Avascular necrosis after surgery of developmental dysplasia of the hip in children after walking age: incidence and risk factors

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Introduction
Developmental dysplasia of the hip (DDH) is a common congenital anomaly in children. It includes a spectrum of anatomic abnormalities ranging from acetabular dysplasia to frank hip dislocation. Avascular necrosis (AVN) is one of the main complications associated with the treatment of DDH. It is a devastating problem that can lead to acetabular dysplasia and joint incongruity and cause premature osteoarthritis. The study aims to evaluate the incidence and risk factors of AVN after open reduction of developmental dislocation of the hip in children after walking age.

Patients and methods
Between the period of April 2014 and April 2019, a retrospective cohort evaluation of DDH cases was managed by surgery in the form of open reduction and pelvic osteotomy with or without femoral shortening. All grades of Tönnis classification were included. This study included 200 cases with an age range from 1 to 7 years, and the average age is 3.5 years at the time of last follow-up. The mean follow was 2.29 years, which ranged from 1 to 4 years. Plain radiography obtained in anteroposterior and frog lateral views after 1 year follow-up to diagnosis AVN as established in the literature.

Results
In this study, the mean time of intervention was 2.26±0.97 years with an age range from 1 to 5 years. Twenty-six (13%) cases were managed only by open reduction and capsulorrhaphy, 174 (72.5%) cases had pelvic osteotomies, either Salter or Dega osteotomy, of whom 104 had femoral shortening and derotational osteotomy (59.77%). No AVN was reported in 159 (79.5%) cases, while AVN was evident in 41 (20.5%) cases.

Discussion
Incidence of AVN after open reduction depend on variable factor discussed in this study with total incidence of AVN 41 (20.5%) cases. This result is similar to other studies, with the incidence of AVN ranging from 15 to 30%. In the present study, the incidence of AVN increased 17 times in cases with postoperative immobilization in the hip spica more than or equal to 60° in the form of 21 cases showed AVN.

Conclusion
Postoperative hip immobilization in spica less than 60° as children with postoperative hip abduction more than or equal to 60° showed an increase incidence of AVN.

Keywords:
avascular necrosis, hip dislocation, open reduction

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Introduction

Developmental dysplasia of the hip (DDH) is a common anomaly that can be treated early with conservative lines and surgically if discovered after the walking age. The reported incidence of DDH ranges between 1 and 28.5 cases per 1000 live births [1].

Numerous possible complications can occur during the management of DDH, including radiolocation, stiffness of the hip, infection, and avascular necrosis (AVN) of the femoral head. The rate of femoral head necrosis varies. It may be anywhere from 0 to 73%. Numerous studies demonstrate that extreme abduction, especially when combined with extension and internal rotation, results in a higher rate of AVN [2].

Mechanisms in the development of AVN are compression of extrinsic blood vessels and excessive pressure on the femoral head, both of which prevent perfusion of the femoral head. Immobilization of the hip in extreme abduction and internal rotation, which in turn causes extrinsic compression of the vessels supplying the femoral head [3].

Other causes may contribute to the development of AVN, including previous treatment with closed reduction, immobilization, traction, or the use of a Pavlik harness, Tönnis grade of dislocation, the age at surgery, the absence of the ossific nucleus, the anatomical interval used at surgery and the position and duration of postoperative immobilization [4].

O'Brien suggested using the growth disturbance lines, commonly known as Harris growth arrest lines, as indicators of the health of the physis and predictor of AVN [5].

One of the strategies is delaying the reduction of a dislocated hip in the absence of the ossific nucleus, which is believed to minimize the risk of AVN in the postoperative course. However, delaying the treatment of a dislocated hip until the ossific nucleus can be seen may increase the risk for residual acetabular dysplasia because it overrides the period of maximal acetabular remodeling. These treatment strategies have the potential to increase the need for future surgeries to treat residual acetabular dysplasia [6,7].

Patients and methods

A retrospective cohort study was carried out between the period April 2014 and April 2019. In this study, a radiological evaluation of all cases of DDH for signs of AVN was performed by one of the senior authors of the paper. All cases of DDH found in the archive system were unilateral or bilateral aged from 1 year of age till 5 years of age, male or female, with no history of previous DDH surgery. All grades of Tönnis classification were included, available radiograph anteroposterior view and frog lateral view after 1 year, patients had open reduction and capsulorrhaphy with or without femoral shortening and derotation and/or pelvic osteotomy in the form of Salter or Dega osteotomy. All patients splinted in hip spica for a period of 8–12 weeks. We excluded patients aged less than 1 year and more than 7 years, cases with neuromuscular disease or teratologic dislocations, history of previous surgery as initial or revision management, incomplete radiographic data, and history of multiple closed reductions. All procedures performed in the current study, which involved human participants, followed the ethical standards of the institutional and/or national research committee, along with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards (Research and Studies Department, Mansoura University IRB). Informed consent was obtained from all patients participating in the current study.

