

Long-Term Outcomes of Displaced Pediatric Femoral Neck Fractures

Deplase Çocuk Femur Boyun Kırıklarının Uzun Dönem Sonuçları

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ABSTRACT

Objective: The aim of the present study was to evaluate the long-term outcomes of displaced pediatric femoral neck fractures.

Methods: Patients under 18 years of age who were treated with a diagnosis of a displaced femoral neck fractures and followed until skeletal maturity were included in the study. Avascular necrosis of femoral head, coxa vara, premature closure of physis, and leg length discrepancy were assessed at the latest follow-up. Ratliff criteria were used for clinical evaluation.

Results: A total of 16 patients with a mean age of 10 ± 3.8 years were included in this study. The mean follow-up time was 68.8 months. Postoperatively, AVN was encountered in 9 patients while coxa vara was detected in 5. Premature physeal closure was observed in 10 patients, and leg length discrepancy was detected in 12. According to the Ratliff criteria, we encountered good outcomes in 12 patients, fair outcomes in 2 patients, and bad outcomes in 2 patients.

Conclusion: According to the results acquired from this study, AVN of the femoral head, premature physis closure, and leg length discrepancy was common after displaced pediatric femoral neck fractures. However, our results demonstrated a 75% good clinical outcome despite higher complication rates.

Keywords: pediatric, femoral neck, fracture, avascular necrosis, leg length discrepancy, coxa vara

ÖZ

Amaç: Bu çalışmanın amacı, deplase çocuk femur boyun kırıklarının uzun dönem sonuçlarını değerlendirilme.

Gereç ve Yöntemler: Bu çalışmaya deplase femur boyun kırığı tanısı ile tedavi edilen ve iskelet olgunluğuna kadar takip edilen 18 yaş altı hastalar dahil edildi. En son takipte femur başında avasküler nekroz, koksa vara, epifiz hattının erken kapanması ve bacak uzunluk farkı değerlendirildi. Klinik değerlendirme için Ratliff kriterleri kullanıldı.

Bulgular: Bu çalışmaya yaş ortalaması $10 \pm 3,8$ yıl olan toplam 16 hasta dahil edildi. Ortalama takip süresi 68,8 aydı. Ameliyat sonrası 9 hastada AVN, 5 hastada koksa vara saptandı, 10 hastada epifiz hattının erken kapanması ve 12 hastada bacak boyu eşitsizliği saptandı. Ratliff kriterlerine göre 12 hastada iyi, 2 hastada orta, 2 hastada zayıf ve 2 hastada ise kötü sonuçlarla karşılaştık.

Sonuç: Bu çalışmadan elde edilen sonuçlara göre, deplase çocuk femur boyun kırıklarından sonra femur başı AVN'u, epifiz hattının erken kapanması ve bacak uzunluğu eşitsizliği sık görülmektedir. Ancak bu yüksek komplikasyon oranlarına rağmen hastalarımızın %75 de iyi klinik sonuçlar elde edildi.

Anahtar Kelimeler: Çocuk, femur boynu, kırık, avasküler nekroz, bacakta uzunluk farkı, koksa vara

INTRODUCTION

Pediatric femoral neck fractures are less common than adult counterparts, and many orthopedic surgeons rarely treat these fractures in their professional life. In children, the periosteum is thicker and stronger at the femoral

neck. Therefore, 50% of these fractures are non-displaced fractures, and internal fixation is rarely needed.¹ However, serious complications such as avascular necrosis (AVN), non-union, malunion (coxa vara), and premature closure may develop even if the fracture is non-displaced.²⁻⁴

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Although closed reduction and spica cast application were previously recommended for the treatment of non-displaced Delbet type I fractures, many authors currently do not advocate it due to failure of achieving and maintaining a complete anatomical reduction.^{5,6} On the other hand, Forlin et al⁷ recommended applying the pelvipedal cast without reduction in children under 2 years of age and performing an osteotomy if coxa vara or shortening developed. In the recent studies, the importance of early fixation and anatomic reduction of displaced fractures has been remarked.⁸

Sensitive vascular supply of the femoral neck makes it prone to serious complications in the postoperative follow-up, especially in displaced fractures.^{9,10} To the best of our current knowledge, serious complications are more common in displaced fractures, thus we aimed to evaluate the long-term radiographic and clinical outcomes of displaced pediatric femoral neck fractures, rather than assessing both displaced and non-displaced fractures together.

