

Radiological and clinical outcomes of medial approach open reduction by using two intervals in developmental dysplasia of the hip



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ABSTRACT

Objective: To evaluate the midterm clinical and radiological outcomes of the medial approach using two intervals for developmental hip dysplasia (DDH).

Methods: The study involved 62 hips of 47 patients (41 girls, 6 boys) treated with medial approach for DDH from 1999 to 2010. The age of the patients at surgery was 18.7 ± 2.25 months. Follow up of the patients was 11.3 ± 3.07 years. The age of the patients at the last follow up was 12.6 ± 1.74 years. According to the Tönnis classification, 13 hips were grade II, 27 hips were grade III and 22 hips were grade IV. Patients were evaluated according to Omeroglu radiological criteria and modified McKay functional criteria. The presence of avascular necrosis (AVN) of the hip was questioned using the KalamchiMacEwen classification.

Results: Radiologically, forty eight (77%) hips were evaluated as “excellent”, 8 (13%) hips as “good” and 5 (8%) hips as “fair plus” and 1 (2%) hip as “fair minus”. Two (3%) patients had type 1 temporary AVN and one (1%) patient had type 4 AVN with coxa magna and overgrowth of the greater trochanter. According to McKay functional criteria, 56 (90%) hips had “excellent” and 6 (10%) had “good” results. Two (3.2%) hips of one patient had to be reoperated with Salter osteotomy and femoral shortening + derotation osteotomy.

Conclusion: Medial approach using two separate intervals for tenotomy and capsulotomy does not jeopardize the medial circumflex or the femoral vessels and yields satisfactory midterm results for children 18 months old with dysplasia of the hip.

Level of evidence: Level IV, therapeutic study.

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Introduction

The main goals of treatment in developmental dysplasia of the hip DDH are to obtain a normal congruent hip joint and provide healthy development of the joint. After the conservative methods are tried out there are several approaches for soft tissue procedures

in surgical treatment of DDH. The choice of operative approach for the reduction is controversial. The anteromedial approach for surgical treatment DDH was first described by Ludloff in 1908.^{1,2} Ferguson, in 1973, modified this approach by traversing the interval posterior to the adductor longus.³ Weinstein and Ponseti have made a modification of the anteromedial approach.⁴ These three approaches are all medial approaches, in contrast to the anterolateral approach between the sartorius and the tensor fasciae latae. One of the most common problems encountered with medial approach is avascular necrosis of the femoral head. This problem may extend as far as into adulthood; thus patients should be followed for long periods of time.^{5,6} Our hypothesis is that the modified medial approach used in this study is safer since the intervals used for iliopsoas tenotomy and capsulotomy do not

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necessitate wide dissections in opposition to the approaches where one common interval is used. Since the medial circumflex artery is not in the surgical field during the tenotomy, the prevalence of avascular necrosis is expected to be lower and the fascia of pectineus protects the femoral nerve and vessels as the capsulotomy is performed in front of the pectineus muscle.

The purpose of this study is to evaluate the functional and radiological outcomes of a medial approach with two separate intervals to release iliopsoas and the capsule in DDH patients and analyze the rate of complications particularly avascular necrosis. In the previous study conducted in our institution, the data regarding the patients operated between 1999 and 2010 for developmental dysplasia of the hip using medial approach two with intervals was gathered in 2012 and published in 2015; the mean follow up period was 5.5 years.⁷ The present study involves a period of follow up that is five years longer. We believe that the results are noteworthy if the follow up of the patients with developmental dysplasia of the hip extends over a long period particularly through puberty whenever possible.

Patients and methods

The charts of the patients operated with “medial approach with two intervals” at our institution were evaluated for clinical and radiographical features to be included in this Institutional Review Board approved retrospective study. 71 hips of 56 patients were treated with modified medial approach for developmental hip dysplasia from 1999 to 2010. Nine patients were lost to follow up. The study involved 62 hips of 47 patients (41 girls, 6 boys; 15 bilateral). Inclusion criteria were patients operated for DDH with medial approach using two separate intervals and patients who had regular follow ups for at least 5 years. Exclusion criteria were patients who had other surgical procedures for DDH including percutaneous tenotomy. Closed reduction was attempted in six patients. Surgeries were performed by a single senior pediatric orthopedic surgeon. The mean age of the patients at surgery was 18.7 ± 2.25 months. The youngest patient in this study was 11 months old. Younger patients were treated with a different protocol involving closed reduction under general anesthesia. When closed reduction was not possible, adductor release with a stab incision was added to the procedure for that young age group. According to the radiological Tönnis classification, 13 hips were grade II, 27 hips were grade III and 22 hips were grade IV. The surgical approach was a modified medial approach that involved a 3 cm transverse incision centered over the attachment of adductor longus (AL) at

