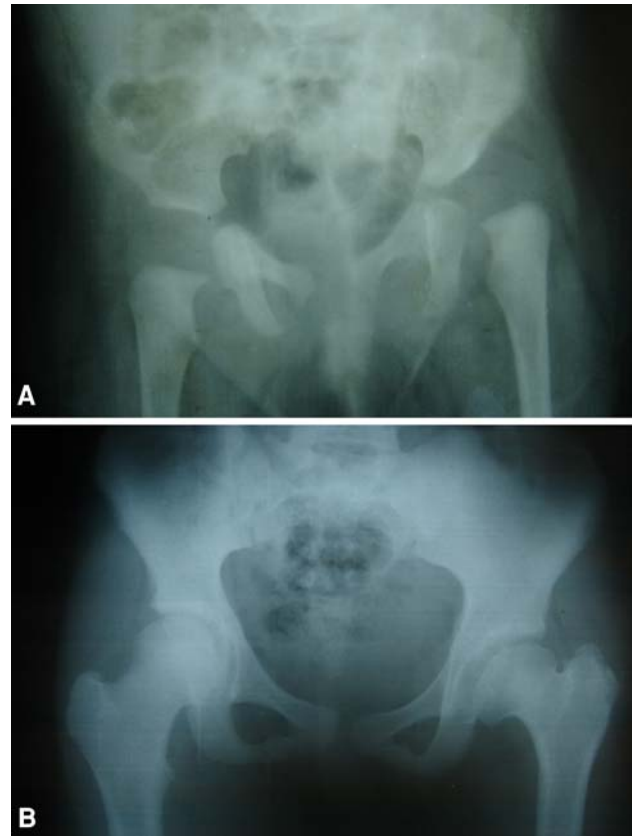
**Fig. 2A–B** (A) Preoperative and (B) 11-year postoperative followup radiographs of a female patient with DDH in the left hip. She was 12 months old at the time of surgery and had a Grade 2 dislocation and AI of 50°. She had transient ischemic changes during the early postoperative period (Type 1 ON) but this resolved without any sequel. At the latest followup the left hip was rated as good.

(one hip); Dega osteotomy (one hip); combined Dega and proximal femoral osteotomies (one hip); combined open reduction, Salter, and proximal femoral osteotomies (one hip); greater trochanteric apophysiodesis (one hip); and proximal femoral medial epiphysiodesis (one hip). We found no correlation between gender, laterality, age, preoperative dislocation grade, preoperative AI, need for open reduction, and rate of secondary operation ( $p > 0.05$ ) (Table 5).

The examining physicians recorded no hip pain in any patients at the latest followup, but slight limping was present in eight patients (6%), and all these patients had a history of severe type of ON.

## Discussion

There is no universally accepted treatment method for DDH in children under 18 months of age, but medial approach open reduction is one of the preferred methods. A surgeon's previous experience is one of the important



**Fig. 3A–B** (A) Preoperative and (B) 12-year postoperative followup radiographs of a female patient with DDH in the left hip. Age at operation was 6 months. Preoperatively she had a Grade 2 dislocation and AI was 40°. An anatomic reduction was obtained without opening the hip capsule. She had Type 4 ON and greater trochanteric apophysiodesis was performed when she was 7 years old. At the latest followup the left hip was rated as fair-minus. Distal transfer of the greater trochanter for the left will be performed in the near future.

factors determining the course of management. Most surgeons are not familiar with the medial surgical approach to DDH, and it seems an inappropriate procedure for the inexperienced. However, we have been performing the posteromedial approach to DDH for many years and rarely perform other surgical approaches for the reduction of the pediatric hip. Nevertheless, we have simplified the procedure to some extent by performing an arthrotomy when needed since 1993, as we presumed such a modification also leads acceptable results and an acceptable rate of complications.