METHODS

Study Population

This retrospective case-series study was performed after obtaining the approval of the institutional ethical review board (Date: April 9, 2007, Decision no: 2007/4). The medical records of the pediatric patients who were diagnosed with

either non-displaced or displaced femoral neck fractures and treated at the Orthopedics and Traumatology Department of Van Yüzüncü Yıl University between September 1994 and June 2007 were retrospectively reviewed. Patients under 18 years of age who were treated with a diagnosis of a displaced femoral neck fracture and followed until skeletal maturity were included in the study. Patients with incomplete medical records and/or follow-up ($n=7$), patients with accompanying trauma at the same extremity ($n=1$), and those with pathological fractures ($n=1$) were excluded.

Surgical Technique

Closed reduction was initially attempted in all patients. If acceptable anatomic reduction could not be achieved in fluoroscopic anterior and lateral images, open reduction by anterior Watson–Jones approach was performed. A spica cast was applied to 2 patients after closed reduction of the displaced fracture. After either open or closed reduction, Knowles pins, Kirshner wires, and 4.0 mm cancellous screws were used for internal fixation (Figures 1 and 2). The patients were followed up at the 15th day, 1st month, 3rd month, 6th month, 12th month postoperatively, and annually thereafter.

Data Evaluation

Patients' age, gender, mechanism of trauma, classification of the fracture according to Delbet classification (5),

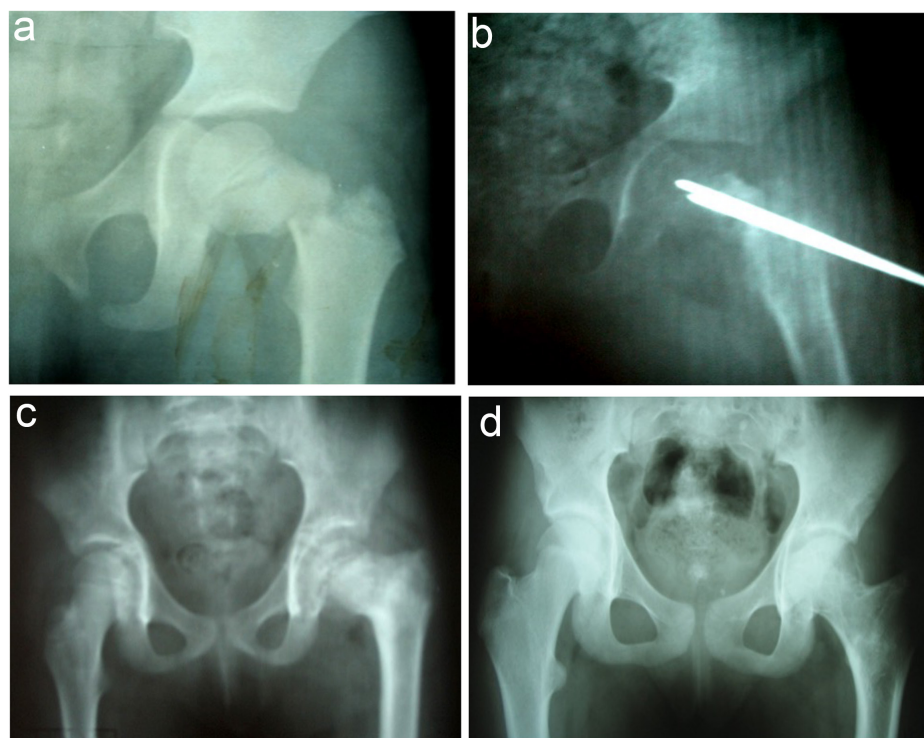


Figure 1. a-d. Radiographs of a 6-year-old girl with a displaced femoral neck fracture, anterior–posterior view (AP) of a Delbet–Colonna type III fracture (a) and AP view after closed reduction and internal fixation with Kirshner wires (b). Postoperative 2-year radiograph demonstrating the coxa vara at the left side of the patient (c) and at skeletal maturity radiograph showing the remodeling of the coxa vara deformity (d).