This study included 200 cases with an age range from 1 to 5 years, and the average age is 3.5 years at the time of last follow-up. In this study, girls predominance was evident in the form of 165 girls. Right-side predominance was reported in 105 (52.5%) cases and the left-side in 95 (47.5%) cases. No bilateral cases were included.

We retrospectively evaluated patients who underwent open reduction for developmental dislocation of the hip at the pediatric orthopedic clinic from April 2014 to April 2019.

(1) Using the anterior approach as described by Somerville [8].
(2) Dega osteotomy was done by a cut made in the pelvis above the acetabulum. Apart from the pelvic bone was bent down to make the socket into more of a cup with a bone graft filled in the space at the osteotomy site. As it heals, the bone graft will become part of the child's pelvic bone [9].
(3) Salter osteotomy is done by transverse osteotomy of the ilium perpendicular to the iliac axis from just above the anterior inferior iliac spine to the sciatic notch. It was designed to preserve the acetabular shape while correcting the abnormal anterolateral facing of the acetabulum in DDH. The pubic symphysis serves as a rotating hinge, and the acetabulum can be redirected to cover the anterolateral deficiency in a concentrically reduced hip after the osteotomy [10].
(4) Femoral osteotomy was used for either femoral shortening and/or derotation. The amount of the required shortening is the overlap between both ends at the osteotomy site, which usually measures 2–3 cm [11]. The mean follow-up was 2.29 years, which ranged from 1 to 4 years.

Radiological evaluation

(1) Plain radiography obtained in anteroposterior and frog lateral views after 1 year follow-up to diagnosis AVN as established in the literature, and AVN was classified according to Kruczynski [12]; other classifications post-DDH surgery are available (e.g. Kalamchi classification) [13], but we choose this classification as we felt it more descriptive:
   (a) Grade I: involvement of the epiphysis, no fragmentation, mild changes.
   (b) Grade II: involvement of the epiphysis with fragmentation, moderate changes.

(c) Grade III: involvement of the epiphysis and lateral part of the metaphysis under the physis, severe changes.
(d) Grade IV: involvement of the epiphysis and the medial metaphysis under the physis, severe changes.
(e) Grade V: involvement of the epiphysis and the entire metaphysic under the physis, severe changes.

(2) Assess the state of the ossific nucleus and femoral head before intervention, and these are evaluated by yes or no questions.
(3) Measure the hip abduction in the cast, we used DeFrancesco *et al.* [14] method in which we used the coronal measure only rather than the axial as we used only plain radiograph not MRI, as in the original paper.

The study protocol was submitted for approval by IRB and the approval of the mangers of our institute.

Results

The mean time of intervention was 2.26±0.97 years with an age range from 1 to 5 years (Table 1). In this study, 26 (13%) cases were managed only by open reduction and capsulorrhaphy, 174 (72.5%) cases had pelvic osteotomies, either Salter or Dega osteotomy, of whom 104 (59.77%) had femoral shortening and derotational osteotomy (Table 2).

Postoperative immobilization in hip spica

In this study, 170 (85%) cases had postoperative hip abduction less than 60°, and 30 (15%) cases had postoperative hip abduction more than 60° (Table 3).

Table 1 Time of intervention in the studied patients

Patients	Mean±SD	Median	Range (minimum–maximum)
All patients (200)	2.26±0.97	3.00	1–5

Table 2 Type of intervention in the studied patients

	Frequency	Percentage
Type		
Open reduction and capsulorrhaphy	26	13.0
Open reduction, capsulorrhaphy and osteotomies (pelvic or femoral osteotomy)	174	87.0

Table 3 Postoperative hip immobilization in hip spica in the studied patients

All patients (*N*=200)	Frequency	Percentage
Abduction		
<60	170	85.0
≥60	30	15.0

Postoperative avascular necrosis in relation to Kruczynski classification [12]

No AVN was reported in 159 (79.5%) cases, while AVN was evident in 41 (20.5%) cases. Different grades in either the right or left-side were mentioned in Table 4.

