ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Author's translation
Acta Orthop Traumatol Turc 2006;40(1):6-14

Evaluation of complications of femoral neck fractures in children operated on at least 24 hours after initial trauma

Femur boynu kırığı nedeniyle ilk 24 saatten sonra ameliyat edilen çocuklarda gelişen komplikasyonların değerlendirilmesi

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Amaç: Femur boynu kırığı nedeniyle ilk 24 saatten sonra ameliyat edilen çocuklarda ortaya çıkan komplikasyonlar ve femur başı avasküler nekrozu (AVN) gelişmesine etki eden faktörler araştırıldı.

Çalışma planı: Femur boynu kırığı nedeniyle ilk 24 saatten sonra ameliyat edilen 22 çocuğun (11 erkek, 11 kız; ort. yaş 10; dağılım 4-14) sonuçları geriye dönük olarak gözden geçirildi. Delbet sınıflamasına göre iki olguda tip I, 11 olguda tip II, dokuz olguda tip III kırık vardı. Yedi hastada ayrıca ek patoloji vardı. Yaralanma ile cerrahi tedavi arasında geçen süre ortalama yedi gün (dağılım 1-15 gün) idi. İki olgu dışında tüm hastalara kapalı redüksiyon yapıldı. Redüksiyondan sonra internal fiksasyon uygulandı. Sonuçlar Ratliff ölçütlerine göre değerlendirildi. Ortalama takip süresi 73 ay (dağılım 18-184 ay) idi. Olgular yaş, kırık tipi, kırık yer değiştirmesi, komplikasyonlar ve AVN açısından değerlendirildi.

Sonuçlar: Ratliff ölçütlerine göre 12 hastada (%54.6) iyi, sekiz hastada (%36.4) orta, iki hastada (%9.1) kötü sonuç alındı. On yedi hastada (%77.3) komplikasyon görüldü; bunların 12'sinde birden fazla komplikasyon vardı. En sık komplikasyon erken fiz kapanması (14 hasta, %63.6) idi; bunu AVN (12 hasta, %54.6) izlemekteydi. Avasküler nekroz gelişen ve gelişmeyen hastalar arasında yaş, kırık tipi açısından; travmadan sonra ilk hafta ve ikinci hafta ameliyat edilen hastalar arasında AVN gelişmesi açısından anlamlı fark saptanmadı (p>0.05).

Çıkarımlar: Çocuklardaki femur boynu kırıklarında ilk 24 saatten sonra yapılan ameliyat sonuçlarını esas olarak AVN gelişip gelişmemesi, ikincil olarak da kırık tipi etkilemektedir.

Anahtar sözcükler: Çocuk; femur başı/fizyopatoloji; femur boynu kırığı/patoloji/radyografi; femur başı nekrozu/komplikasyon; kırık tespiti, internal/yöntem; kalça eklemi.

Objectives: We evaluated complications and the factors affecting the development of avascular necrosis of the femoral head in children who underwent surgery for femoral neck fractures after at least a 24-hour delay.

Methods: We reviewed the results of 22 children (11 boys, 11 girls; mean age 10 years; range 4 to 14 years) who were operated on after the first 24 hours for femoral neck fractures. According to the Delbet classification, two patients had type I, eleven patients had type II, and nine patients had type III fractures. Associated injuries were detected in seven patients. The mean duration from trauma to surgery was seven days (range 1 to 15 days). Internal fixation was performed following closed (n=20) or open (n=2) reduction. The results were assessed using the Ratliff criteria at the end of a mean follow-up of 73 months (range 18 to 184 months). The patients were evaluated with respect to age, type of fracture, displacement, complications, and avascular necrosis.

Results: The results were good in 12 (54.6%), fair in eight (36.4%), and poor in two patients (9.1%). Complications developed in 17 patients (77.3%), 12 of whom had more than one. The most frequent complication was premature physeal closure (n=14; 63.6%) followed by avascular necrosis (n=12; 54.6%). No significant differences were found *(i)* with regard to age and the type of fracture between patients with and without avascular necrosis, and *(ii)* with regard to avascular necrosis between patients who were treated within the first and second week of trauma (p>0.05).

