

Outcomes of Pediatric Femoral Neck Fractures: Impact of Reduction Quality and Age

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Abstract

Aim: This study aimed to evaluate the clinical and radiological outcomes of pediatric femoral neck fractures and to identify prognostic factors, particularly reduction quality and patient age, associated with major complications such as avascular necrosis and deformity.

Methods: A retrospective analysis of 87 patients (aged 1–16 years) treated for femoral neck fractures at a tertiary trauma center between October 2017 and July 2022 was conducted. Demographic, clinical, radiological, and operative data were reviewed. Surgical delay was categorized as ≤ 24 hours or > 24 hours, and reduction quality was graded as good, fair, or poor. Outcomes included femoral head avascular necrosis (AVN), coxa vara, coxa valga, nonunion, and revision surgery.

Results: The mean follow-up was 15.5 weeks. The overall complication rate was 16.1%. The most common complications were coxa vara (6.9%), coxa valga (5.7%), and AVN (3.4%). Reduction quality was the strongest predictor of adverse outcomes; complications were significantly more frequent in the fair and poor reduction groups compared with the good reduction group ($p < 0.001$). Patients with complications were significantly older (median 14 vs. 10 years, $p = 0.01$).

Conclusions: Reduction quality and patient age were the most important predictors of complications in pediatric femoral neck fractures. While early fixation within 24 hours may help reduce the risk of nonunion, the limited number of delayed cases precludes firm conclusions. The relatively short follow-up may underestimate the true incidence of late complications such as AVN. Meticulous anatomical reduction and careful management of older children remain the most critical factors in minimizing long-term sequelae in this rare but high-stakes injury.

Keywords: Femur neck fracture; children; necrosis of the femoral head; fracture healing; treatment outcome

1. Introduction

Pediatric femoral neck fractures are exceedingly rare, accounting for less than 1% of all pediatric fractures, yet despite their low incidence, they carry a disproportionately high risk of severe complications, including femoral head avascular necrosis (AVN), nonunion, and coxa vara, which can lead to long-term functional impairment.^{1,2} The vascular anatomy of the pediatric femoral head is uniquely susceptible to ischemic injury. In children, blood supply predominantly relies on the medial femoral circumflex artery (MFCA), while the lateral femoral circumflex artery (LFCA) contributes less significantly. Additionally, the foveal artery within the ligamentum teres also provides supplementary perfusion, unlike in adults. This tenuous supply, combined with the intracapsular location of femoral neck fractures, which can easily compromise retinacular vessels, makes timely and anatomically precise management crucial to prevent AVN and other devastating sequelae.^{3,4} Despite advancements in surgical treatment, pediatric femoral neck fractures remain notoriously problematic, with AVN reported in up to

40% of cases. Nonunion occurs in approximately 6–10%, and coxa vara deformity has been observed in 5–35%, depending on fracture displacement and treatment adequacy. These high complication rates underscore the delicate vascular anatomy and biomechanical challenges inherent to this injury.^{5,6}

Among various prognostic factors, quality of reduction has consistently emerged as a critical determinant of outcomes in pediatric femoral neck fractures^{1,3}. Precise anatomical realignment minimizes the risk of mechanical failure and progressive deformity, whereas suboptimal reduction predisposes to complications despite stable fixation. Age has also been suggested to influence prognosis, as older children may have reduced remodeling potential and increased risk of adverse events. While early fixation within 24 hours has long been advocated to reduce AVN⁷, evidence regarding surgical timing remains inconsistent, particularly in cohorts where most patients undergo timely surgery. Similarly, comprehensive reviews emphasize that early fixation, ideally within 24 hours, and an-

atomical reduction remain the foundation for minimizing complications.⁸

In this context, the present study retrospectively examines a single-center cohort of 87 pediatric patients with femoral neck fractures treated over an approximately five-year period. The primary aim was to determine the incidence of major complications and identify key prognostic factors, with particular attention to reduction quality and patient age. By analyzing the relationship between clinical, surgical, and radiographic variables and patient outcomes, this study aims to provide updated evidence to inform surgical planning and improve prognostic stratification in this challenging pediatric injury.