Preoperative femoral head assessment

In this study, the femoral head was not affected in 142 (71.0%) cases, while 44 (22.0%) cases had delayed appearance of the ossific nucleus. Fourteen (7.0%) cases had flattened femoral heads (Table 5).

In this study, comparison of incidence of AVN according to age groups showed statistically significant differences (P<0.05) between patients with and without AVN. The incidence of AVN increased after 2.5 years by 35 (85%) cases (Table 6).

In this study, a comparison of sex and side between patients with and without AVN showed a statistical insignificant difference (P>0.05) (Table 7).

In this study, the preoperative femoral head state showed a statistical significant difference (P<0.05) between patients with and without AVN. No AVN was reported in 159 cases, of whom 120 (75.5%) cases showed the femoral head was not affected, while 30 (18.8%) cases presented with delayed appearance of

Table 4 Postoperative avascular necrosis in relation to Kruczynski classification in the studied patients

All patients (*N*=200)	Frequency	Percentage
AVN		
None	159	79.5
Grade I	14	7.0
Grade II	6	3.0
Grade III	10	5.0
Grade IV	11	5.5

AVN, avascular necrosis.

Table 5 State of the femoral head before intervention in the studied patients

All patients (*N*=200)	Frequency	Percentage
Not affected	142	71.0
Delayed appearance of the ossific nucleus	44	22.0
Flattening of head femur	14	7.0

Table 6 Comparison of incidence of avascular necrosis according to age groups in the current study

Age group	No AVN [*n* (%)]	AVN [*n* (%)]	*P*
<2.5 years	113 (71)	6 (15)	
2.5–4 years	30 (19)	17 (41.5)	0.013
>4 years	16 (10)	18 (43.5)	

AVN, avascular necrosis.

Table 7 Comparison of sex and side between patients with and without avascular necrosis in the current study

	No AVN (*N*=159) [*n* (%)]	AVN (*N*=41) [*n* (%)]	*P*
Sex			
Male	27 (17.0)	8 (19.5)	0.704
Female	132 (83.0)	33 (80.5)	
Side			
Right	87 (54.7)	18 (43.9)	0.216
Left	72 (45.3)	23 (56.1)	

AVN, avascular necrosis.

the ossific nucleus, and nine (5.7%) cases presented with flattening of the femoral head.

AVN was reported in 41 cases in the form of 22 (53.7%) cases with the femoral head not affected, 14 (34.1%) cases presented with delayed appearance of the ossific nucleus, and five (12.2%) cases presented with flattening of the femoral head (Table 8).

In this study, the time of intervention between patients with and without AVN showed a statistical significant difference ($P<0.05$) with the mean time of AVN cases was 3.2 ± 1.15years while the type of intervention (pelvic osteotomy and or femoral osteotomy) showed statistically insignificant difference ($P>0.05$) between patients with and without AVN (Table 9).

In this study, postoperative immobilization in hip spica between patients with and without AVN showed a statistically significant difference ($P<0.05$). One hundred fifty cases with postoperative hip abduction less than 60° showed no AVN while the other 20 cases showed AVN. Nine cases with postoperative hip abduction more than or equal to 60° showed no AVN, while the other 21 cases showed AVN (Tables 10, 11).

Case presentation

Female patient, 2 years her mother noticed limping gait. General examination and examination of the hip showed leg length discrepancy with the left side shorter by 2 cm. Plain radiograph of the hip anteroposterior view and frog lateral view showed left DDH. Open reduction and capsulorrhaphy+Dega osteotomy+derotation osteotomy+femoral shortening was done. Follow-up done after 2 years, either clinical or radiological (Figs 1–3).

Table 8 Comparison of state of the femoral head before intervention between patients with and without avascular necrosis in the current study

	No AVN (*N*=159) [*n* (%)]	AVN (*N*=41) [*n* (%)]	*P*
Not affected	120 (75.5)	22 (53.7)	
Delayed appearance of the ossific nucleus	30 (18.8)	14 (34.1)	0.022
Flattening of head femur	9 (5.7)	5 (12.2)	

AVN, avascular necrosis.

Table 9 Comparison of time and type of intervention between patients with and without avascular necrosis in the current study

	No AVN (*N*=159)	AVN (*N*=41)	*P*
Time of intervention	2.31 ± 1.081	3.22 ± 1.151	<0.001
Type [*n* (%)]			
Open reduction and capsulorrhaphy	24 (15.1)	2 (4.9)	0.083
Open reduction, capsulorrhaphy, and osteotomies (pelvic or femoral osteotomy)	135 (84.9)	39 (95.1)	

AVN, avascular necrosis.