A major limitation of the present study was the lack of followup of all hips until skeletal maturity. Radiological results obtained before skeletal maturity can appear more optimistic when compared to radiographs taken after skeletal maturity in the same hips [12]. The acetabulum has the potential to develop until skeletal maturity [19], but in normal hips the acetabulum reaches its normal radiographic slope values at the age of 7 to 8 years [10]. In our

**Table 2.** Comparison of mean hip scores with relation to gender, side, age, preoperative dislocation grade, preoperative AI, need for open reduction, and occurrence, and type of ON (mean  $\pm$  standard deviation)

Variable	Mean hip score [12]	p Value
Gender		
Female (N = 166)	5.45 $\pm$ 0.91	0.198
Male (N = 19)	5.16 $\pm$ 1.17	
Side		
Right (N = 92)	5.43 $\pm$ 1.03	0.851
Left (N = 93)	5.41 $\pm$ 0.85	
Age		
3–10 months (N = 76)	5.61 $\pm$ 0.61	0.009*
11–18 months (N = 109)	5.28 $\pm$ 1.10	
Preoperative Dislocation Grade		
Low (Grade 2) (N = 132)	5.58 $\pm$ 0.74	0.004*
High (Grades 3 and 4) (N = 53)	5.04 $\pm$ 1.24	
Preoperative AI		
$\leq 45^\circ$ (N = 86)	5.65 $\pm$ 0.61	0.001*
$> 45^\circ$ (N = 99)	5.22 $\pm$ 1.12	
Need For Open Reduction		
Yes (N = 96)	5.28 $\pm$ 1.14	0.032*
No (N = 89)	5.57 $\pm$ 0.64	
ON		
Yes (N = 36)	4.42 $\pm$ 1.44	$< 0.001^*$
No (N = 149)	5.66 $\pm$ 0.55	
Type of ON		
Mild (Type 1) (N = 26)	5.00 $\pm$ 0.85	$< 0.001^*$
Severe (Types 2, 3 and 4) (N = 10)	2.90 $\pm$ 1.60	

AI = acetabular index angle; ON = osteonecrosis of the femoral head; N = number of hips.

\* significant difference.

study, closure of the triradiate cartilage was observed in nearly 15% of the hips and mean age of the patients at the latest followup was nearly 8.5 years. Therefore, we believe that the mid-term radiographic results obtained from this study can be considered valuable, although the risk of overestimating the results still exists as all the hips have not been followed until skeletal maturity. We used no standardized outcome measures, so all clinical results are based upon subjective physician ratings.

Our data suggest this procedure produces acceptable radiographic outcomes in 91% of the hips, physicians' judgments of no complaints in 94% of the patients, and relatively low complication rates (ON 19.5%, redislocation 2.2%, and secondary operation 6.5%) after a mean followup period of 7.5 years. The data also support our suggestion that an arthrotomy can be performed when judged necessary rather than in a routine manner: the arthrotomy group had lower hip scores than the nonarthrotomy group, although

anatomic reduction was initially obtained in both groups. One explanation for this finding may be that the need for open reduction seems to increase in older patients, patients with highly dislocated hips and hips with severe acetabular dysplasia, and such patients already have lower hip scores and higher complication rates. However, arthrotomy does not lead to proximal femoral growth disturbance, increase in redislocation or secondary procedure rates. A similar surgical procedure has been reported in the literature [1], but the hip capsule was not opened following the adductor longus and iliopsoas tenotomies through the medial approach because the authors considered opening the joint capsule unnecessary; they recommended avoiding opening the capsule to reduce the risk of ON. We do not entirely agree with the recommendation as our data demonstrate an anatomic reduction could not be obtained in nearly half of the hips following these extraarticular releases. Our previous experience suggests intraoperative anatomic reduction either closed or open is mandatory, otherwise the risk of redislocation and ON increases even in the cases in which an arthrographic slight lateralization of the femoral head has initially been considered acceptable [3].

Performing a medial approach surgical procedure in DDH is usually recommended for patients under 12 months old, as it is believed that walking may have some adverse effects on the results and capsulorrhaphy is needed to provide more stability after 12 months of age [5]. Our data shows patients operated on before they are walking have higher hip scores and lower ON rates than patients operated on after the walking age. However, age does not affect the severity of ON, or the rates of redislocation and or secondary operation. The proximal femur tends to displace laterally and proximally and acetabular dysplasia increases while the patient is growing if the hip is left untreated [5, 17, 20]. The data support this opinion, as patient age at operation correlated with preoperative dislocation grade and preoperative AI. We still believe the safe patient age cutoff for medial-approach surgical treatment for DDH is 18 months, but it is the surgeon's own choice to perform soft tissue surgery or postpone the treatment for performing a more aggressive bony surgery 2 to 3 months later in borderline cases (especially in the 15- to 18-month age group).

