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# Functional results after surgical treatment of pediatric femoral neck fractures

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**Abstract**

This study aims to present the functional outcomes of patients who were treated surgically for childhood femoral neck fractures. In addition, to obtain information about the complications seen after these fractures, especially avascular necrosis of the femoral head (AVN), and to investigate the relationship with the treatment process. Our study is a retrospective study including 22 fractures of 22 patients operated for femoral neck fractures between 2012 and 2021. Thirteen of the patients were boys and 9 were girls The mean age at the time of trauma was 12.6 years (5-17 years). The fractures were classified based on the Delbet/Colonna classification. Fracture type and its effect on functional outcomes and the effect of fracture type on complications were investigated. The relationship between the time and type of treatment and AVN was evaluated. The mean follow-up period of the patients included in the study was 36.9 (12-132 months) months. Orthopedic injury in combination with femoral neck fracture was seen in 4 patients. Femoral neck fractures were classified as type 1 in 1 patient, type 2 in 15 patients, type 3 in 4 patients, and type 4 in 2 patients. In our study, 5 of 8 complications were AVN. The clinical results of the patients were classified with Ratliff score and 14 patients had good, 3 patients had fair and 5 patients had poor results. According to this classification system, 5 patients who developed AVN had a poor outcome, but no significant correlation was found between AVN and the timing of surgery and treatment method. All of the cases with AVN were Type 1 and Type 2 fractures. Pediatric femoral neck fractures are inherently difficult fractures for orthopedists who need long-term follow-up. Although the appropriate time, methods, and materials for surgical management are frequently discussed, the severity of the injury and the anatomical location of the fracture is most important in the development of AVN.

**Keywords:** Femoral neck fractures, pediatric, avascular necrosis

## Introduction

Femoral neck fractures are less than 1% of the fractures seen in pediatric patients. In children between 10-13 years of age, it is more frequently encountered and boys are affected approximately 2 times more often than girls [1]. In the adult age group, femoral neck fractures are mostly seen after low-energy injuries such as simple falls, while in the pediatric group, on the contrary, 90% of cases develop after high-energy traumas such as traffic accidents, falls from a height, and only 10% of cases are seen after low-energy injuries [2]. Even though pediatric femoral neck fractures are rare, they may cause major problems especially due to avascular necrosis (AVN) at the head and neck of the femur. Degenerative changes in the hip joint can be observed with osteonecrosis that may develop after the fracture [3]. This can result in long-term functional loss and disability.

These fractures were categorized by Delbet/Colonna [4]. This categorization has a prognostic effect on the incidence of AVN. Pediatric femoral neck fractures are separated into 4 types: Type 1 transepiphyseal, type 2 transcervical, type 3 basicervical, and type 4 intertrochanteric fractures. The risk of AVN development

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decreases from type 1 to type 4 and type 4 is not observed at all because it is a fracture external to the hip capsule.

In this study, we aimed to reflect on the functional outcomes of our patients who underwent surgical treatment for pediatric femoral neck fractures and to evaluate the incidence of complications after these fractures, especially AVN, and the relationship of these complications with factors such as time from injury to surgery, type of treatment, and fracture type.

## Material and Methods

Our study is a retrospective study involving patients who were diagnosed with femoral neck fractures and operated surgically at Inonu University Orthopedics and Traumatology clinic between 2012 and 2021. This study was ethically approved by Inonu University Scientific Research and Publication Ethics Committee with decision number 4610. Our study consisted of patients younger than 18 years of age, patients with complete files, and patients with fractures affecting the femoral neck and intertrochanteric region. Patients with pathologic fractures of the proximal femur, incomplete files and refused treatment, stress fractures of the femoral neck, and isolated subtrochanteric fractures were excluded.