Table 10 Postoperative immobilization in hip spica between patients with and without avascular necrosis in the current study

	No AVN (*N*=159) [*n* (%)]	AVN (*N*=41) [*n* (%)]	*P*
Abduction			
<60	150 (88.24)	20 (11.76)	<0.001
≥60	9 (30)	21 (70)	

AVN, avascular necrosis.

Table 11 Odds ratio occurrence of avascular necrosis according to qualitative variables

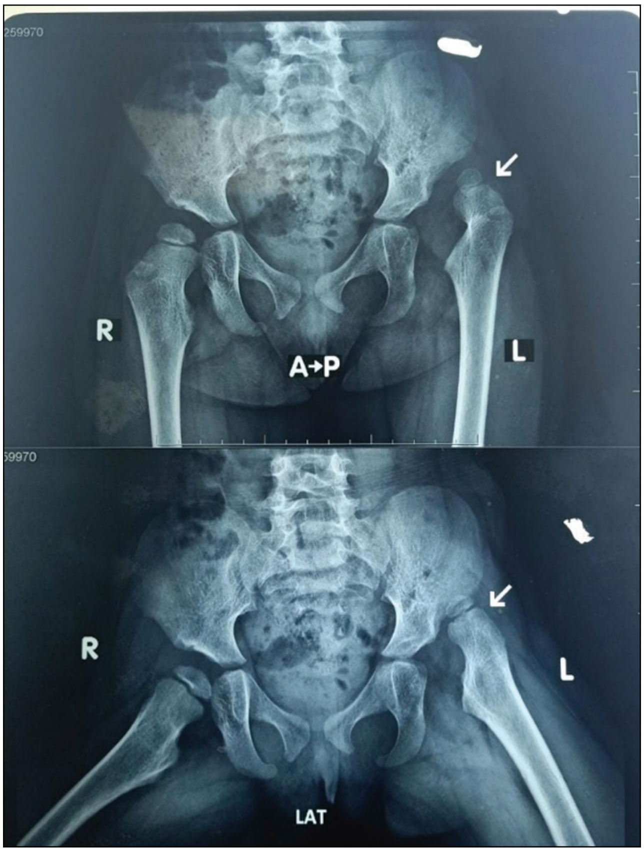
	Odds ratio
Female sex	0.844
Left side	1.544
Osteotomies (pelvic or femoral)	3.467
Abduction ≥60	17.500
Delayed appearance of the ossific nucleus	2.230
Flattening of head femur	2.315

Discussion

DDH is very common in some communities, and it is believed it can be reduced by using the surveillance program for early detection. The reported incidence of DDH ranges between 1 and 28.5 cases per 1000 live births [15].

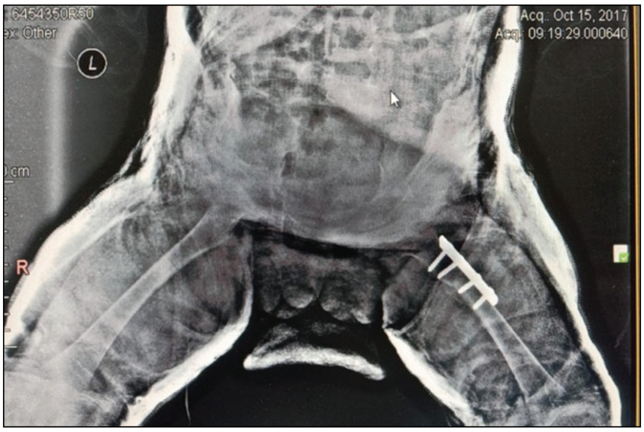
The main purpose of DDH treatment in all stages is to provide reduction, correct joint instability, and achieve the normal development of the hip [16].