the ischion pubis. After the bleeding was controlled using electrocautery, the fascia over adductors was incised transversely at the insertion of AL and longitudinally along the course of AL. Adductor longus was cut with electrocautery at its insertion. As partial tenotomy was sometimes not adequate, total tenotomy had to be performed. Partial tenotomy could be applied to the other adductor tendons if they were still tight after adductor longus tenotomy. The iliopsoas tenotomy and the “T” shaped capsulotomy were performed through different intervals according to a technique described previously.⁷ (Fig. 1). For iliopsoas tenotomy, either the AL-pectineus interval anterior to AL or the interval between AL and brevis which is posterior to AL was used. For type II and III dislocations, iliopsoas (IP) tenotomy was performed through the interval posterior to AL whereas in type IV dislocations the interval anterior to AL was utilized. Pectineus was retracted laterally with the femoral artery vein and nerve. Adductor brevis was retracted medially and IP was revealed at the level of trochanter minor. At the level of trochanter minor, the circumflex vessels were not confronted directly in the surgical field. After determining the interval (either anterior or posterior to AL) for IP tenotomy, trochanter minor was palpated with the tip of the index finger while rotating the hip. IP tendon was released and allowed to escape proximally. Then, “T shaped” capsulotomy was performed through the interval between iliopsoas and pectineus. The capsule was not reached through IP tenotomy but rather through pectineus muscle and fascia. The fascia which is located anterolateral to the pectineus muscle protected the femoral vessel pack during the capsulotomy. A retractor was placed over the capsule under the fascia and the pectineus muscle and the capsule was dissected free towards the superolateral acetabulum with scissors. The same dissection around the capsule was carried out inferomedially towards the transverse acetabular ligament. Pectineus and adductor longus muscles were retracted with a second retractor. Thus the capsule could be exposed easily. Joint capsule was incised longitudinally along the longitudinal axis of femoral neck. Transverse acetabular ligament ligamentum teers and pulvinar was excised if they were thick enough to be an obstacle to reduction. Following this step the femoral head was easily reduced. In the Tönnis type 4 hips, the capsule was found to be in “hourglass” shape mostly. Since inadequate opening of the capsule might lead to lateralization of the hip, the capsule had to be opened meticulously in a wider manner. In cases with inverted labrum; the labrum attached to the labrum was released and allowed to heal in proper position without applying any sutures to the capsule. These two precautions provided a safe and easy reduction in cases with type IV hips.

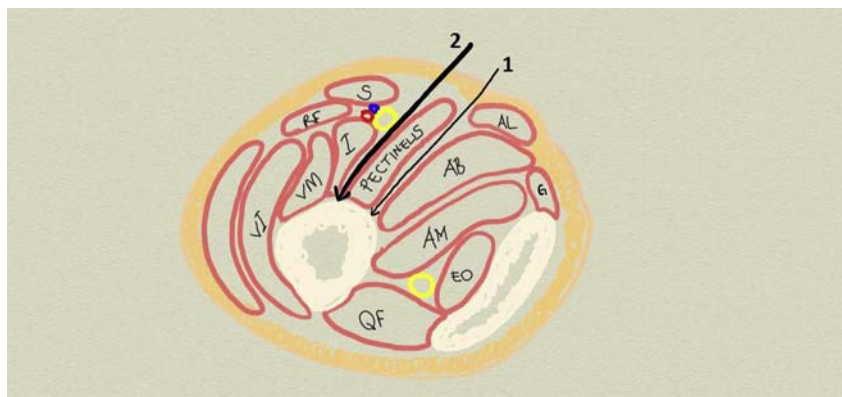


Fig. 1. Schematic drawing of the coronary section of the surgical field. Two different intervals are used: After a tenotomy to AL using a cautery, interval (1) is used for iliopsoas tenotomy and (2) is used for “T” shaped capsulotomy. VI:vastus intermedius, VM:vastus medialis, RF:rectus femoris, I:iliopsoas, S:sartorius P:pectineus AL:adductor longus, G:Gracilis, AB:adductor brevis, AM:adductor magnus, QF:Quadratus femoris, EO:obturator externus.