Conclusion: The results of surgery performed after the first 24 hours are mainly influenced by the occurrence of avascular necrosis and, secondarily, by the type of fracture.

Key words: Child; femur head/physiopathology; femoral neck fractures/pathology/radiography; femur head necrosis/complications; fracture fixation, internal/methods; hip joint.

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Received: 11.05.2005 **Accepted:** 13.09.2005

Hip fractures in children are usually the result of high-energy trauma.[1-3] Because of the vulnerability of the blood supply to the femoral head and the growth plate, these fractures are prone to serious complications (i.e. avascular necrosis (AVN), premature physeal closure (PPC)) at a high rate.[4-9] In addition, leg length discrepancy and coxa vara, which had been claimed to be the result of the injury to the growth plate, inadequate reduction or failure to maintain the reduction, can be encountered.[2,5,7,9-12] Togrul et al.[13] claimed that the method of treatment is also effective on the results. The most serious complication of the collum femoris fractures in children is AVN. There is neither agreement regarding the management of complications after femoral neck fracture, nor avoiding AVN, which is the most devastating complication. The degree of initial trauma, age, the type of fracture, displacement of the fracture and the interval between initial trauma and treatment were emphasized as factors effected on AVN.[14-19] In recent literature it has been reported that the rate of complication can be reduced considerably with open or closed reduction and internal fixation within first 24 hours.[9,20,21] However, there is not clear information in the literature that how much complication rates raise if operation performed on after first 24 hours and how much the factors which affect the results in the first 24 hours, had influence on the outcomes after first 24 hours. The aim of the study is to evaluate the changes of complication rates and the factors which affect AVN occur when femoral neck fractures were operated on after the critical time.

Materials and methods

In this two-centered retrospective case series the records that belonged to the period between 1982 and 1999, were reviewed for cases with femoral neck fractures that were younger than fifteen years of age at the time of injury. The results of cases, who were performed on open or closed reduction and internal fixation 24 hour after initial trauma, because of the reasons out of control, were investigated. We included only Delbet type I, II, III fractures operated after at least 24 hours after injury with at least 18 months follow-up.[22] Twenty-two patients fulfilled the criteria (eleven males and eleven females). According to Delbet's classification, two cases were of type I, eleven cases of type II and nine cases of type III.[22] The mean age at the time of injury was ten years (range: four to fourteen years). All of the fractures were caused by high-energy trauma. Seven patients had associated injuries; two pelvis, one tibia, two humerus, one forearm fractures and one abdominal trauma. Eight fractures resulted from a car occupant injury, nine from a fall from a height and five from having been struck by a car. The time interval between the injury and the treatment varied considerably but always after first 24 hours, depending on the condition of the patient and the hospital (average seven days, range: one to 15).

If closed reduction failed, that was routinely attempted at first in all displaced fractures (twenty patients), reduction was achieved by open surgery (two patients). After reduction (closed or open), internal fixation was performed in all cases. In transepiphyseal fractures, K-wire fixation was preferred to minimize the damage to the growth plate. In Delbet type II and III fractures, threaded material (i.e. pins, screws) was preferred in all cases, except one. All patients under ten years of age, except one, were placed into a hip spica for six weeks postoperatively.