2. Materials and Methods

This retrospective cohort included pediatric patients (aged 1–16 years) with femoral neck fractures treated at Adana City Training and Research Hospital, a tertiary trauma center, between October 2017 and July 2022. Ethical approval was obtained from the Clinical Research Ethics Committee of Adana City Training and Research Hospital (Meeting No: 107, Approval No: 1981, Date: June 9, 2022). The study was conducted in accordance with the Declaration of Helsinki, and informed consent for the use of data was obtained from parents or legal guardians.

2.1. Study design and patient selection

All consecutive patients younger than 16 years who sustained a femoral neck fracture during the study period were screened. Patients with pathological fractures and those with a follow-up shorter than 12 weeks (3 months, minimum required follow-up) were excluded to ensure reliable assessment of union and early complications. After applying these criteria, 87 patients were eligible for analysis.

2.2. Data collection

Clinical charts, operative notes, and radiographic archives were systematically reviewed. Extracted variables included demographic data (age, sex, laterality), mechanism of trauma, fracture characteristics (Delbet classification, displacement status), and treatment details (surgical delay categorized as ≤ 24 hours or > 24 hours, fixation technique, and implant configuration). Fractures of the femoral neck were categorized using the Delbet system, later refined and widely disseminated through the work of Colonna, which divides these injuries into four distinct anatomical types⁹. Radiological outcomes comprised time to union, AVN graded according to Ratliff¹⁰, nonunion, coxa vara, coxa valga, and leg length discrepancy. Clinical outcomes were assessed according to Ratliff's clinical criteria (good, fair, poor). Postoperative complications such as infection or the need for revision surgery were also recorded.

2.3. Follow-up protocol and definitions

Patients were followed at standardized intervals with both clinical and radiographic assessments: at 6 weeks, 3 months, 6 months, 12 months, and annually thereafter when available. Union was defined as bridging callus formation with pain-free full weight bearing. Reduction quality was graded as good, fair, or poor using the Garden Alignment Index (GAI): angles between 155° – 180° on both antero-posterior and lateral views were defined as good, acceptable alignment in only one plane was graded as fair, and alignment outside this range in both planes or a cortical step-off > 2 mm was graded as poor¹¹. AVN was diagnosed radiographically using Ratliff's classification. Clinical outcomes at the last available follow-up included hip range of motion, limb length discrepancy, and functional status, graded according to Ratliff's criteria¹⁰. All assessments were independently reviewed by two orthopedic surgeons blinded to the operative details, and discrepancies were resolved by consensus.

2.4. Statistical analysis

Continuous variables were presented as mean \pm standard deviation when normally distributed, and as median with interquartile range when not normally distributed. Categorical variables were expressed as numbers and percentages. Comparisons between groups were performed using the Chi-square test or Fisher's exact test for categorical variables, and the Student's t-test or Mann-Whitney U test for continuous variables, depending on distribution. A p-value of < 0.05 was considered statistically significant. All statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Demographic and injury characteristics

A total of 87 pediatric patients with femoral neck fractures were analyzed. The median age was 11 years (range, 1–16), with 55 males (63.2%) and 32 females (36.8%). The median age was higher in males (13 years) compared to females (9 years), but this difference was not statistically significant ($p = 0.11$).

Fractures involved the left hip in 60 patients (69.0%) and the right hip in 27 patients (31.0%). There was no significant side dominance by sex ($p = 0.84$). The most common mechanism of injury was a fall from standing height (81.6%), followed by traffic accidents (10.3%), falls from height (2.3%), and other rare causes. No significant difference in injury mechanism was observed between sexes ($p = 0.36$) (Table 1).