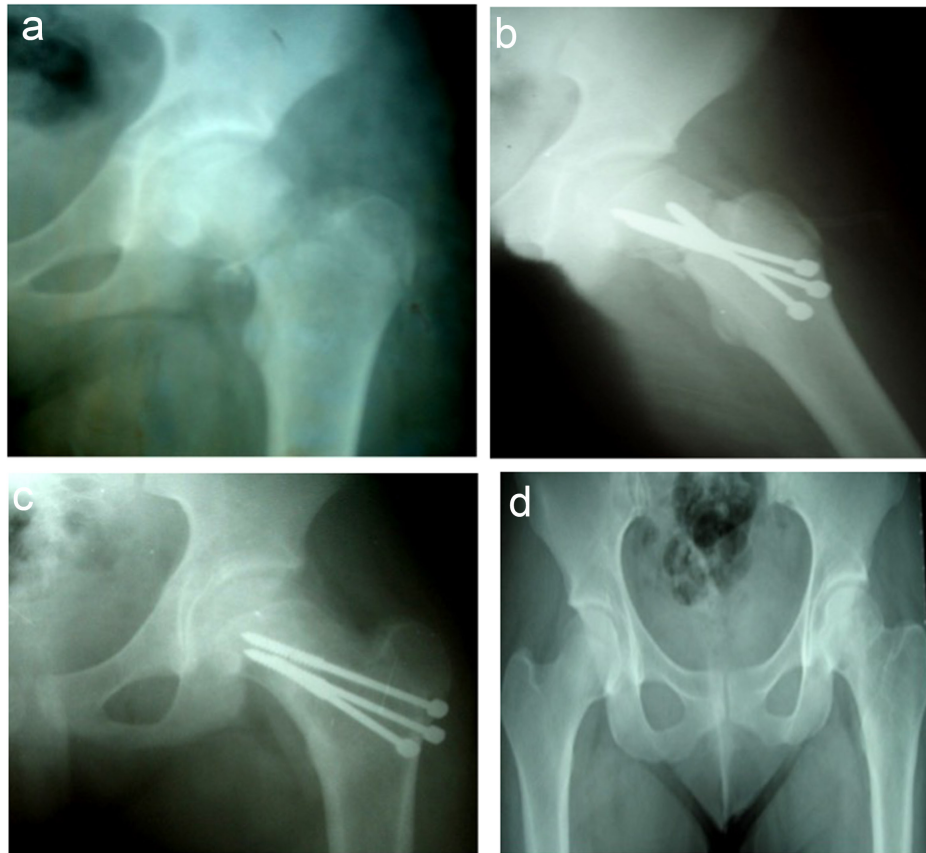


Figure 2. a-d. Anterior-posterior view (AP) radiograph of an 11-year-old girl with a displaced femoral neck fracture (a) and lateral view after open reduction and fixation with Knowles pins. (b) AP view of the patient at postoperative 2 years follow-up and (c) AP view at skeletal maturity(d).

and time from injury to operation were recorded through medical charts. The operative data were noted through medical records. Preoperative and last follow-up radiographs were evaluated by a single observer through pelvis anteroposterior and lateral radiographs. Femur shaft-neck angle (FSNA) was measured from the last-follow-up radiographs. Avascular necrosis of femoral head was classified according to Ratliff's classification.¹ Leg length discrepancy was assessed for each patient, and Ratliff criteria were used for the assessment of clinical outcome. All complications were recorded.

Statistical Analysis

Descriptive analysis was performed by using Statistical Package for the Social Sciences software 25.0 (IBM SPSS Corp.; Armonk, NY, USA.) Numerical variables were given as means and standard deviations, and categorical variables were given as frequencies and percentages. We did not perform a normality analysis because of small number of cohort, and the comparison of means were performed by non-parametric Mann-Whitney *U* test, while comparison of frequencies were performed by Fisher's exact chi-squared test. *P* values lower than .05 were considered as statistically significant.

RESULTS

A total of 16 patients (8 girls, 8 boys) with the mean age of 10 ± 3.8 years (range: 4-17 years) participated in this study. The mean follow-up time was 68.8 ± 35.5 months (range: 20-134 months). The clinical data of patients are demonstrated in Table 1.

Postoperatively, AVN was encountered in 9 of 16 patients (56%), while coxa vara was detected in 5 (31%). Premature physeal closure was observed in 10 patients (62%), and leg length discrepancy was detected in 12 (75%). We evaluated the relationship between complications and clinical data. Our results showed that AVN was significantly higher among females and in those who underwent open reduction ($P = .026$ and $.039$, respectively) (Table 2). According to the Ratliff criteria, we encountered good outcomes in 12 patients (75%), fair outcomes in 2 patients (12.5%), and bad outcomes in 2 patients (12.5%).