Mean follow-up was seventy-three months (range: 18 to 184 months). At final follow-up, the results were assessed using Ratliff's criteria[19] that

Table 1. Ratliff's classification of the results of treatment for fracture of the hip[19]

	Good	Fair	Poor
Pain	None or patient ignores it	Occasional	Disabiling
Movement	Full or terminal restriction	Greater than 50 per cent	Less than 50 per cen
Activity	Normal or patient avoids games	Normal or patient avoids games	Restricted
X-ray	Normal or some deformity of femoral neck	Severe deformity of femoral neck and mild avascular necrosis	Severe avascular necrosis, degenerative arthritis, arthrodesis

Table 2. Results of surgical treatment according to the type of fracture

Fracture (according toDelbet)[22]	AVN(according to Ratliff[19]	Classification of final results(according to Ratliff[19]			
		Good	Fair	Poor	*Total*
Type I	None	–	–	–	–
	Type I	–	–	–	–
	Type II	–	1	–	1
	Type III	–	1	–	1
Type II	None	3	–	–	3
	Type I	–	–	1	1
	Type II	–	3	1	4
	Type III	3	–	–	3
Type III	None	6	1	–	7
	Type I	–	1	–	1
	Type II	–	1	–	1
	Type III	–	–	–	–
Total	–	12	8	2	22

based on hip pain, range of motion (ROM), daily activities and radiological findings(Table 1). AP and lateral hip views were obtained for radiographic evaluation. The patients who developed complications were analyzed considering age, type of fracture, displacement of fragments and being achieved anatomic/non-anatomic reduction. The patients who developed complications were analyzed considering age, type of fracture, displacement of fragments and being achieved anatomic/non-anatomic reduction. The results according to Ratliff's criteria were evaluated considering whether AVN developed or not. Patients were divided in two groups, who were operated in 2-7 days (13 cases) and 8-15 days (nine cases) after initial trauma. These two groups which were similar about the age and type of fracture were compared considering whether AVN developed or not. The way of handling and results of complications were reviewed. The results were analyzed statistically by Fisher's exact test and $p<0.05$ was accepted significant.

Results

The overall results assessed according to Ratliff's criteria were classified as 'good' in twelve patients (54.6%), as 'fair' in eight (36.4%) and as 'poor' in two (9.1%) (Table 2). Different complications occurred in 17 patients (77.3%) and 12 of them had more than one complication (Table 3). The second most frequent complication was AVN (12 patients-54.6%) after PPC (14 patients-63.6%) and its fre-

Table 3. Complications*

Complications	Type of AVN	Number of patients	Rate
Nonunion	–	1	4.6
Delayed union	–	1	4.6
Coxa vara	–	3	13.6
Implant failure	–	1	4.6
Septic artritis	–	1	4.6
PPC	–	14	63.6
AVN	I	2	9.1
	II	6	27.3
	III	4	18.2

*Some patients had more than one complication.

quency differed according to the type of the fracture (Table 2).

Closed reduction was successful in both two patients with transepiphyseal fractures in our series. The fractures were stabilized with K-wires. One child was placed in a hip spica; and for the other child skin traction was applied after operation. In both patients, AVN (former Ratliff type III, latter Ratliff type II) and PPC developed; and the final results were 'fair' in both of them.

Of the 11-transcervical fractures, nine were displaced. As two of them did not need reduction, closed reduction was successful in eight of these displaced fractures, so that open reduction had to be performed only in one case (Fig. 1- a, b). In one of the two patients with non-displaced fracture, Ratliff type III AVN and PPC developed. The other one recovered without any complication. The results were classified as 'good' in both of them. One of the nine displaced Delbet type II fractures did not heal. In this case, Pauwel's valgus osteotomy was performed to promote healing (Fig. 2 a-e). The second stage was successful in this case, but the results was 'fair' because of the developing Ratliff type II AVN and PPC. Coxa vara occurred in one patient whom was performed on closed reduction and internal fixation. In this patient mild deformity remodeled in the following years and the result was 'good'. Among the other patients, there were three 'good', two 'fair' and two 'poor' results. All of the seven patients occurring PPC had AVN.