Postoperatively, a hip spica cast in human position was applied for three months for the patients who were between 11 and 18 months old. The time for cast was 3.5 months for patients older than 18 months. After cast removal, a modified Ilfeld brace (with flexion bands, abduction bar and shoulder straps) was applied for 4 months in patients 11–18 months old and for 6 months in patients older than 18 months. Modified Ilfeld brace was used for 2 h during night time for an additional period of two months in all of the patients. The routine follow up for the developmental dysplasia of hip in our department consisted of clinical examination and radiographs every three months in the postoperative first year and every six months in the postoperative second year. In the postoperative third and fourth years the follow ups were done annually and every two years after that until maturity. Radiographs were taken and the physical examination was performed for those patients without any follow up during the last year. Direct anteroposterior and frogleg radiographs of hips taken at the last follow-up were evaluated for appearance of the femoral head with signs of avascular necrosis of the femoral head or degenerative arthritis. Wiberg's central-edge (CE) angle, acetabular angle of Sharp and articulo trochanteric distance was measured in the direct AP radiographs. Patients were evaluated according to Omeroglu radiological criteria using these three parameters and each parameter was assigned a point score as 0,1 and 2.⁸ (Table 1). Three corrective criteria were also used: the presence of middle/posterior acetabular deficiency, need for secondary surgery, resubluxation/redislocation. For the presence of any of these three criteria –1 point was added during assesment. The presence of avascular necrosis of the hip was questioned using the Kalamchi–MacEwen classification.⁹ (Table 2). Comorbidities, details of the surgical procedure and postoperative therapy, complications were noted. Signs and symptoms of the patients were evaluated according to modified McKay functional criteria.¹⁰ (Table 3). Clinical and radiological outcome analysis was performed by one of the authors. All of the patients were informed about the details of the study and informed

consent was gathered. Statistical analysis was performed with paired t test for evaluation of acetabular index (AI) angles pre and postoperatively and independent two sample t test was used to compare the angle of Sharp and CE angles of the operated and the contralateral hips. MedCalc for Windows v12.5 (MedCalc Software, Ostend, Belgium). P values less than 0.05 were considered statistically significant.

Results

Mean follow up of the patients was 11.2 ± 3.07 years. The mean age of the patients at the last follow up was 12.6 ± 1.74 years. At the last follow up, the mean acetabular angle of Sharp was $45.20 \pm 3.8^\circ$. The mean CE angle was $26.6^\circ \pm 1.06^\circ$. The mean acetabular index angle was $12.87 \pm 2.53^\circ$ (Table 4). The articulo trochanteric distance was between 0 and 10 mm in 51 hips (82%), –1 to –5 mm in 6 hips (10%) and >10 mm in 5 hips (8%). The decrease of acetabular index angle was statistically significant at the last follow up ($p < 0.01$). When the angle of Sharp and CE angles on the operated side (for unilateral cases) were compared to the normal side at the last follow up, the difference was statistically insignificant ($p > 0.05$). According to Omeroglu radiological criteria, forty eight (77%) hips were evaluated as “excellent”, 8 (13%) hips as “good” and 5 (8%) hips as “fair plus” and 1 (2%) hip as “fair minus” thus 56 (90%) hips had a “satisfactory” result whereas 6 (10%) hips were found to be “unsatisfactory” (Fig. 2a–c). (Fig. 3a–c). According to Kalamchi Mac–Ewen classification, two (3%) patients had type I temporary avascular necrosis and one (1%) patient had type 4 avascular necrosis with flattening of the femoral head, coxa magna and overgrowth of the greater trochanter. According to McKay functional criteria, 56 (90%) hips had “excellent” and 6 (10%) hips had “good” results. Two (3.2%) hips of one patient who had the medial approach surgery at 21 months of age had to be reoperated At 25 months of age, Salter osteotomy and femoral shortening and derotation osteotomy was performed for the right side and at 33 months for

Table 1
Omeroglu radiographic classification system⁸ to assess the results.