It is generally accepted that ON is the most important complication following the treatment of DDH [5, 17, 20]. It is commonly believed it is multifactorial and patient age, appearance of the ossific nucleus, use of prerotation traction, presence of adduction contracture, type of reduction, force of reduction, position of the hip in a spica cast, preoperative dislocation grade, and individual predisposing factors involving the vascular system such as coagulopathy are associated with the development of ON [5, 17, 20]. The reported rate of ON following posteromedial open

**Table 3.** Correlation between gender, side, age, preoperative dislocation grade, preoperative AI, need for open reduction, and the occurrence and type of ON

Variables	No ON	Mild ON (Type 1)	Severe ON (Types 2, 3 and 4)	p Values
<b>Gender</b>				
Female	137 (82.5%)	21 (12.7%)	8 (4.8%)	0.062 <sup>*</sup> ; 1.0 <sup>†</sup>
Male	12 (63.2%)	5 (26.3%)	2 (10.5%)	
<b>Side</b>				
Right	77 (83.7%)	9 (9.8%)	6 (6.5%)	0.281 <sup>*</sup> ; 0.260 <sup>†</sup>
Left	72 (77.4%)	17 (18.3%)	4 (4.2%)	
<b>Age</b>				
3–10 months	67 (88.2%)	7 (9.2%)	2 (2.6%)	0.029 <sup>**†</sup> ; 1.0 <sup>†</sup>
11–18 months	82 (75.2%)	19 (17.4%)	8 (7.4%)	
<b>Preoperative Dislocation Grade</b>				
Low (Grade 2)	113 (85.6%)	15 (11.4%)	4 (3.0%)	0.006 <sup>**†</sup> ; 0.463 <sup>†</sup>
High (Grades 3 and 4)	36 (67.9%)	11 (20.8%)	6 (11.3%)	
<b>Preoperative AI</b>				
≤ 45°	78 (90.7%)	7 (8.1%)	1 (1.2%)	0.001 <sup>**†</sup> ; 0.397 <sup>†</sup>
> 45°	71 (71.7%)	19 (19.2%)	9 (9.1%)	
<b>Need for Open Reduction</b>				
Yes	73 (76%)	17 (17.7%)	6 (6.3%)	0.108 <sup>*</sup> ; 0.527 <sup>†</sup>
No	76 (85.4%)	9 (10.1%)	4 (4.5%)	
Total	149 (80.5%)	26 (14.1%)	10 (5.4%)	

AI = acetabular index angle; ON = osteonecrosis of the femoral head.

\* p value for the comparison of the occurrence rate of ON between the groups within the variables; † p value for the comparison of the rate of mild and severe types of ON within the ON cases seen.

‡ Significant difference.

**Table 4.** Correlation between gender, side, age, preoperative dislocation grade, preoperative AI, and need for open reduction

Variables	Redislocation	p Value
<b>Gender</b>		
Female	4 / 166 (2.4%)	1.0
Male	0 / 19 (0%)	
<b>Side</b>		
Right	2 / 92 (2.2%)	1.0
Left	2 / 93 (2.2%)	
<b>Age</b>		
3–10 months	1 / 76 (1.3%)	0.645
11–18 months	3 / 109 (2.8%)	
<b>Preoperative Dislocation Grade</b>		
Low (Grade 2)	1 / 132 (0.8%)	0.072
High (Grades 3 and 4)	3 / 53 (5.7%)	
<b>Preoperative AI</b>		
≤ 45°	2 / 86 (2.3%)	1.0
> 45°	2 / 99 (2.0%)	
<b>Need for Open Reduction</b>		
Yes	3 / 96 (3.1%)	0.622
No	1 / 89 (1.1%)	
Total	4 / 185 (2.2%)	

AI = acetabular index angle.