Of the nine-cervicotrochanteric fractures, eight were displaced. Closed reduction was successful in seven of the eight displaced fractures, so that open reduction was necessary only in one case. In one patient, breakage of the implant led to delayed union that healed by stabilizing the fracture line with K-wires. In this case, the threaded part of the screw did not pass well across the fracture line. The result was 'good'. One patient with type Ratliff I AVN was treated with the articulated distraction method, but the fixator had to be removed after a short time because of the psychological and social intolerance of the patient and her family. The result was 'fair'. In this group, the second patient with AVN who was treated with non-weight bearing, the final result was 'fair'. Coxa vara developed in two patients; the one with more severe deformity has undergone valgus

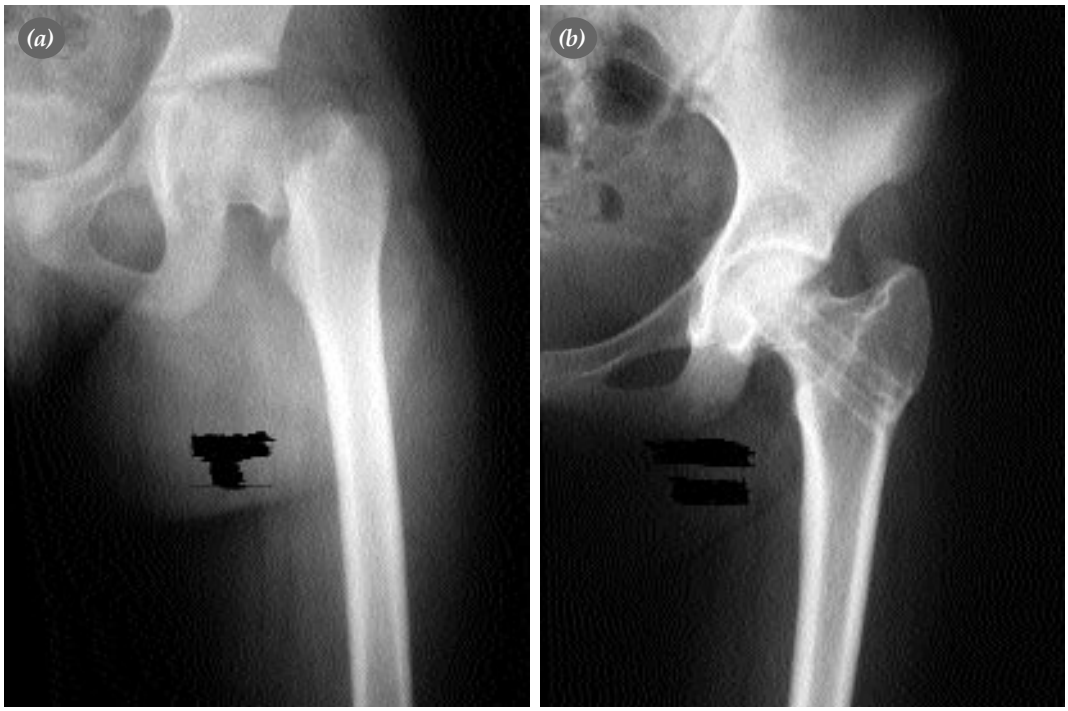

Figure 1. (a) AP radiograph of a 11 year old girl with transcervical femoral neck fracture. **(b)** Eleven days after the trauma closed reduction and internal fixation was performed with two screws. AP radiograph at 59-months follow-up shows coxa vara deformation. The result was classified as 'good' according to Ratliff's criteria.

osteotomy, but the final result was 'fair'. In the other patient that had mild deformity, we were content with the observation only, and the final result was 'good' in this case. PPC occurred in five patients.