Figure 1



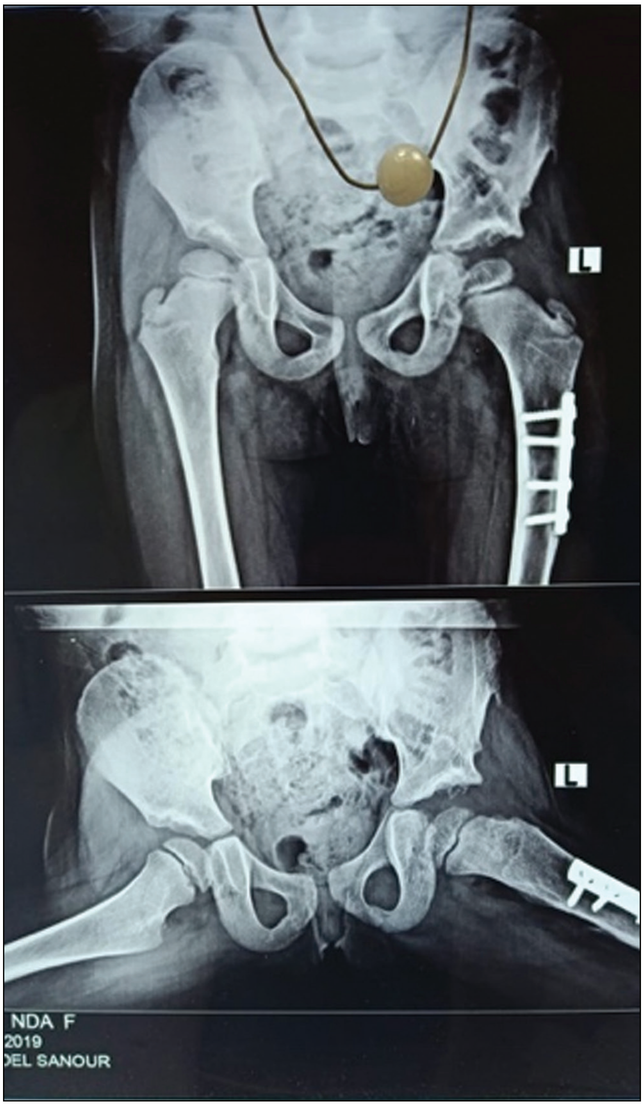
Preoperative radiograph.

Figure 2



Immediate postoperative radiograph.

Figure 3



Follow-up radiograph after 2 years.

AVN of varying severity is a well-known complication of the treatment of DDH. It can be a devastating complication potentially resulting in premature debilitating osteoarthritis [17].

Risk factors for osteonecrosis are older age at diagnosis and treatment, higher Tönnis grade, a high displacement of the femoral head, and more complex treatment regimens (from closed reduction to open reduction with multiple soft tissue releases to osteotomies at acetabular or femoral or both levels) [18]. The aim of this study was to evaluate the incidence of AVN after open reduction of developmental dislocation of the hip in children after walking age; which done on 200 cases with the age children ranging from 1 to 5 years at the time of last follow-up with mean age at the time of surgery 2.26 ± 0.97 years.

Incidence of AVN after open reduction depend on variable factor discussed in this study with total incidence of AVN 41 cases (20.5%). This result is similar to other studies with incidence of AVN ranging from 15 to 30% [19,20].

In the present study, AVN was classified according to Kruczynski classification based on radiographs into grade I, presented in 14 hips; grade II, presented in six hips; grade III, presented in 10 hips; and grade IV, presented in 11 hips with a total incidence of AVN 41 (20.5%) hips.

Weinstein and Dolan [21] investigated 109 hips, with girls predominance by 86%. The mean age at the time of reduction was 11.6 months, and the incidence of AVN was 15% which agreed with this study, while Cooper *et al.* [22] examined 35 hips with girls predominance by 92%. The mean age at the time of reduction was 14 months, and the mean follow-up was 19.4 years, and the incidence of AVN was 43% which disagreed with this study, most probably due to long-term follow-up.

Sex in this study was 35 (17.5%) boys and 165 (82.5%) girls, which did not affect the AVN frequency with a statistical insignificant correlation (P=0.704), which agreed with other studies with girls predominance by 80%. This is probably due to increased ligamentous laxity in females as a result of the circulating maternal relaxin hormone [20].

In this study, the incidence of DDH on the left side was 47.5% (95 hips) and that on the right-side was 52.5% (95 hips). The side did not affect the AVN frequency with a statistical insignificant correlation (P=0.216). Loder *et al.* [23] reported left-side predominance by 64% with a statistical insignificant correlation. This difference is due to case selection.

The time of intervention in this study showed a statistical significant correlation (P<0.001) with the mean time of AVN cases was 3.2 ± 1.15 years and the incidence of AVN increased after 2.5 years by 35 (85%) cases. This result agreed with other studies with the mean time of AVN cases was more than 3 years with a statistical significant correlation, which might be because children presented at a higher age needed additional acetabular or femoral procedures, and the chances of iatrogenic damage to blood supply in these procedures were more [24].