Radiographic parameters	2 points	1 point	0 point
CE angle of Wiberg (°)	>15° >20°	0–14 ^a 5–19 ^b	<0° <5°
Acetabular angle of Sharp	<49 ^a <43 ^b	50–55 ^a 44–49 ^b	>55a >49b
Articulo trochanteric distance	From 0 to +10 mm ^a From –11 to 1 mm ^b	–1 to –5mm and +11 to +15 mm ^a –12 to –17 and +2 to +7 mm ^b	<–5 mm and >+15 mm ^a <–17 mm and >+7 mm ^b

Corrective criteria: (1) existence of an acetabulum in which there is considerable distance between the most lateral point of subchondral sclerosis and the most lateral point of acetabular roof and the subchondral sclerosis is ill defined and irregular (2); secondary procedures performed (closed reduction, soft tissue and/or bone procedures) (3); early redislocation/resubluxation. Total points 6 = excellent, 5 = good; 4 = fair plus, 3 = fair minus, <3 = poor. ≥ 5 = satisfactory, $4 \leq$ = unsatisfactory.

^a Skeletally immature hip: 1 or more of the following are visible on plain radiographs triradiate cartilage, proximal femoral epiphysis, greater trochanter epiphysis.

^b Skeletally mature hip: none of the above are visible on plain radiographs.

Table 2
Kalamchi–Mac Ewen classification.

	Criteria for Kalamchi–MacEwen classification system for AVN
Group 1	Failure of appearance of the ossific nucleus during the first year after reduction; Broadening of the femoral neck. Increased radiographic density followed by fragmentation
Group 2	Present of persistent stiffness after cast removal even without radiological criteria may be the earliest sign of ischemic necrosis Damage of the lateral aspect of the growth plate Radiographs show lateral physseal bridging, and a lateral metaphyseal notch/defect Patients in this group develop subcapital coxa valga, with a tendency to have poor acetabular coverage
Group 3	Damage of the physis with a large central defect A short femoral neck without varus or valgus
Group 4	Relative 'overgrowth' of the greater trochanter and limb-length discrepancy Damage to the entire femoral head and physis Irregular femoral head with varus, flattening, and coxa magna 'Overgrowth' of the greater trochanter, limb-length inequality, and subsequent early arthritis

Table 3
Modified Mc Kay Criteria for functional results.

Grade	Criteria
Excellent	Stable, painless hip, no limp, negative Trendelenburg sign, and a full range of movement
Good	Stable, painless hip, slight limp, negative Trendelenburg sign, and a slight decrease in range of movement
Fair	Stable, painless hip, limp, positive Trendelenburg sign, and limitation of movement
Poor	Unstable or painful hip, or both; positive Trendelenburg sign

the left side. Bony procedures were not performed for the other patients.

Discussion

The choice of treatment in DDH for children younger than 18 months is controversial. Medial approach is one of the preferred methods. It is usually recommended in children under walking age since some authors believe that walking may affect the results adversely. Ludloff's method has been described as a simple method requiring minimal dissection which results in minimal blood loss relatively. This approach facilitated access to the principal structures perceived as responsible for hip instability. Anteroinferior tightness may be addressed as the iliopsoas tendon and the constricted anteroinferior part of the capsular ligament and transverse acetabular ligament are released. An adductor release can be easily performed through the same incision with the medial approaches.^{2,3,11,12} Abductor muscles and the iliac apophysis are not violated. The residual scar is usually acceptable cosmetically. Injury to the medial circumflex artery is a major concern. Medial circumflex vessels which cross the operative field should be retracted meticulously; some authors like Mau et al recommend ligation of the vessels but this may further compromise the vascular supply of the femoral head.^{4,13} However, it is uncertain that a relationship with avascular necrosis exists.^{12,14} Another disadvantage of Ludloff approach is that it is not feasible to either perform a capsulorrhaphy or to evert the limbus for improvement of the stability of the reduction which creates an additional risk of residual subluxation or redislocation.¹⁶ The results of this procedure have been described in many reports, however the outcome remains controversial.^{15,17,18} Koizumi states that medial approach is a limited one and can not deal with extraarticular factors like adhesion of posterior aspect of capsule to ilium, contracture of the external rotators or torsion of the capsule.¹⁸ This may create additional risk of subluxation or dislocation.¹⁵

The previous belief that "normal osseous development of the femoral head or acetabulum is no longer possible after 18 months" was popularized by Salter.¹⁹ Recent studies have stated that acetabulum continues to develop until the patient is 8–10 years as long as concentric reduction of the femoral head is maintained.^{20,21} Thus, the main goal of treatment should be maintaining concentric reduction and follow up period should extend to skeletal maturity.

In our study, twenty eight patients (59%) were skeletally immature at the last follow up this may be concerned as a limitation of this study.