Of twelve patients with AVN in this series; two were classified as Ratliff type I AVN, six Ratliff type II and four Ratliff type III (Table 2). The patients, who were ten years old or younger, and older than ten years, were compared statistically regarding of developed AVN. The difference was not significant ($p>0.05$). All of the fractures were caused by high-energy trauma. The rates of AVN in Delbet type I (100%, 2 out of 2 patients) and II fractures (72.7%, eight out of 11 patients) were higher compared to Delbet type III (22.2%, two out of 9 patients) but it was not statistically quite significant ($p>0.05$). The incidence of Ratliff type I AVN which has worst prognosis, among the patients had AVN was higher in Delbet type type III fractures (50%) compared to Delbet type II (12.50%) and Delbet type I (0%). The difference was not statistically significant($p>0.05$). The patients who obtained good results were analyzed statistically whether they had AVN or not. The result was very significant ($p<0.005$). The difference

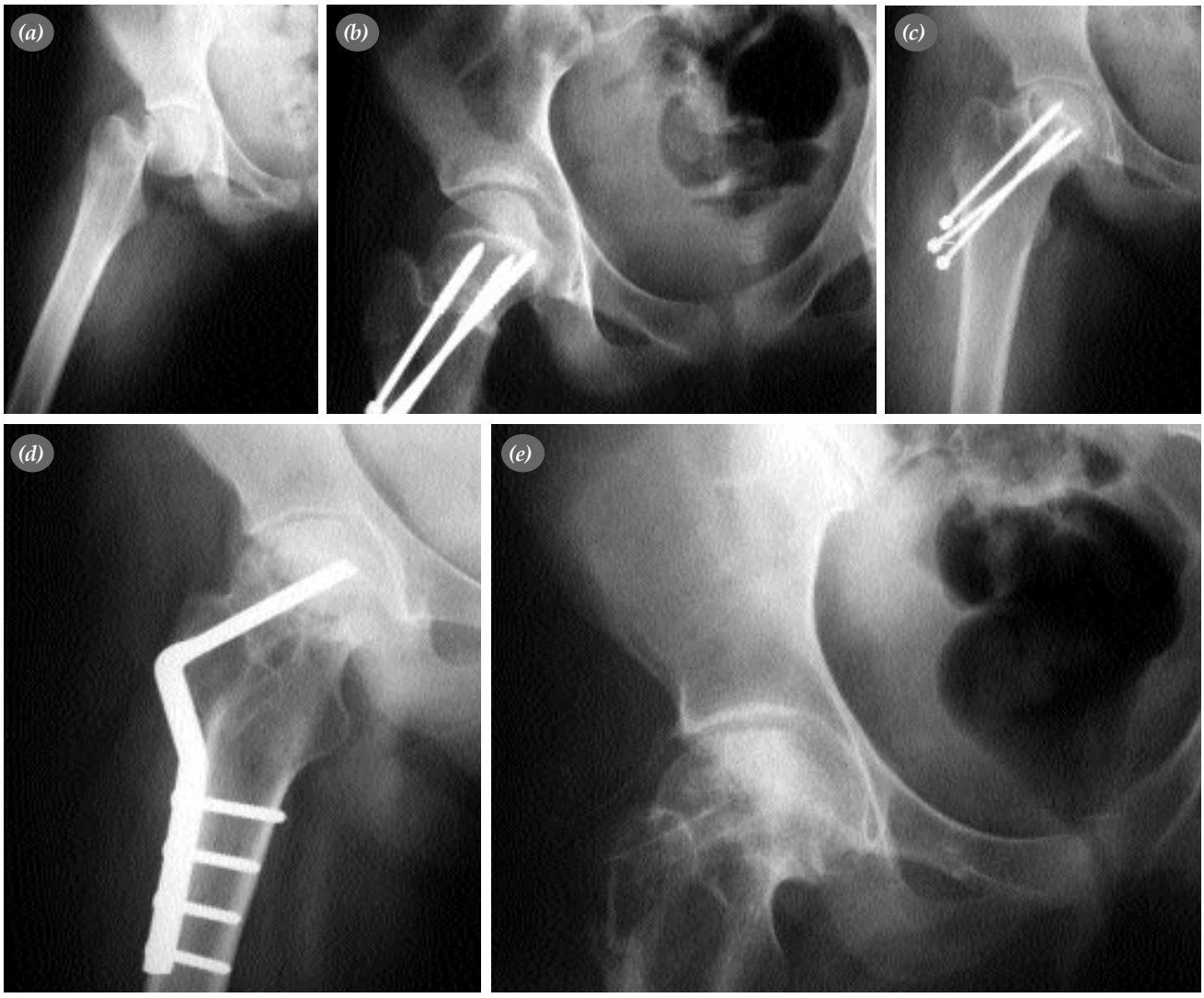

Figure 2. **(a)** AP radiograph of a 13 year old girl with transcervical femoral neck fracture. **(b)** The radiograph of the patient on who closed reduction and internal fixation was performed, shows non-anatomic reduction and improper placement of the screws on AP view at 1-month after the operation. **(c)** AP radiograph at 15-month follow-up. Union still is not complete. AVN of the femoral head was evident. **(d)** AP view at 5 months after Pauwels' valgization osteotomy and 21 months after fracture. AVN of the femoral head is still evident. **(e)** AP view at 56 months post-operatively. Union is completed but there appears irregularities on the femoral head. The result was classified as 'fair' according to Ratliff's criteria.

was not significant between the patients who were operated between 2-7 days and 8-15 days considering whether AVN develops or not (p>0.05).

Delayed/non-union developed in two patients (9.1%). Of the 14 patients who had PPC (63.6%), 11 developed AVN. Coxa vara, which was defined as a neck-shaft angle less than 130 degrees, was apparent in three patients (13.6%) (Table 3). One of these cases which has severe deformity, has been performed valgus osteotomy, as in two cases deformity improved partly with time.

Discussion

