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Original Research

Outcome Of Paediatric Femoral Neck Fractures managed with Moore's Pinning: A Retrospective Study

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ABSTRACT:
Introduction: In the pediatric population, femoral neck fracture is a relatively rare injury with a high rate of complications, despite appropriate diagnosis and treatment. The anatomy and blood supply of the proximal femur in the skeletally immature patient differs from that in the adult patient. **Aim:** This retrospective study aimed to analyze the radiological and clinical results of pediatric femur neck fractures. **Methods**: This study included 15 children (mean age 10.8 years, range 5 to 13 years) who had a femoral neck fracture and had at least one year of complete follow-up. The most common etiologic factor was a traffic accident, and the most common associated skeletal injury was a pelvic fracture. **Results:** According to the Delbet classification system, there was no type I (transepiphyseal) fractures and 11 Type II (transcervical) and 4 Type III (cervicotrochanteric) fractures. The mean follow-up was 2.2 (1–2.4) years. Satisfactory outcome according to Ratliff radiological and clinical criteria was obtained in 11 (73.3%) hips. Avascular necrosis (AVN) of the femoral head was observed in 2 (13.33%) hips, and the rate of satisfactory outcome was significantly higher in hips without AVN than in hips with AVN ($P < 0.001$). Transcervical fractures had the worst outcome ($P = 0.012$) and the highest rate of AVN ($P = 0.065$) compared with cervico-trochanteric fractures. No significant correlation was found between outcome and development of AVN and age, sex, laterality, amount of fracture displacement, time to treatment, and type of reduction (open/closed) ($P < 0.05$). **Conclusions:** It was concluded that the development of AVN primarily affects the outcome of femoral neck fractures in children and that fracture type is substantially correlated with the development of AVN and outcome.
Keywords: Femur neck fracture, Children, Hip, Avascular necrosis of the femoral head

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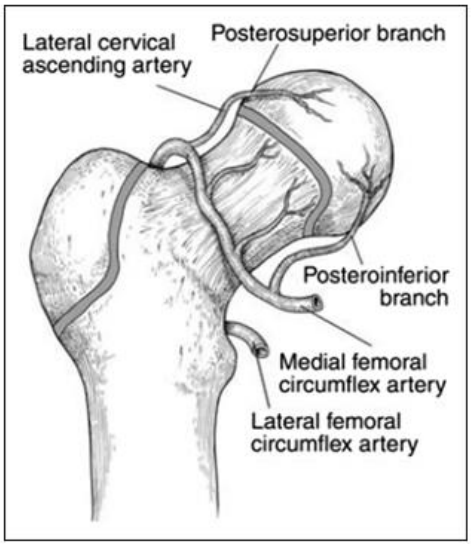
INTRODUCTION

Fractures of the femoral neck in children are rare injuries that carry the risk of serious complications and potential long-term disability. Single-institution series from academic pediatric tertiary referral centers report an incidence of femoral neck fractures in children of 1.2 to 2 cases per year, suggesting that femoral neck fractures represent 0.3% to 0.5% of fractures in children annually.[1-4] Peak Incidence is aged 10 to 13 years (range 1 day to 18 years), with a ratio of boys to girls of 1.3 to 1.7:1.[3,5,6] In long-term follow-up, adverse outcomes, which include pain and disability secondary to osteonecrosis, coxa valga, proximal femoral physeal arrest, and nonunion are reported in 20% to 50% of patients.[1-3,7-9]

We originally hypothesized that there should be some factors determining the clinical and radiographic outcomes of femoral neck fractures in children. This retrospective study aimed to evaluate the clinical and radiological outcomes of pediatric patients with femoral neck fractures using Moore's pins and to evaluate the influence of several preoperative, intraoperative and postoperative factors such as age, sex, laterality, type of fracture, amount of fracture displacement, treatment time, open reposition allowing simultaneous drainage of intracapsular hematoma and AVN on clinical and radiological results. Generally, these fractures are the result of high-energy trauma and are categorized using the Delbet classification system. This system guides treatment and helps the doctor determine the risk of

osteonecrosis after these fractures. Other complications include body arrest, coxa vara, and nonunion. Multiple methods of fracture fixation were used, with the overall goal of anatomical reduction with stable fixation.The proximal femoral physis separates the vascular supply of the femoral neck and epiphysis from childhood through young adulthood, rendering the developing proximal femur susceptible to vascular injury.[10] [Fig 1]

Figure 1: Illustration of the posterior view of the vascular supply of a skeletally immature proximal femur. (Reproduced from Boardman MJ, Herman MJ, Buck B, Pizzutillo PD: Hip fractures in children. J Am Acad Orthop Surg 2009;17[3]:162-173.)