Good results have been reported in a study involving 21 hips of 15 patients 2–4 years age with a relatively short term, follow up.²² Konigsberg et al have stated satisfactory results in 75% of 40 hips.¹⁷ Kalamchi et al have reported that the medial approach resulted in inadequate concentric reduction, with a high incidence of avascular necrosis but this study involves only 15 hips of 11 patients with unsuccessful closed reduction attempts before surgery.¹⁵ In a study involving 115 hips of 103 patients operated via medial approach with a mean follow up 20 years, 60% of the patients were classified as acceptable (Severin I or II) according to Severin classification; in that study, twenty of the 21 patients who had to be reoperated were older than 12 months at index surgery and the authors concluded that this approach is only appropriate before ambulatory age.²³ In another study which involves 66 patients, the rate of secondary acetabular procedures is 33% and the rate of avascular necrosis is 11%; it is concluded that the medial approach is safe and acceptable for children less than 24 months old but the mean follow-up period is six years.⁶ In a study involving 43 patients with a mean follow-up of 16 years, it has been concluded that medial approach yields unacceptable results if the patients are older than 17 months.²⁴ Tumer et al reported good results in patients younger than 18 months and added that the incidence and the severity of avascular necrosis is not related to the ossification of the femoral head.⁵ Mean age of the patients in the current study is 18.7 months, thus the age limit is a little bit higher than the limits in the literature.

Ludloff's original incision is 15 cm long and the interval is anterior to pectineus, between iliopsoas and pectineus muscles.² Mau et al and Weinstein-Ponseti have also used the anteromedial approach.^{4,13} Mau et al have described a 5 cm incision in their report.¹³ Weinstein and Ponseti have reported that they used a technique similar to Ludloff's method except that the incision was transverse and extended from the medial of adductor longus to a point slightly medial to the neurovascular bundle and they did not suture the capsule as Ludloff did.⁴ Staheli has depicted the interval as between pectineus and adductor brevis.²⁵ Ferguson has described a posteromedial approach with a longitudinal incision which uses the interval between adductor longus and brevis behind the pectineus muscle.³ Tumer et al have reported that they used the Ferguson approach with a 5 cm incision.⁵

After an analysis of the different surgical techniques used for medial approach we came to the conclusion that the capsule and the iliopsoas tendon are reached through a common interval in all of the methods. With the conventional medial approaches where one common interval is used for the tenotomy and capsulotomy, a wide exposure to expose the tendon and capsule at the same time is needed. The usage of a common interval necessitates the tying or exclusion of the medial circumflex artery since it is confronted directly in the surgical field.^{3,4,6,25} This clearly compromises

Table 4
Acetabular index angle, angle of Sharp and CE angle values of the patients.

	Mean	Min	Max	P value
Acetabular Index unaffected side preoperatively	22.9	18	29	0.008 ^a
Acetabular Index affected side preoperatively	36.7	25	49	
Acetabular Index affected side final follow up	12.53	8	20	
Angle of Sharp unaffected side postoperative (final follow up)	41.6	36	50	0.98
Angle of Sharp affected side postoperative (final follow up)	43.1	37	53	
CE angle unaffected side (final follow up)	29.4	10	42	0.84
CE angle affected side (final follow up)	26.6	6	38	

^a Statistically significant.