Femoral neck fractures are usually the result of high-velocity trauma and the lateral epiphyseal artery that is vulnerable at the proximal femoral epiphysis, either can be torn or kinked over the fracture ends. Consequently, AVN, which is the most devastating complication after hip fractures, may develop.

Some studies have shown that the incidence of complications after femoral neck fractures can be as high as 60 %.[10,12] AVN is the leading cause of poor results which can be done very little to change it and the incidence of AVN ranges from zero to 92%.[7,12,19,20] Forlin et al[7] and Bagatur and Zorer[10] performed on osteotomy for containment of the femoral head in acetabulum and found that extensive operative procedures seem not to change the outcomes considerably. Recently some authors stated that hyperbaric oxygen therapy had some effects in the treatment of stage I AVN of the femoral head and Baksi[14] reported good results with multiple drilling and muscle-pedicle bone graft.[23,24] Although there are some good results for management of AVN, there is no documented effective treatment.

The overall incidence of complication in the present series was 77.3 %. AVN (54.5 %) was second after PPC (63.6 %) in frequency. The most determining factors to develop AVN in femoral neck fractures are still controversial. Mostly discussed subjects are displacement of the fragments, type of the fracture, age of the patient and aggressive surgical treatment.[14-19] Favorable results were reported especially in the children with femoral neck fractures which were operated during the first 24 hours.[9,20,21]

As stated in the other series, AVN and PPC are frequent complications after Delbet type I fracture treated with open or closed reduction with/without internal fixation.[3,17,18] Forlin et al.[25] and Jerre and Karlsson[26] reported very good results of treatment with a spica cast without closed or open reduction and internal fixation even in case of delayed initial treatment (12,17). In both series, PPC and coxa vara were very common complications but there were no AVN. In these series mentioned above, children were younger and consequently its remodeling potential was higher as different from this series. Therefore, closed reduction and internal fixation was performed in the present series. However, at the follow-up AVN occurred in both of two patients. We believe that closed reduction maneuver or internal fixation, rather than late initial treatment, played a role in the highest complication rate in Delbet type I fractures with prevalence of AVN and PPC in two out of two patients.