**Table 5.** Correlation between gender, side, age, preoperative dislocation grade, preoperative AI, need for open reduction, and rate of secondary operation

Variables	Secondary operation	p Value
<b>Gender</b>		
Female	9 / 166 (5.4%)	0.111
Male	3 / 19 (15.8%)	
<b>Side</b>		
Right	5 / 92 (5.4%)	0.563
Left	7 / 93 (7.5%)	
<b>Age</b>		
3–10 months	2 / 76 (2.6%)	0.127
11–18 months	10 / 109 (9.2%)	
<b>Preoperative Dislocation Grade</b>		
Low (Grade 2)	5 / 132 (3.8%)	0.072
High (Grades 3 and 4)	7 / 53 (13.2%)	
<b>Preoperative AI</b>		
≤ 45°	3 / 86 (3.5%)	0.123
> 45°	9 / 99 (9.1%)	
<b>Need for Open Reduction</b>		
Yes	9 / 96 (9.4%)	0.098
No	3 / 89 (3.4%)	
Total	12 / 185 (6.5%)	

AI = acetabular index angle.

reduction in the literature ranges from 0% to 67% [2], and the authors' previously reported rate of ON ranges from 9% to 31% [9, 18, 19]. The rate of ON was 13% and 16 of 18 hips with ON were considered cases of Type 1 ON in the earlier report of the current data [2]. The ON rate in our study is higher than the previous study. We believe the reasons are: (1) Type 2 ON that needs longer followup to be evaluated could not be verified in the previous study, and (2) ON was somewhat higher in recently added cases with minimum 5 years followup. Although our rate of ON was 19.5%, nearly  $\frac{3}{4}$  of them were considered Type 1 ON which would heal with or without minor proximal femoral deformity [6]. The data reveal rate of ON is associated with age at operation, preoperative dislocation grade, and preoperative AI which have been considered related factors. Occurrence of ON, especially the severe types, has detectable adverse effects on the latest radiographic outcome. Such hips usually undergo secondary operations to provide the congruency, as we found. There may be some explanations for the higher probability of ON development in highly dislocated and severely dysplastic hips such as preoperative direct pressure of the acetabular edge on the dislocated head may cause injury or the blood vessels of the femoral head may be subject to direct stretch in highly dislocated hips or although, blood flow from the ligamentum teres is commonly considered unimportant, it may be obscured in highly dislocated hips [17]. Besides these, more injurious intraoperative manipulations and/or application of a hip spica cast in an improper position to obtain more stability may be performed in these severely dysplastic hips [17]. We believe performing a radiographically confirmed, gentle intraoperative anatomic reduction with a wide safe zone [13] ( $> 30^\circ$ ) is the key for avoiding the development of severe proximal femoral growth disturbance, and all extraarticular (and intraarticular if necessary) obstacles must be eliminated to obtain such an intraoperative reduction. We try to adhere to this simple rule in our surgical procedure and this may be the reason why our rate of severe ON is low, although the total rate of ON may be considered somewhat higher. We have obtained gentle reduction with a wider safe zone in all hips, but if this cannot be obtained even with all the previously mentioned extraarticular and intraarticular releases, then the hypertrophic pulvinar, the only remaining intraarticular obstacle, may need to be excised.

Redislocation and need for secondary operation are the two other important unwanted occasions seen following the treatment of DDH. The rates of these complications were considered acceptable, but we found no specific factor affecting the rate of such complications.

We do not recommend performing posteromedial limited surgery in hips with preoperative Tönnis Grade 1 dislocation. Closed reduction with or without adductor

tenotomy followed by a 3-month immobilization in a hip spica in human position is an adequate management protocol for such hips.

Arthrotomy is not always needed during posteromedial surgical treatment of DDH. Limited surgical treatment of DDH through the posteromedial approach is a simple, time-consuming, bloodless, safe, and effective procedure for children up to 18 months old with higher radiographic and clinical success rates and lower complication rates after a minimum followup of 5 years. The success or failure of this modified procedure is related to more than one factor, and pre-walking infants with less proximally displaced femoral heads and less acetabular dysplasia preoperatively and a lack of ON during followup seem to have better radiographic outcome at the latest followup.