DISCUSSION

The most important finding of this study was observing good clinical outcomes despite encountering high

Table 1. Clinical Data of the Patients

No	Age (years)	Gender	Side	Delbet Classification	Mechanism of Injury	Time until Surgery (hours)	Reduction	Fixation Material	FSNA - (Coxa Vara Degree)	AVN type	Premature Physis Closure	Leg Length Discrepancy(cm)	Ratiff Score
1	13	Boy	R	3	MVA	9	Closed	3 Knowles pin	-	-	(+)	1	Good
2	16	Girl	R	2	Fall from Height	21	Closed	3 Knowles pin	104 (-12)	-	-	1.5	Good
3	11	Girl	L	2	MVA	6	Open	3 Knowles pin	-	Type 3	(+)	1	Good
4	6	Boy	L	3	Fall from Height	45	Closed	3 Kirschner wire	-	-	-	-	Good
5	4	Boy	L	2	MVA	8	Closed	Spica cast	-	-	-	-	Good
6	13	Boy	R	3	Fall from Height	30	Open	2 Cancellous screw	-	-	-	1	Good
7	17	Boy	R	2	Fall from Height	75	Open	4 Knowles pin	95	Type 1	(+)	1	Fair
8	10	Girl	R	3	MVA	48	Open	3 Knowles pin	118 (-12)	Type 3	(+)	1	Good
9	13	Boy	L	3	Fall from Ground Level	14	Open	2 Cancellous screw	-	Type 1	(+)	1.5	Bad
10	6	Girl	L	3	Fall from Height	90	Open	2 Kirschner wire	-	Type 3	(+)	1	Good
11	7	Girl	L	2	MVA	24	Open	3 Cancellous screw	-	Type 3	(+)	1	Good
12	11	Girl	L	2	Fall from Ground Level	8	Open	3 Knowles pin	-	-	-	-	Good
13	12	Girl	R	2	Fall from Height	90	Open	2 Cancellous screw	100	Type 1	(+)	3	Bad
14	6	Boy	R	1	MVA	25	Open	3 Kirschner wire	-	Type 1	(+)	3	Fair
15	7	Boy	L	2	Fall from Height	2	Closed	Spica cast	-	-	-	-	Good
16	9	Girl	L	2	Fall from Height	26	Closed	3 Kirschner wire	100 (-36)	Type 3	(+)	2	Good

R, right; L, left; MVA, motor vehicle accident.

Table 2. Relationship Between Postoperative Complications and Clinical Data of the Patients

	AVN (n=9) (56%)	Coxa Vara (n=5) (31%)	Premature Epiphyseal Closure (n=10) (62%)	Leg Length Discrepancy (n=12) (75%)
Age at the injury (years)	10.06 ± 3.8	12.8 ± 3.5	10.4 ± 3.5	11 ± 3.6
P	.491	.071	.690	.062
Gender				
Girl	6	4	6	7
Boy	3	1	4	5
P	.026	.106	.302	.248
Mechanism of Injury				
Motor vehicle accident	4	1	5	5
Fall from height	4	4	4	6
Fall from ground level	1	0	1	1
P	.680	.245	.411	.641
Delbet classification				
Type 1	1	0	1	1
Type 2	5	4	5	6
Type 3	3	1	4	5
P	.514	.411	.660	.641
Time until surgery				
<24 hours	2	1	3	4
>24 hours	7	4	7	8
P	.143	.197	.152	.146
Reduction				
Open reduction	8	3	8	9
Closed reduction	1	2	2	3
P	.039	.889	.062	.074
Fixation				
K-wire	3	1	3	3
Cancellous screw	3	1	3	4
Knowles pin	3	3	4	5
Spica cast	0	0	0	0
P	.551	.565	.271	.056
Ratliff score				
Good	5	3	6	8
Fair	2	1	2	8
Bad	2	1	2	2
P	.003	.646	.202	.411

frequency of complications. Interestingly, our results demonstrated that avascular necrosis and leg length discrepancy were not correlated with the clinical outcomes

according to the Ratliff criteria. We only observed a significant relationship between avascular necrosis, gender, and reduction types of the patients.