Canale and Bourland[11] found that most of the fractures in their series, which developed AVN, were displaced. Many investigators pointed out to the relation between AVN and the initial displacement of fragment ends because of the insult to the blood supply at the time of injury.[1,3,7,12,15,18,27] On the other hand, Cheng and Tang[20] achieved excellent result with displaced fractures. Other series with displaced fractures also reported low rates of AVN.[9,18] And also there are reported cases of AVN of femoral head following undisplaced femoral neck fractures.[6,11] Maruenda et al.[28] reported that only 30% of the displaced fractures revealed decreased scintigraphy uptake. These authors stated that patients with undisplaced fractures are subject to a high risk of bone blood flow tamponade, because of the presumed integrity of the hip joint capsule as in case of some displaced fractures.[28] Most of fractures in our series were significantly displaced. Despite, they were reduced and fixed after twenty-four hours after injury, some developed AVN, and some did not. The number of the patients with displaced and undisplaced fractures was limited, therefore we were unable to relate the occurrence of AVN to the initial displacement. However, the results of this study support that the amount of displacement was not primary factor whether to develop AVN or not.

In the series with higher complication rates, it was documented that AVN had a high prevalence in patients with transcervical fracture and that the

worst results occurred in this type of fracture.[3,18] Canale and Bourland[11] reported that the incidence of AVN is higher in type I(100%) and type II(50 %) fractures, lower in type III(27%) according to Delbet in the patients, most of them treated by immediate open surgery. In this study, the incidences of AVN of 100% and 22.2%, in Delbet type I and Delbet type III respectively were similar to those in the patients described by Canale and Bourland,[11] but in Delbet type II, the rate was much higher (72.7%). The incidence of AVN was higher in transcervical and transepiphyseal fractures compared to the other type although it is not statistically significant (p>0.05). In addition, two of Ratliff type I AVN (total involvement) which had worst prognosis and 'poor' results in our series, belonged to the patients with transcervical and basoservical fracture. Nevertheless, one of the two AVN in the patients with basocervical fracture was Ratliff type one. We found that, the more the fracture line was located distally, the rate of Ratliff type I AVN is higher in the patients AVN occurred. The vascular anatomy seems to be important in the incidence of this type of AVN.

It was suggested that the age at the injury was a factor influencing the outcome, because the capacity of the femoral head for the revascularization and the remodeling diminish as the child gets older.[11] On the other hand, Leung and Lam[29] stated that the serious complications were found to be unrelated to age, but the fractures were either Delbet type II or type III. In this study we were not able to find any relation between the age and developing AVN (p>0.05). The younger children with AVN may have a higher percentage of better results related to the remodeling potential of the acetabulum and cartilaginous femoral head. However, it seems that the age in which femoral neck fractures occurred, has no effect on whether to develop AVN after femoral neck fracture or not.

Some believe that, AVN may be unavoidable, as the blood supply was damaged at the initial injury.[1,4,12,15,18,27] On the other hand, good results were published in cases operated on during very early period after injury.[20] Swiontkowski and Winquist[9] reported an incidence of 10% in children with femoral neck fractures, treated by urgent open reduction, internal fixation. More recently, the incidence of AVN was 6% in the patients operated on within the first 24 hours period after injury in Flynn's[21] series. The high rate of AVN (12 patients, 54.6%) in the present series compares with the figure reported by Bagatur and Zorer[10] (53%) and is little higher than the figures of Davison and Weinstein,[5] Morrisy,[12] Ratliff,[19] Canale and Bourland[11] (respectively; 47%, 40%, 42%, 43%) in which the time till operation was not clear.

It was reported that patophysiologic events related to the blood supply of femoral head was reversible in the first 24 hours.[9,20,21] We did not find any difference between the cases who were operated in the first seven days and eight days and later, related to AVN (p>0.05). These findings indicate that the rate of complication increases significantly in the procedures which was performed after first 24 hours and does not change afterwards considerably.