Twenty-two fractures of 22 patients operated on for femoral neck fractures were enrolled. Thirteen (59.1%) of our patients were boys and 9 (40.9%) were girls. The side of the injury was right-sided in 10 patients (45.4%) and left-sided in 12 patients (54.5%). The mean age of the patients at the time of trauma was 12.6 years (5-17 years). The most common mechanism of injury was high-energy trauma, which was reported in 18 patients (81.8%). Among these, falls from a height were found in 13 (59.9%), non-vehicle traffic accidents in 3 (13.64%), in-vehicle traffic accidents in 1 (4.5%), being under a heavy object; fracture development after a blow to the hip was found in 1 (4.5%) patient. Fracture development after low-energy trauma caused by falling from the same level while running or walking was seen in 4 (18.2%) patients. Demographic data and categorization of the fractures are given in Table 1.

The initial assessment of the patients in the emergency department and/or outpatient clinic started with orthopedic and systemic examination. Findings related to the extremity and fracture such as pain, pathologic posture, and joint movements were recorded. Femoral neck fracture was documented with hip anteroposterior and lateral or oblique radiographs (Figure 1). None of the patients underwent preoperative capsulotomy or hip decompression with needle aspiration. Patients with femoral neck fractures were operated on during the first 24 hours unless there was a vital contraindication. In the presence of contraindications and patients with delayed admissions, surgery was performed in the late period. The mean time to surgery after injury was 23.45 hours (1-240 hours).

Our patients were operated under general anesthesia in supine position. Closed reduction was first applied for the fracture. Open reduction was performed in cases that could not be reduced closed. Reduction was evaluated with anteroposterior and lateral views under fluoroscopy. Fixation was not started until complete anatomical reduction was achieved. After reduction, the fractures were fixed with 4 or 6.5 mm cannulated screws depending on the patient's weight, age, and bone characteristics. The number of screws was decided according to the quality of intraoperative fixation. In type 1 and 2 fractures, due to the nature of the fracture, the epiphysis could not be protected during screw application because it was too close to or included the epiphysis. However, in type 3 and 4 fractures, attention was taken to preserve the epiphyseal line as much as possible in selected patients based on stable fixation.

**Table 1.** Demographic characteristics of patients and outcomes score

| | |
|---|---|
| **Number of patients** | 22 |
| **Average age** | 12.6 (5-17) |
| **Sex** | |
| **Boy** | 13 (%59.1) |
| **Girl** | 9 (%40.9) |
| **Side of injury** | |
| **Right** | 10 (%45.4) |
| **Left** | 12 (%54.5) |
| **Delbet Classification** | |
| **Type 1** | 1 (%4.55) |
| **Type 2** | 15 (%68.1) |
| **Type 3** | 4 (%18.2) |
| **Type 4** | 2 (%9.1) |
| **Type of reduction** | |
| **Close** | 21 (%95.45) |
| **Open** | 1 (%4.55) |
| **Ratliff outcome's score** | |
| **Good** | 14 (%63.6) |
| **Fair** | 3 (%13.6) |
| **Poor** | 5 (%22.7) |

**Figure 1.** Anteroposterior and oblique radiographs of the left femoral neck fracture at the time of injury

In the postoperative follow-up, a hip-supported splint was used for 6 weeks in patients younger than 10 years of age. Sutures

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were removed in week 2. Continuity of reduction and fixation and union were checked in the outpatient clinic with anterior-posterior hip radiographs (Figure 2). At the last outpatient visit, patients were scored with Ratliff's [5] clinical and radiologic evaluation score (Table 2).