In this study, the type of intervention, either open reduction and capsulorrhaphy or open reduction, capsulorrhaphy and osteotomies (pelvic or femoral), showed a statistical insignificant difference (P>0.05) with two of 26 cases with open reduction and capsulorrhaphy showed AVN, 39 of 174 cases with pelvic osteotomy showed AVN and 26 of 104 cases with femoral shortening showed AVN. The incidence of AVN in this study increased 3.5 times with pelvic osteotomy and 1.8 times with femoral osteotomy, most probably due to the chances of iatrogenic damage to blood supply in these procedures being more.

Hegde [25] showed out of 41 hips (34 patients) operated, 15 hips underwent open reduction and capsulorrhaphy (type I), and 16 hips underwent open reduction and capsulorrhaphy+pelvic osteotomy (type II), 10 hips underwent open reduction and capsulorrhaphy+pelvic osteotomy+derotation osteotomy+femoral shortening (type III).

AVN was seen in 33% of patients who received type I surgery, 31% of patients who received type II surgery, and 66.7% of type III surgery. The relation between the type of surgery and AVN was not statistically significant (P=0.176), which is similar to our result.

An anterior approach was used in the present study for open reduction with a total incidence of AVN reported of 20.5%, which was not similar to Sherrod *et al.* [26], who used an anterior approach for open reduction with the incidence of AVN (38%) in the unilateral group and 55% in the bilateral group most probably due to short-term follow-up in this study.

Bache *et al.* [4] used a medial approach for open reduction of the congenitally dislocated hip. By observation, hips out of 109 had evidence of AVN, for an overall incidence of 41%, most probably due to the risk of injury to the medial femoral circumflex artery.

In the present study, the preoperative femoral head state showed a statistical significant correlation (P=0.022) with the incidence of AVN increased two times in cases presented with delayed appearance of the ossific nucleus. This result agreed with other studies, which show 17 (40%) cases presented with delayed appearance of ossific nucleus showed no AVN, while 25 (60%) cases presented with AVN [16].

Segal *et al.* [27] showed a statistically significant correlation between the absence of an ossific nucleus and AVN in 25 hips with an ossific nucleus present radiographically. Only one patient developed AVN. This contrasts with the 17 of 32 hips without an ossific nucleus that developed AVN.

Bache *et al.* [4] reported that 31 hips were identified in the age range 7–12 months. In 17, the ossific nucleus was present, and in 14, the nucleus was absent. AVN occurred in three of 17 in the former group and eight of 14 in the latter group (P<0.5).

In the present study, the incidence of AVN increased 17 times in cases with postoperative immobilization in hip spica more than or equal to 60° in the form of 21 cases showed AVN (P<0.001) similar to Gardner *et al.* [28] showed increased risk of AVN with immobilization in abduction more than 60° by 60% (P=0.006) while Bache *et al.* [4] showed rate of AVN with abduction more than 60° (67 hips) was 30%, compared with 12.3% (114 hips) with less than 60° abduction (P=0.003). This suggested a positive correlation between AVN and increased postoperative abduction, which agreed with this study, most probably due to impingement of the posterosuperior retinacular branch of the medial femoral circumflex artery in postoperative hip abduction more than or equal to 60°.

Conclusion

Incidence of AVN increases in cases with delayed time of intervention with delayed appearance of the ossific nucleus and postoperative hip abduction more than or equal to 60. There are other factors for the development of AVN, but we think the position of the hip in the cast is one modifiable factor for this complication.

Limitations of this study

The main drawback of the current study was the relatively short-term follow-up. Therefore, more studies with long periods of follow-up should be conducted in the near future.

Another limitation of the study is that this was a retrospective study and some of the information was missing, like if the femoral shortening is done with derotation or not and how much shortening was done. Moreover, the Dega and Salter osteotomy can be considered as a variable in the incidence of AVN, which we did not include in the analysis.

Availability of data and material

All the data related to the study are mentioned in the manuscript; however, the raw data are available with the corresponding author and will be provided on a written request.

Authors' contribution

K.Z., W.E.A.: conceived the study and performed the surgeries. K.Z., A.S.: carried out data acquisition and assessment. K.Z., A.S.: performed a literature search, drafted the manuscript, and designed the figures. K.Z., A.E.: did the critical revision. All authors discussed the results and commented on the manuscript. All authors read and approved the final manuscript.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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