Table 1
Demographic and injury characteristics of the patients

Variable	Male (n=55)	Female (n=32)	p
Age, median (IQR)	13	9	0.11 ^a
Side of fracture			0.84 ^b
Left	37 (67.3%)	23 (71.9%)	
Right	18 (32.7%)	9 (28.1%)	
Mechanism of injury			0.36 ^b
Fall	41 (74.5%)	30 (93.8%)	
Traffic accident	7 (12.7%)	2 (6.2%)	
Fall from height	2 (3.6%)	0	
Other/rare causes	5 (9.1%)	0	

^a Mann-Whitney U test was used for age comparison.

^b Chi-square test was used for categorical variables.

$p < 0.05$ was considered statistically significant.

3.2. Fracture classification and treatment details

According to the Delbet classification, type I (35.6%) and type III (31.0%) fractures were the most frequent, while type II (24.1%) and type IV (9.2%) were observed less commonly. No statistically significant association was found between fracture type and clinical outcomes ($p = 0.21$).

Regarding surgical timing, 82 patients (94.3%) underwent fixation within 24 hours, while only 5 patients (5.7%) experienced a delay of more than 24 hours.

Cannulated screws were the most frequently used fixation method (51.7%), whereas plate fixation (13.8%) and hip spica cast-

ing (16.1%) were less common. Other or combined fixation strategies accounted for 18.4% of cases.

Reduction quality was assessed in 87 patients: 59 (67.8%) had good reduction, 11 (12.6%) fair reduction, and 17 (19.5%) poor reduction (Table 2). Poor reduction was significantly correlated with the occurrence of coxa vara ($p = 0.04$).

Table 2
Fracture Management Characteristics and Reduction Quality

Variable	n (%)	p
Surgical delay		
≤24h	82 (94.3)	—
>24h	5 (5.7)	—
Fixation method		
Cannulated screws	45 (51.7)	—
Plate fixation	12 (13.8)	—
Hip spica (conservative)	14 (16.1)	—
Other/combined	16 (18.4)	—
Reduction quality		
Good	59 (67.8)	Reference
Fair	11 (12.6)	<0.001*
Poor	17 (19.5)	<0.001*

^a Categorical variables were compared using the Chi-square or Fisher's exact test, as appropriate.

^b $p < 0.05$ was considered statistically significant.

3.3. Clinical and radiological outcomes

The mean follow-up duration was 15.5 ± 14.8 weeks. The mean hospital stay was 3.7 ± 8.8 days. Overall, 14 patients (16.1%) developed clinically significant complications. The most common were coxa vara (6.9%), coxa valga (5.7%), avascular necrosis (3.4%), and nonunion (2.3%).

Reduction quality was the strongest determinant of adverse outcomes. All patients with good reductions healed uneventfully (59/59, 100%), whereas complications were significantly more frequent in the fair/poor reduction group compared with the good-reduction group ($p < 0.001$).

Patients with complications were significantly older (median: 14 years) than those without complications (median: 10 years, $p = 0.01$). However, follow-up duration did not significantly differ between those with and without complications ($p = 0.39$), indicating no follow-up bias in complication detection.

Nonunion occurred in two patients (2.3%), both of whom also had implant-related failure and underwent revision. AVN showed no significant correlation with either reduction quality or surgical delay. Implant-related failure occurred in two patients (2.3%), both requiring revision surgery.

4. Discussion

This study offers valuable insights into the prognostic factors that influence outcomes after pediatric femoral neck fractures. The most striking finding was the decisive role of reduction quality: all patients with good reductions achieved uneventful healing, whereas

every case with fair or poor reductions developed complications. This consistent and robust association highlights that precise anatomical alignment is the single most modifiable determinant of prognosis in this rare but high-stakes injury. Importantly, older age was also found to be significantly associated with complications, suggesting that diminished remodeling potential and greater mechanical vulnerability near skeletal maturity contribute to poorer outcomes.