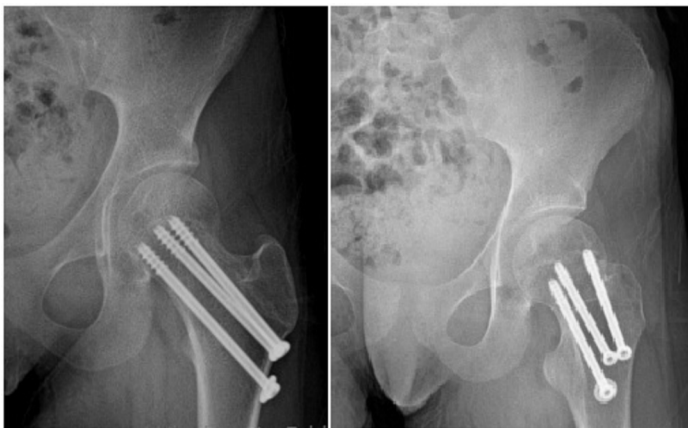

**Figure 2.** Postoperative follow-up of the fracture with 3 screws fixation radiographs

**Table 2.** Ratliff's criteria for functional assessment of the results of treatment

| | Good | Fair | Poor |
|---|---|---|---|
| **Pain** | None or 'ignores' | Occasional | Disabling |
| **Movement** | Full or terminal restriction | Greater than 50% | Less than 50% |
| **Activity** | Normal or avoids games | Normal or avoids games | Restricted |
| **Radiographic findings** | Normal or some deformity of the neck | Severe deformity of the neck | Severe avascular necrosis, degenerative arthritis |

Concomitant orthopedic injuries and other organ-system injuries were documented along with these fractures. Complications after femoral neck fractures such as nonunion, septic arthritis, coxa vara, osteonecrosis, premature physeal closure, and posttraumatic slipped capital femoral epiphysis were analyzed. The relationship between osteonecrosis, the most serious complication seen after these fractures, and the type of fracture, time of surgery, and the surgery performed was investigated.

IBM (New York, USA) SPSS (Statistical Package for the Social Sciences) Statistics 26.0 package program was used for statistical evaluations. In descriptive statistical analyses, mean ± standard deviation and median (minimum-maximum) were given for continuous variables; number and % were given for categorical variables. Correlation analyses were performed with Chi-Square Test. The statistical significance level was accepted as $p<0.05$.

## Results

The mean follow-up period of our patients was 36.9 (12-132 months) months. The concomitant orthopedic injury was seen in 4 patients (18.1%). In 2 patients (9.1%), pelvic fracture was seen in addition to femoral neck fracture and these fractures were not surgically managed and followed conservatively. One patient (4.55%) had a contralateral femoral shaft fracture and one patient (4.55%) had a distal radius fracture. Femur and distal radius fractures were treated surgically in the same session in patients operated on for femoral neck fractures. None of our patients had organ-system injuries other than extremities. In all patients, complete anatomical reduction was confirmed by postoperative radiographs following intraoperative images.

According to the Ratliff clinical and radiologic scoring system, 14 patients (63.6%) had good, 3 patients (13.6%) had fair and 5 patients (22.7%) had poor results. One of our patients with poor outcomes was a patient with mucopolysaccharidosis and a comorbid condition such as mental retardation. Surgery was performed 10 days after the fracture due to late admission. In this patient with type 2 fracture, 2 cannulated screw was applied. In the other 4 patients with poor outcomes, except for one, all had Type 2 fractures. Surgeries were performed in the early period and there were no comorbidities in their medical history.

There were 3 patients (13.6%) in whom surgery could not be performed in the first 24 hours. 2 patients had type 2 fractures. One patient had a type 4 extracapsular fracture and surgery was performed 48 hours after the injury. Closed reduction was performed in 21 cases (95.45%) and open reduction in 1 case (4.55%). In 12 patients (54.55%) 3 screws, in 10 patients (45.45%) 2 screws were applied. In 1 patient (4.5%), a proximal femoral nail was used for fracture fixation. The patient was 16 years old and the fracture was a Delbet Type 4 non-capsular intertrochanteric fracture.

A total of 8 patients (36.3%) developed complications. Avascular necrosis of the femoral head was detected in 5 patients (22.7%). Coxa vara, determined by measuring the femoral neck-shaft angle during follow-up, was detected in 3 patients (13.6%). No complications such as nonunion, septic arthritis, premature physeal closure, or posttraumatic slipped capital femoral epiphysis were observed in any patient. The details of patients with osteonecrosis in terms of fracture type, procedure type, and number of screws used are given in Table 3.