PATIENTS AND METHODS

This retrospective study was done at the Post Graduate Department of Orthpaedics, Govt. Hospital for Bone and Joint Surgery, an Associated hospital of Government Medical College, Srinagar after approval by the ethics committee board of Government Medical College, Srinagar. Inclusion criteria were Delbet classification Type I, II, and III fractures aged between 5-15 years. Exclusion Criteria were patients with Age <5yrs and >15yrs, Type 4 Delbet classification (inter-trochanteric fractures), Infective pathological fracture and delayed presentation to the hospital (>2 weeks). Eighteen hips of 18 consecutive patients (12 males and 6 females) whose ages ranged from 5 to 13 years were treated for femoral neck fractures at our department between March 2020 and December 2021. Among these, 15 patients had at least one year of complete clinical and radiological follow-up and were included in this study. The mean age of the included patients was 10.8 ± 2.7 (5-13) years and 11 were male and 4 were female. Among the three excluded patients, one died in the early postoperative period due to multisystem injury and one was lost to follow-up within the first 3 months, postoperatively.

The most common etiological factor of femoral neck fracture was a traffic accident (motor vehicle or pedestrian), followed by a fall from a height (Table 1). At least one associated skeletal injury was present in 4 patients (26.6%), and the most common was a pelvic fracture, followed by a distal radius fracture (Table 2). The affected side was the right side in 9 patients and the left side in 6 patients.

Our primary aim was to perform definitive treatment of all children with femoral neck fractures within the first 24 hours of admission to our hospital, but a significant number of patients were referred from other district hospitals. Therefore, the time from initial trauma to definitive treatment could exceed 24 hours for patients with a delayed referral from other hospitals. Obtaining immediate radiographic anatomic reduction in two planes and safely maintaining this reduction were the main points of our treatment protocol. All hips were initially closed under fluoroscopic control under general anesthesia. In two hips, closed anatomic reduction failed, and open reduction was performed in these hips, simultaneously ensuring drainage of the intracapsular hematoma. After reduction, the fracture was stabilized by internal fixation under fluoroscopic control. The configuration of internal fixation was chosen by the attending surgeon, and three Moore's pins were used in 6 patients and two pins in 9 patients. Needle aspiration of the intracapsular fracture hematoma was not performed in any of the intracapsular fractures in which successful closed reduction could be achieved. Partial and full weight bearing was allowed at postoperative 6 and 12 weeks.

Fractures of the femoral neck were initially classified according to the four-part classification system described by Delbet and popularized by Colonna [3]. "Type I" was an intra-articular transepiphyseal fracture, "type II" an intra-articular transcervical fracture, "type III" an intra-articular

cervicotrochanteric fracture, and “type IV” an extracapsular intertrochanteric fracture. Fractures were also classified as “non-displaced” and “displaced” (from minimal to complete). The time period from the initial trauma to the final treatment was divided into two groups, "Before 24 hours" and "After 24 hours".

SURGICAL TECHNIQUE

The choice of closed versus open reduction depended on the extent of fracture displacement and the surgeon's ability to achieve an anatomic or near-anatomic reduction. Patients were positioned supine on either a radiolucent operating table or a fracture table, and reduction was assessed by intraoperative fluoroscopy. In closed reduction with the patient on the fracture table, the hip was hyperextended with abduction and internal rotation, and slight knee flexion was maintained. Gentle longitudinal traction was applied and fixation was done using Moore’s pins [Fig 2]. Open reduction was done where anatomical reduction couldn't be achieved. Open reduction and internal fixation (ORIF) were typically used for severely displaced fractures or in patients in whom anatomic reduction couldn't be achieved with closed reduction. Fractures that required ORIF were approached through an anterior (Smith-Peterson) approach to the hip. Patients were followed closely after surgery, with X-rays taken to determine if there has been displacement of the fracture or implant failure. The need for additional cast immobilization after surgical stabilization depended on the type of fracture, the age of the patient, the quality of fixation, and compliance with postoperative weight and activity restrictions. Fracture immobilization or weight-bearing measures was continued for 6 to 8 weeks or until fracture healing was achieved.

Clinical and radiological outcomes of the hips at the last follow-up were assessed using the Ratliff classification (Table 3). A good result was scored as a "satisfactory result" and fair and poor results were scored as "unsatisfactory result." AVN of the proximal fragment was classified according to the Ratliff classification system [4], as this system has become the gold standard in pediatric femoral neck fractures for many years. Type I has a diffusely increased density of the proximal fragment and is accompanied by a total collapse of the epiphysis. Type II has less pronounced local changes and is accompanied by a minimal collapse. Type III has changes that are limited to the neck of the femur, excluding the physis. [Fig 3]

Table 1: The etiological factors for femoral neck fractures in the present series

Etiology	Number of patients	%
Traffic accident	6	40.00
Fall from height	5	33.33
Simple fall	2	13.33
Fall from bicycle	2	13.33
Total	15	100

Table 2: List of the associatedskeletal injuries seen in 15 patients

Pelvis fracture	2
Distal radius fracture	1
Femur distal fracture	1

Table 3: The clinical and radiographic assessment system[4]

Good: clinically, no or negligible pain, full or minimal restrictive hip movement, and normal activity or the avoidance of games. Normal or some deformity of the femoral neck in the radiograph
Fair: clinically, occasional pain, hip movement restriction of less than 50%, and normal activity or the avoidance of games. Severe deformity of the femoral neck, mild avascular necrosis in the radiograph
Poor: clinically, disabling pain, hip movement restriction of more than 50%, and restricted activity. Severe AVN, degenerative arthritis, arthrodesis in the radiograph

STATISTICAL ANALYSIS

The Chi-square and Fisher’s exact tests were used for the comparison of the ratios in different groups and a P-value of less than 0.05 was considered to be significant.