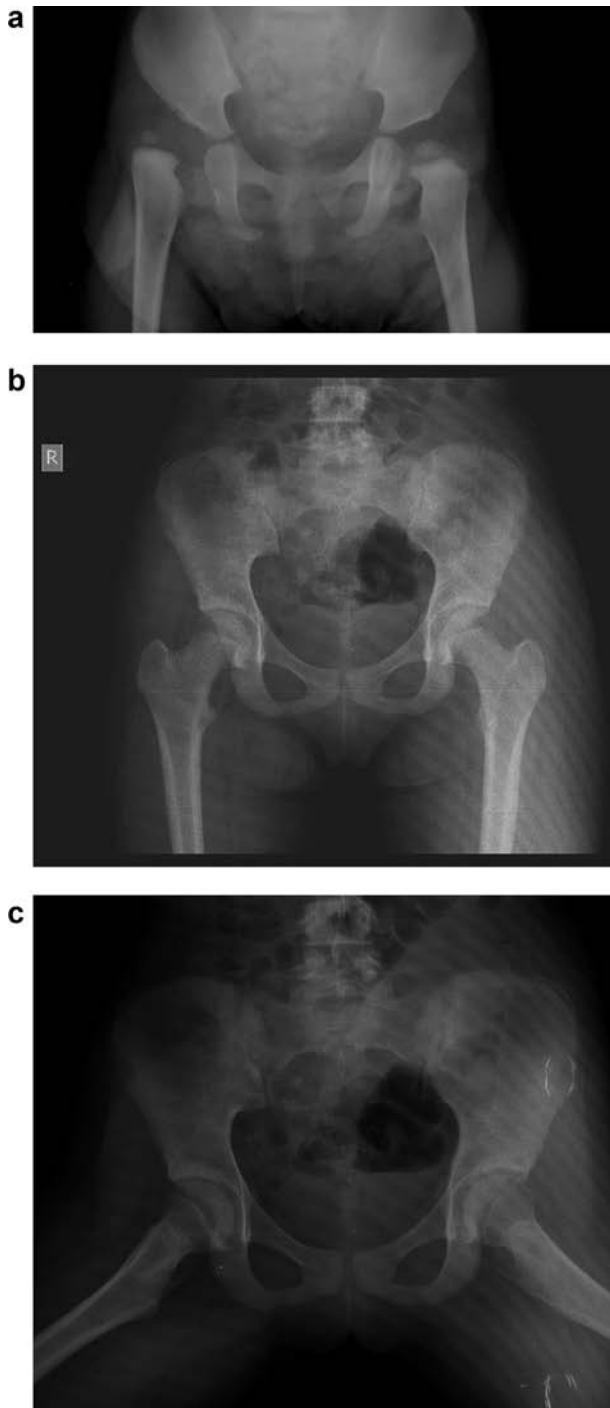


Fig. 2. a 21 months old girl with right DDH; preoperative AP radiograph of both hips. b. AP radiograph of both hips 13 years after surgery with medial approach. Both hips are concentrically reduced showing no signs of avascular necrosis and the clinical result is excellent according to Modified McKay criteria. c. Frogleg radiograph of both hips of the same patient 13 years after surgery.

the viability of the femoral head increasing the risk of avascular necrosis. Further consideration of this fact has led us in search for a safer method where the medial circumflex vessels or femoral vessels are less jeopardized. Ludloff's original technique involves a 15 cm incision that traverses through the interval between adductor longus and pectineus muscles and femoral vessel nerve pack is retracted laterally. The posteromedial approach described by Ferguson did not necessitate identification and protection of

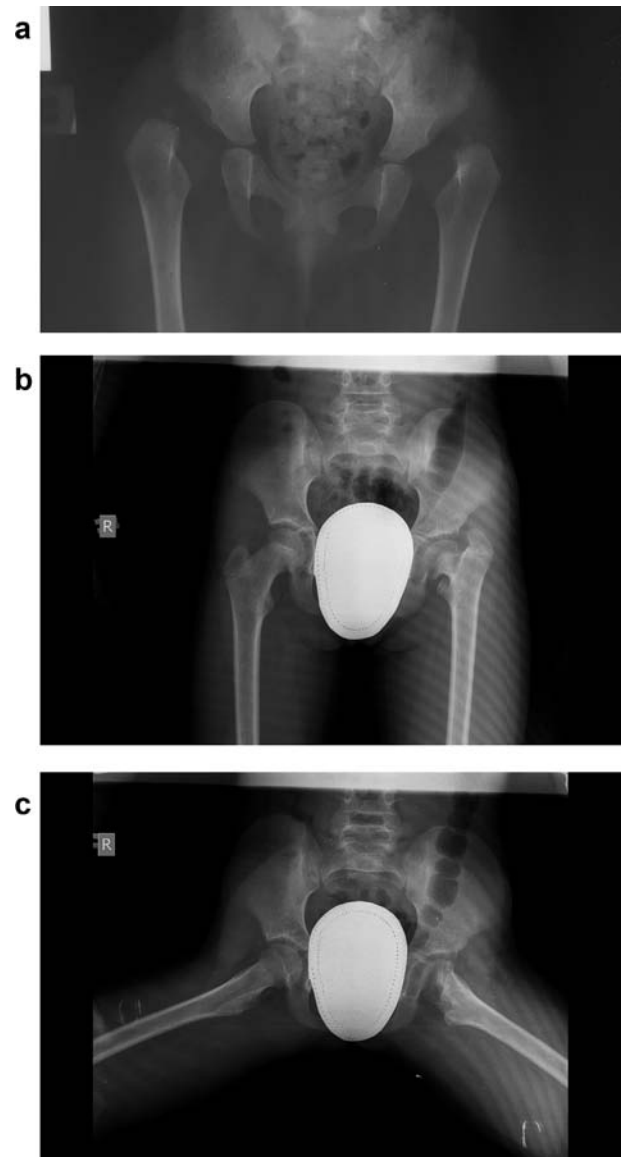


Fig. 3. a AP radiograph of a 16 months old girl with bilateral DDH. b. AP radiograph 12 years after medial approach. Patient has signs of avascular necrosis (Group III according to Kalamchi–Mac Ewen classification) and clinical result is good according to Modified McKay criteria. c. Frogleg radiograph of the same patient 12 years after medial approach.