**Table 3.** Findings of patients with avascular necrosis

| | Age | Delbet classification | Time for surgery after injury | Reduction | Number of screws using |
|---|---|---|---|---|---|
| **Patient 1** | 11 | Type 1 | 8 hours | Close | 2 |
| **Patient 2** | 13 | Type 2 | 10 days | Open | 2 |
| **Patient 3** | 15 | Type 2 | 5 hours | Close | 3 |
| **Patient 4** | 13 | Type 2 | 2 hours | Close | 3 |
| **Patient 5** | 14 | Type 2 | 4 hours | Close | 3 |

All cases of osteonecrosis were seen in type 1 and 2 fractures. Clinical correlation and statistical significance were found between fracture type and osteonecrosis. All patients who developed osteonecrosis were over 10 years of age and the

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number of screws used in treatment varied. However, no statistically significant relationship was found between AVN and age or number of screws separately p>0.05). The surgical time between osteonecrosis and injury was divided into the first 24 hours and surgeries performed after 24 hours. There was no significant relationship between early surgery and delayed surgery in terms of osteonecrosis development (p>0.05). There was no significant correlation between Ratliff scores, which were used to evaluate the clinical and radiologic results of the patients, and fracture type (p>0.05).

**Discussion**

Pediatric femoral neck fractures are relatively rare compared to other fractures and the incidence is higher in boys than in girls [1,6]. High-energy trauma is the most frequently reported mechanism of injury. Traffic accidents and falls from height are the main etiologic factors [7]. In addition to the occurrence of these fractures as a result of high-energy trauma, the incidence of concomitant orthopedic injuries and serious life-threatening head, abdominal and chest traumas increases. This may lead to a decrease in quality of life and disability [3,6,8]. In our study, boys were dominant. While falls from heights were the most commonly seen cause, fractures in 18 patients developed as a result of high-energy trauma. Contrary to the literature, there were no comorbid organ system injuries in our patients, but osseous pathologies such as distal radius and pelvic fractures were found to accompany femoral neck fractures.

The classification system used in femoral neck fractures not only describes the location of the fracture but may also provide statistical predictions for the surgeon regarding AVN that may develop after treatment. In particular, type 1 fractures have been correlated with high AVN rates independent of factors such as treatment and time to surgery [7,9,10]. Type 1 cases are less common than type 2 and 3 cases [6]. Type 2 fractures are important because of their high incidence and high complication rates. AVN is less common as the fracture moves away from the femoral head and outside the hip joint capsule. Since intertrochanteric Type 4 fractures are outside the hip joint capsule, it is natural that AVN is not seen after these fractures. In our study, Type 2 fractures were found in 15 of 22 patients. And 4 of the 5 patients who developed AVN were also Type 2 fractures. We have 1 patient with rare Type 1 fractures and AVN developed. Statistically, there was a statistical correlation between Delbet type 1 and 2 fractures and osteonecrosis.

The femoral head blood circulation for AVN has been anatomically analyzed. It has been reported that the absence of collaterals between the femoral head and neck and the epiphysis acting as a barrier in children compared to adults are facilitating factors in the development of AVN after fractures [11]. AVN is a devastating complication with no treatment. Therefore, surgeons focus on the management of these fractures to prevent AVN rather than treatment. Answers to questions such as the most appropriate time, which method, and how are being investigated.

The question of when surgical treatment should be performed in pediatric femoral neck fractures is still a controversial issue. In a study advocating surgical treatment in the first 24 hours, it was reported that avascular necrosis developed in more than half of the patients with late surgery. High complication rates were given [12]. In another study with long-term results, early treatment was advocated by finding that none of the patients treated within 24 hours developed AVN [13]. In contrast to these studies, no difference was found in terms of AVN development in studies comparing early and late treated patients [14,15]. In our study, surgery was performed in the first 24 hours in 4 of our 5 patients who developed AVN. It was found that there was no significant relationship between the timing of surgery and the risk of AVN development. However, we think that we should focus on the questions of how late it is after the first 24 hours and whether there is a definite time frame to call 'late treatment'.