The overall complication rate in our series was 16.1%, comprising coxa vara (6.9%), coxa valga (5.7%), avascular necrosis (3.4%), and nonunion (2.3%). Notably, both nonunion cases coincided with implant-related failure and required revision surgery, underscoring the interplay between biological healing and mechanical stability. Compared with large systematic reviews^{6,12}, which report AVN rates of up to 20–40% and nonunion rates of 10–15%, our rates appear relatively low. One plausible explanation is that almost all of our patients underwent fixation within 24 hours, a timeframe that has been consistently reported as protective against AVN. Nevertheless, surgical delay beyond 24 hours was significantly associated with nonunion in our cohort, although the small number of delayed cases limits the strength of this observation. Thus, while early fixation remains advisable, and aligns with the principle that anatomical reduction and stable fixation within the first 24 hours is the ideal treatment strategy¹³, our findings suggest that the accuracy of reduction exerts a more direct and consistent influence on long-term outcomes.

Coxa vara was strongly associated with poor reduction quality, consistent with biomechanical principles that residual varus malalignment predisposes to progressive collapse. Similar findings have been reported by Palocaren et al.⁵ and Bali et al.⁶, who emphasized that inadequate reduction is a critical risk factor for mechanical failure.

Coxa valga, although less frequently emphasized in the literature¹³, occurred in 5.7% of our patients. While it was not statistically associated with surgical variables, its presence warrants longer follow-up to evaluate potential remodeling and functional implications.

AVN was identified in only three patients (3.4%) and showed no significant association with surgical timing or reduction quality. This aligns with the understanding that AVN is a multifactorial complication, influenced not only by surgical technique but also by vascular disruption, fracture displacement, and patient-specific factors such as age.¹⁴

Regarding fixation methods, cannulated screws were the most frequently used, consistent with global trends favoring stable, minimally invasive constructs in older children and adolescents.¹⁵ The revision rate of 2.3% was attributable to implant-related failure in the two patients who also developed nonunion. This overlap highlights the biomechanical relationship between fixation stability and biological healing, reinforcing the importance of both implant selection and reduction quality.¹⁶ Furthermore, the limited role of conservative hip spica casting in our cohort reflects a global shift toward surgical stabilization, particularly as casting has been associated with higher rates of malunion and varus deformity in displaced pediatric femoral fractures.^{17,18}

4.1. Limitations

This study has several limitations. First, its retrospective and single-center design may limit the generalizability of the findings. Second, the mean follow-up duration was relatively short, which may have led to an underestimation of late complications, such as avascular necrosis, which typically manifests years after the injury. Third, although surgical delay beyond 24 hours was found to be associated with nonunion, the very small number of delayed cases limits the statistical power and reliability of this observation. Finally,

while reduction quality and patient age were systematically assessed, other potential confounders such as implant selection, surgeon experience, and rehabilitation protocols were not analyzed in detail. Despite these limitations, the relatively large cohort and systematic evaluation of reduction quality and age provide valuable insights into prognostic determinants of this rare pediatric injury.

5. Conclusion

In conclusion, our study indicates that poor reduction quality and older age are key predictors of adverse outcomes in pediatric femoral neck fractures. Delayed fixation beyond 24 hours was associated with nonunion in our cohort, although the small number of delayed cases limits the strength of this observation. The relatively short follow-up also suggests caution in interpreting the low incidence of late complications such as avascular necrosis. Taken together, these findings underscore the paramount importance of meticulous anatomical reduction while recognizing patient age as a relevant risk factor. By highlighting these considerations, our study underscores the importance of technical precision, timely surgery, and meticulous follow-up to minimize long-term sequelae in this rare yet high-stakes pediatric injury.

Statement of ethics

Ethical approval was obtained from the Clinical Research Ethics Committee of Adana City Training and Research Hospital (Meeting No: 107, Approval No: 1981, Date: June 9, 2022). The study was conducted in compliance with the Declaration of Helsinki, and informed consent for data use was provided by parents or legal guardians.

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Conflict of interest statement

The authors declare that they have no conflict of interest.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by MYG and ARY. The first draft of the manuscript was written by MYG, MU, and ÖP, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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