Canale and Bourland[11] were not able to find any differences between the patient with AVN who was treated and was not. The literature reveals that surgical treatment did not favorable effect on the natural history of AVN.[7,10] Some authors have recommended prolonged non-weight bearing when AVN occurred, but precise duration is not clear.[2,18,30] Recently some good results reported with hyperbaric oxygen therapy.[23,24] In this series, we recommended non-weight bearing (as intervals of 6-12 weeks, for 12-18 months after first symptoms were appeared) for treatment in all patients except one, when the patient had pain and limited ROM related to AVN clinically or findings on radiograph in favor of AVN. This only excluded patient with Ratliff type I AVN was tried to treat with the articulated distraction method using the Ilizarov device, but the fixator had to be removed after a short time because of the psychological and social intolerance of the patient and her family.[31,32] The result was 'fair'. In the other cases, patients' harmony for the prolonged non-weight bearing was not pretty good. Although we have limited experience with surgical treatment, we believe that surgical treatment of AVN cause additional trauma with no use.[7,12,31]

Besides, the outcome was 'good' in all of our cases without AVN except in one that was graded as 'fair' result. In the patients with AVN, nearly all 'good' and 'fair' results were associated with Ratliff type II and III AVN, while the results was fair in one and poor in another of cases developed Ratliff type I

AVN. These findings support the statement that the final result was very closely related to whether AVN existed or not, and if so, the type of the AVN, which closely related to the extension of vascular insult of femoral head.

In the present series, the most frequent complication was PPC (63.6%). It was stated that there was a close relation between the PPC and the vascular insult in femoral neck fractures.[12,15,18] The prevalence of PPC has been reported to be between 6 to 94 % however usually at a near AVN rate.[2,7,9,12,21] Some studies revealed that coxa vara and PPC alone is not responsible for poor results.[5,7] Of the twenty-two children in our series, fourteen had PPC, and among these fourteen patients, AVN developed in eleven. In the present study, we were not able to study the influence of the PPC on the final result because most of the PPC were accompanied with AVN. We believe that vascular insult can be common cause in both AVN and PPC.

There was only one case in our series with established non-union and one delayed union. The non-union and delayed union complication rate of 9.1% in this study is less than Davison and Weinstein's,[5] Morrisy's[12] and Bagatur and Zorer's[10] series (respectively 21%, 36%, 24%). The case with non-union had Ratliff type II AVN at the same time. We obtained union after Pauwels' osteotomy. In the case with delayed union, the threaded part of the screw did not pass well across the fracture line; so, there was a problem with fixation. We achieved union after re-fixation. In the literature, non-union has been associated with significant displacement, poor or late reduction and poor fixation.[1,12,15,18,19,33] The reasons were the same in our series.

Some investigators recommend non-operative treatment in basocervical fractures, although this management was very often complicated by coxa vara.[1,2,5,9,17,18,34] Coxa vara occurs because of injury to the epiphyseal plate, AVN, insufficient reduction and/or fixation.[5,11,12] There is a good potential for spontaneous correction of this deformity if the growth plate is open and the deformity is mild.[7] Our policy in this type of fracture, with the exception of the impacted abduction type fractures, was open reduction and internal fixation. Coxa vara occurred in three patients (13.6%). It is almost the same with the figure of Forlin et al.[7] (13 %) but lower than Davison and Weinstein's,[5] Morrisy's[12] and Heiser and Oppenheim's[15] (respectively 33%, 36%, 32%). Of three patients with coxa vara, two had mild post-operative deformity, but they healed spontaneously parallel with our expectation. The results were 'good'. One patient with more severe deformity had undergone valgus ostotomy. The result was 'fair'. We have the opinion that mild coxa vara did not alter the result, but over treatment of this deformity may result in further complications.

In conclusion, in children with femoral neck fracture when the operation performed after first 24 hours, complications of AVN and PPC were higher compared to the series in the literature operated in the first 24 hours period. In these patients, AVN is the most serious complication. Type of the fracture and age has not significant effect on whether AVN occurs or not. Considering prevalence of AVN, the results of treatment, which performed during the first week and the second week, were not significantly different after first 24 hours. The prevalence of AVN was highest in Delbet type I fractures. The outcomes of treatment mainly depends upon whether AVN developed or not, and secondary upon the fracture type.

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