## References

1. Arac S, Bozkurt M, Kiter E, Gunal I. Medial approach without opening the joint capsule for developmental dislocation of the hip. *J Orthop Sci.* 2003;8:522–525.
2. Bicimoglu A, Agus H, Omeroglu H, Tumer Y. Six years of experience with a new surgical algorithm in developmental dysplasia of the hip in children under 18 months of age. *J Pediatr Orthop.* 2003;23:693–698.
3. Bicimoglu A, Agus H, Omeroglu H, Tumer Y. The effects of arthrographically detected femoral head lateralization and soft tissue interposition during closed reduction of developmental dislocation of the hip on mid-term results [in Turkish]. *Acta Orthop Traumatol Turc.* 2004;38:1–7.
4. Ferguson AB Jr. Primary open reduction of congenital dislocation of the hip using a median adductor approach. *J Bone Joint Surg Am.* 1973;55:671–689.
5. Herring JA. *Tachdjian's Pediatric Orthopaedics*. 3rd ed. Philadelphia, PA: WB Saunders Company; 2002:513–654.
6. Kalamchi A, MacEwen GD. Avascular necrosis following treatment of congenital dislocation of the hip. *J Bone Joint Surg Am.* 1980;62:876–888.
7. Ludloff K. The open reduction of the congenital hip dislocation by an anterior incision. *Am J Orthop Surg.* 1913;2–10:438–454.
8. Mau H, Dorr WM, Henkel L, Lutsche J. Open reduction of congenital dislocation of the hip by Ludloff's method. *J Bone Joint Surg Am.* 1971;53:1281–1288.
9. Mergen E, Adyaman S, Omeroglu H, Erdemli B, Isiklar U. Medial approach open reduction for congenital dislocation of the hip using the Ferguson procedure. A review of 31 hips. *Arch Orthop Trauma Surg.* 1991;110:169–172.
10. Omeroglu H, Bicimoglu A, Agus H, Tumer Y. Acetabular development in developmental dysplasia of the hip. A radiographic study in anatomically reduced and uncomplicated hips. *Bull NYU Hosp Jt Dis.* 2007;65:276–279.
11. Omeroglu H, Ucar DH, Tumer Y. A new measurement method for the radiographic assessment of the proximal femur: the center-trochanter distance [in Turkish]. *Acta Orthop Traumatol Turc.* 2004;38:261–264.
12. Omeroglu H, Ucar DH, Tumer Y. A new, objective radiographic classification system for the assessment of treatment results in developmental dysplasia of the hip. *J Pediatr Orthop B.* 2006;15:77–82.



13. Ramsey PL, Lasser S, MacEwen GD. Congenital dislocation of the hip. Use of the Pavlik harness in the child during the first six months of life. *J Bone Joint Surg Am.* 1976;58:1000–1004.
14. Severin E. Contribution to the knowledge of congenital dislocation of the hip; Late results of closed reduction and arthrographic studies of recent cases. *Acta Chir Scand.* 1941;84(Suppl 63):1–142.
15. Sharp IK. Acetabular dysplasia: the acetabular angle. *J Bone Joint Surg Br.* 1961;43: 268–272.
16. Thieme WT, Thiersch JB (translators). Classic. Translation: Hilgenreiner on congenital hip dislocation. *J Pediatr Orthop.* 1986;6:202–214.
17. Tönnis D. *Congenital Dysplasia and Dislocation of the hip in Children and Adults.* Berlin; Heidelberg, Germany: Springer Verlag. 1987:100–155, 268–290.
18. Tumer Y, Ward WT, Grudziak J. Medial open reduction in the treatment of developmental dislocation of the hip. *J Pediatr Orthop.* 1997;17:176–180.
19. Ucar DH, Isiklar ZU, Stanitski CL, Kandemir U, Tumer Y. Open reduction through a medial approach in developmental dislocation of the hip: a follow-up study to skeletal maturity. *J Pediatr Orthop.* 2004;24:493–500.
20. Weinstein SL. Developmental hip dysplasia and dislocation. In: Morrissy RT, Weinstein SL, eds. *Lovell and Winter's Pediatric Orthopaedics.* 5<sup>th</sup> edition. Philadelphia: Lippincott Williams & Wilkins; 2001:905–956.
21. Weinstein SL, Mubarak SJ, Wenger DR. Developmental hip dysplasia and dislocation: Part II. *J Bone Joint Surg Am.* 2003;85:2024–2035.
22. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint; With special reference to the complication of osteoarthritis. *Acta Chir Scand.* 1939;83(Suppl 58):1–135.