Avascular necrosis is a devastating complication that can be seen in up to 90% of pediatric femoral neck fractures.⁴ It has been shown to negatively affect clinical and radiological results. The age of the child, the type of fracture, the amount of displacement, the time of treatment, and the treatment method are important factors that play a role in the development of avascular necrosis.^{1,3,4,11} In their meta-analysis, Moon et al⁴ reported that age and fracture types are the most important factors in AVN development. Yeraniosian et al⁶ mentioned that avascular necrosis depends on the type of fracture and the time until the intervention may affect the development of avascular necrosis. These studies showed that Delbet type 1 and type 2 fractures have a higher risk of disrupting the femoral head's vascular circulation compared to type 3 fractures; thus, AVN is seen at higher rates in these fracture types.^{4,6} Wang et al¹² reported that the amount of displacement when fracture occurs was associated with the development of AVN. High-energy injuries increase the fracture displacement rate, and the risk of AVN increases with impaired vascular circulation in the weak and sensitive femoral head. In our study, we detected AVN in 56% of our cases. Our results demonstrated that females and those who underwent open reduction had significantly higher AVN rates. Consistent with the literature, our results also showed a higher AVN rate in type 2 and high-energy fractures. We also observed higher AVN rates in patients who underwent surgery after more than 24 hours from the injury.

Coxa vara deformity (femur neck-shaft angle <100 degrees) is a common complication after pediatric femoral neck fractures. Despite being a preventable complication related to fracture reduction quality and fixation, the coxa vara deformity may also develop secondary to AVN, epiphyseal plate damage, and nonunion. Toğrul et al¹³ reported coxa vara deformity in 8% of their cases, and Lam et al² reported a rate of 23% in their series. We observed coxa vara in 31% of our patients at the latest follow-up. Coxa vara is important with its potential to cause arthrosis. While remodeling occurs with growth in mild cases, intertrochanteric valgus osteotomy may be required in more severe deformities.^{6,9,13,14} We observed the remodeling of the coxa vara deformity during the follow-up of a patient.

Premature physis closure was seen at a rate of 17-62% after pediatric femoral neck fractures. Lam et al² detected early growth cartilage closure at a rate of 17% in their study, and the authors stated that there was a shortening of 1.3-3.2 cm in their patients. This may be caused by direct physical damage or disruption of the vascular circulation of the physis during trauma. In addition, fixation material may also interrupt physeal growth. When the fixation material needs to cross the physeal line, it is

recommended to use a straight pin and remove it after the fracture union. We detected premature physis closure in 10 (62.5%) of our patients, all of which also had AVN. The fixation material that was used in 5 of these cases had passed the physis growth line. To the best of our current knowledge, the contribution of the proximal femur growth plate to the entire femur length is approximately 15%. Studies report that if there is a physeal growth retardation before the age of 10 years or for more than 2 years, it may result in a shortening of >2 cm.^{1,6,14} In our cases, we detected a mean 1.46 cm (1-3 cm) of shortness, and all these cases also had AVN, premature physis closure, and coxa vara.

Nonunion is a rare complication after pediatric femoral neck fractures than adult counterparts, and it has been reported with a rate of up to 10%. While it is most common in Delbet type 2 fractures, it may develop due to non-anatomical reduction or improper fracture fixation. Valgus osteotomy can provoke union by converting the shear forces in the fracture line to compression force. Osteosynthesis with fibula is another option; however, it does not prevent coxa vara deformity, which is frequently present in cases of nonunion.^{6,9,14,15} There was no patient with nonunion among our treated cases.

The main limitations of this study were its limited cohort and retrospective design. However, it is difficult to achieve a larger cohort in this rare clinical entity. Also, we evaluated a specific patient population treated in the same center in the same manner. Another limitation of this study is its low statistical power due to the limited number of cases which prevents us from reaching a higher level of evidence. Nevertheless, this is the first study in the literature reporting the clinical and radiographic outcomes of displaced femoral neck fractures only.

According to the results acquired from this study, AVN of the femoral head, premature physis closure, and leg length discrepancy were common after displaced pediatric femoral neck fractures. However, our results demonstrated a 75% rate of good clinical outcome despite higher complication rates. Despite the complications detected being relatively high, we think that the improvement in the long follow-up period was due to the high remodeling capacity in children, which resulted positively in clinical and functional outcomes.

Ethics Committee Approval: Ethics committee approval for this study was obtained from the Ethics Committee of Van Yüzüncü Yıl University (Date: April 9, 2007; Decision no: 2007/4).

Informed Consent: Verbal and written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

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