femoral nerve and vessels.³ Mau et al stated that the several superficial branches of medial circumflex artery and accompanying veins have to be coagulated in the lateral corner of the wound and a deep branch of medial circumflex artery has to be retracted or ligated in front of the capsule.¹³ Weinstein and Ponseti, traversing the interval directly anterior to the joint between the pectineus and the femoral vein have recommended gentle lateral retraction of the femoral nerve and vessels with iliopsoas, identification and protection of the anterior branch of obturator nerve while trying to protect the medial circumflex artery and although the attempt had usually failed.⁴ Some authors have stated that increased age at surgery (i.e older than 17–18 months) is a major risk factor for avascular necrosis.^{23,24} Biçimoğlu et al have reported that patients operated after walking age, patients with higher preoperative dislocation grade and patients with osteonecrosis have lower hip scores.²⁶ Extrinsic contractures, injury to medial circumflex artery, unresolved impingements on femoral head after reduction and

position of the hip in the cast are among the other probable risk factors that contribute to avascular necrosis.⁶ There are various reports on the rate of avascular necrosis after medial approach. The rate of AVN was reported as 5% (2/46 hips) by Mau et al and as 11% (7/61 hips) by Mankey et al.^{6,13} Koizumi et al have stated the rate as 42.9% (15/35 hips) and Weinstein-Ponseti have reported it as 10% (2/22 hips).⁴ Kalamchi et al have encountered AVN in 67% of their patients¹⁵; this high rate may be attributed to the fact that the patients were operated after failed closed treatment. Since only one patient (2%) had avascular necrosis (type IV) in our study it is not possible to make an assumption on the causal factors including the grade of dislocation and sex. According to Omeroglu criteria, 1 hip was fair minus whereas 5 hips were evaluated as fair plus. The fair minus hip was Tönnis grade IV and the fair plus group consisted of 2 grade III and 3 grade IV hips preoperatively. Thus, 4 of the 22 hips that were Tönnis grade IV and 2 of the 27 Tönnis grade III preoperatively were evaluated as unsatisfactory. These results were found to be statistically significant. In terms of Kalamchi classification and Mc Kay functional criteria the results were found to be statistically insignificant in terms of relation to the Tönnis grade of the hips. Having no control group which may have consisted of patients operated with classical medial approach may be considered as a limitation of our study. In our study using the medial approach with 3 cm incision described previously, the iliopsoas tenotomy is performed through the interval between pectineus and adductor brevis. Then “T” shaped capsulotomy is performed in front of pectineus similar to the method described by Mau et al or Weinstein and Ponseti.⁷ (Fig. 1). During the capsulotomy, the fascia of pectineus protects the femoral nerve and vessels. The low rate of avascular necrosis and the need for secondary interventions may be attributed to the relatively safe surgical method used. The femoral nerve and vessels are not revealed and the medial circumflex artery is kept away from the surgical field. In conclusion, medial approach using two intervals is safe in relevance to the risk of avascular necrosis with satisfactory midterm results for children with dysplasia of the hip and who are 18 months old.