Another point that remains unclear is the type of reduction and the materials used in surgical treatment. There are studies indicating that open reduction is superior to the closed reduction in terms of AVN and outcomes in displaced and unstable fractures [16,17]. In another study, an increase in osteonecrosis was found with open reduction and internal fixation [18]. In a study of 20 patients, various materials were used for the fixation of femoral neck fractures. The use of fixation materials such as thin and old-generation K-wires and new implants were compared and the incidence of AVN was found to be significant with the use of K-wires [13]. In another study, it was reported that in pediatric femoral neck fractures fixed with cannulated screws, it was recommended that fixation with 2 screws should be placed in the appropriate configuration [19].

Open reduction is usually performed in cases with late diagnosis and treatment and after the failure of unstable closed reduction. In our study, open reduction was used in only 1 of 22 fractures. This patient with type 2 fracture was a late case in which surgery was performed 10 days after the injury. In addition, We usually used 2 or 3 cannulated screws for fixation after reduction. The number of screws varied in patients who developed AVN. In our study, no significant correlation was found between AVN and the number of screws and type of reduction. We think that intraoperative anatomical reduction and stabilization are more valuable than the reduction and number of screws.

Another important factor investigated in pediatric femoral neck fractures is the relationship between advancing age and AVN. There is still no consensus on this issue due to different results. There is a study suggesting that increasing age increases the possibility of AVN secondary to changes in the blood supply to the femoral head. According to this article, 12 years of age is given as the limit [20]. However, there are studies indicating that advanced age is not a risk factor for AVN in femoral neck fractures [21]. In our series, all but one of the patients who

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developed AVN were over 12 years of age. However, this was not found to be significant. We think that the development of AVN is independent of age and it may be wrong to conclude that there may be an increased risk of AVN based only on the age of the patient.

Coxa vara is another important complication that occurs after pediatric femur fractures. It is reported to develop as a result of a non-anatomical reduction in closed reduction of fractures [11]. It has been associated with other complications such as nonunion, osteonecrosis, and leg length inequality. Moderate deformities seen in younger patients can be followed conservatively and they have the capacity for remodeling. However, advanced deformities in older children may require surgery [22]. In our series, coxa vara was seen in 3 patients during follow-up. One patient with coxa vara was 10 years old and the other two patients were over 10 years old. Nonunion and osteonecrosis were not observed in any of them. No additional surgery was performed for coxa vara. Longer follow-up may be useful in patients with coxa vara in terms of the development of osteonecrosis and worsening of the current clinic.

In a study including 10 patients who underwent open reduction, AVN was observed in 1 case and 90% good result was obtained according to Ratliff criteria [23]. In another study including 8 patients who performed closed reduction and fixation with cannulated screws, 75% good results were obtained [19]. Unlike these studies, another study with a higher number of patients and a longer follow-up period reported a 26% poor outcome [24]. In our 22 patients, we found 63.6% good results and 22.7% poor results. The number of good results was similar to the studies, but the problem in the management of these fractures is the development of AVN even in appropriately treated patients. A recent study has tried to standardize the management of pediatric femoral neck fractures to achieve the best results [25]. Early surgery, proper anatomical reduction, and choice of implants have a definite influence on the outcome. However poor outcomes and development of AVN can occur sometimes even in the most appropriately treated patients.

Our study has several limitations. This retrospective study included relatively few patients. Evaluation of functional outcomes with longer follow-up periods may be more valuable.

## Conclusion

Pediatric femoral neck fractures are less frequently encountered by orthopedists but can cause serious problems if not treated appropriately. In these surgically treated fractures, early surgery, closed or open anatomical reduction and stable fixation using new generation implants result in good outcomes in approximately 4 of 5 cases. Nevertheless, sometimes even with optimal surgical management, AVN can occur, the pathogenesis of which is well known. The treating surgeon should be aware of this unpredictable complication, especially in Delbet type 1 and 2 fractures.

**Conflict of Interests**
*The authors declare that there is no conflict of interest in the study.*

**Financial Disclosure**
*The authors declare that they have received no financial support for the study.*

**Ethical Approval**
*Our study was conducted with the approval of the Samsun Training and Research Hospital's non-interventional clinical research ethics committee under the permit number GOKA/2021/10/4.*

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