References

- Ludloff K. Zur blutigen Einrenkung der angeborenen Hüftluxation. *Z Orthop Chir.* 1908;22:272–278.
- Ludloff K. The open reduction of the congenital hip dislocation by an anterior incision. *Am J Orthop Surg.* 1913;210(3):438–454.
- Ferguson Jr AB. Primary open reduction of congenital dislocation of the hip using a medial adductor approach. *J Bone Joint Surg Am.* 1973 Jun;55:671–689.
- Weinstein SL, Ponseti IV. Congenital dislocation of the hip. Open reduction through a medial approach. *J Bone Joint Am.* 1979 Jan;61(1):119–124.
- Tumer Y, Bicimoglu A, Agus H. Surgical treatment of hip dysplasia through the medial approach. *Acta Orthop Traumatol Turc.* 2007;41(1):31–36.
- Mankey MG, Arntz GT, Staheli LT. Open reduction through a medial approach for congenital dislocation of the hip. A critical review of the Ludloff approach in sixty-six hips. *J Bone Joint Surg Am.* 1993 Sep;75(9):1334–1345.
- Iyetin Y, Turkmen I, Saglam Y, Akcal MA, Unay K, Unsac B. A modified surgical approach of the hip in children: is it safe and reliable in patients with developmental hip dysplasia? *J Child Orthop.* 2015 Jun;9(3):199–207.
- Omeroglu H, Ucar DH, Tümer Y. A new, objective radiographic classification system for the assessment of treatment results in developmental dysplasia of the hip. *J Pediatr Orthop B.* 2006 Mar;15(2):77–82.
- Kalamchi A, MacEwen GD. Avascular necrosis following treatment of congenital dislocation of the hip. *J Bone Joint Surg Am.* 1980;62:876–888.
- McKay DW. A comparison of the innominate and pericapsular osteotomy in the treatment of congenital dislocation of the hip. *Clin Orthop Relat Res.* 1974;98:124–132.
- Staheli LT. Medial approach open reduction for congenitally dislocated hips: a critical review of forty cases. In: Tachdjian MO, ed. *Congenital Dislocation of the Hip.* New York: Churchill Livingstone; 1982:295–303.
- Chiari K. Die operative Behandlung am Hüftgelenk bei der angeborenen Hüftgelenksverrenkung. *Wiener Med Wochenschr.* 1957;107:1020–1023.
- Mau H, Dörr WM, Henkel L. Open reduction of congenital dislocation of the hip by Ludloff's method. *J Bone Joint Surg Am.* 1971;53(7):1281–1288.
- Fisher III EH, Beck PA, Hoffer MM. Necrosis of the capital femoral epiphysis and medial approaches to the hip in piglets. *J Orthop Res.* 1991;9:203–208.
- Kalamchi A, Schmidt TL, MacEwen GD. Congenital dislocation of the hip. Open reduction by the medial approach. *Clin Orthop Relat Res.* 1982 Sep;169:127–132.
- Simons GW. A comparative evaluation of the current methods for open reduction of the congenitally displaced hip. *Orthop Clin N Am.* 1980 Jan;11(1):161–181.
- Konigsberg DE, Karol LA, Colby S, O'Brien S. Results of medial open reduction of the hip in infants with developmental dislocation of the hip. *J Pediatr Orthop.* 2003 Jan-Feb;23(1):9.
- Koizumi W, Moriya H, Tuchiya K, et al. Ludloff's medial approach for open reduction of congenital dislocation of the hip: a 20-year follow-up. *J Bone Joint Surg Br.* 1996 Nov;78(6):924–929.
- Salter RB. Innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip. *J Bone Joint Surg Br.* Aug. 1961;43:518–539.
- Lalonde FD, Frick SL, Wenger DR. Surgical correction of residual hip dysplasia in two pediatric age-groups. *J Bone Joint Surg Am.* 2002;84(7):1148–1156.
- Lempicki A, Wierusz-Kozłowska M, Kruczyński J. Abduction treatment in late diagnosed congenital dislocation of the hip. Follow-up of 1,010 hips treated with the Frejka pillow 1967–76. *Acta Orthop Scand Suppl.* 1990;236:1–30.
- Fuentes-Nucamendi MA, Martínez-Bonilla E, Bonfil-Ojeda JR, Camarena-Hernández HP. The Ludloff-Ferguson approach for congenital hip dislocation in children ages 2–4 years. *Acta Ortop Mex.* 2011 Jan-Feb;25(1):21–26.
- Yamada K, Mihara H, Fujii H, Hachiya M. A long-term follow-up study of open reduction using Ludloff's approach for congenital or developmental dislocation of the hip. *Bone Joint Res.* 2014 Jan 7;3(1):1–6.
- Yamada K, Takahashi K, Enomoto H, Osaki M, Shindo H. Long term outcome of Ludloff's medial approach for open reduction of developmental dislocation of the hip in relation to the age at operation. *Int Orthop.* 2009 Oct;33(5):1391–1396.
- Mallon WJ, Fitch RD. The medial approach to the hip revisited. *Orthopedics.* 1993 Jan;16(1):39–42.
- Bicimoglu A, Agus H, Omeroglu H. 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;6:693–698.