RESULTS

There were no type I fractures and 11 type II (73.3%) and 4 type III (26.66%). There were 12 displaced (80%) and three non-displaced (20%) fractures. The mean time from initial trauma to definitive treatment was 32.6(18-144) h.

The mean follow-up was 2.2 (1–2.4) years. The clinical and radiographic outcomes at the latest follow-up were considered to be good in 11 (73.3%), fair in two (13.3%), and poor in two (13.3%) hips. AVN was seen in 2 (13.33%) patients and both were type II. A satisfactory outcome was observed in all patients without AVN except one who had a deep wound infection, which would lead to further hip arthrodesis.

There was a significant correlation between fracture

type and outcome; type II fracture had the worst outcome (P = 0.014) (Table 4). Type II fractures also had the highest incidence of AVN (P = 0.077) (Table 5). There was no statistically significant correlation between outcome and the incidence of additional AVN with age, gender, laterality, the magnitude of displacement, treatment time, or type of reduction (P < 0.05) (Tables 4). A superficial wound infection was observed in one patient and resolved completely after parenteral antibiotic treatment. Persistent deep wound infection was observed in one 14-year-old patient in which closed reduction and fixation of the femoral neck fracture was performed. However, an early Staphylococcus aureus infection developed in the fracture and this infection further affected the hip joint. A year after the operation, a hip joint arthrodesis was performed for joint destruction, limitation of movement, and pain.

Figure 2: Anteroposterior hip radiographs of a 9-year-old girl who had a right displaced cervicotrochanteric femur neck fracture due to a fall from height. a Preoperative. b Postoperative. c At 6 months postoperatively. d At 18 months postoperatively showing complete union.

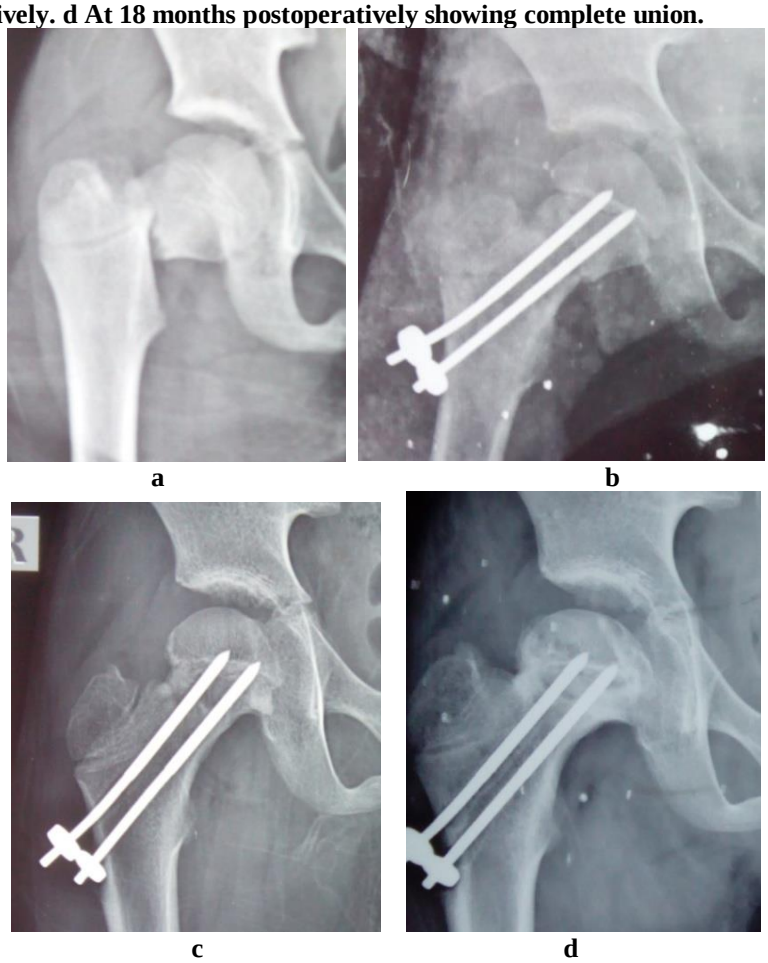


Table 4: Correlation between several factors and clinical and radiographic outcomes

	Satisfactory Outcome	Unsatisfactory Outcome	p-value
Age			
<10 years	5	2	0.288
≥10 years	6	2	
Laterality			
Right	6	3	0.477
Left	5	1	
Fracture type			
Transcervical (II)	9	2	0.014
Cervicotrochanteric (III)	2	2	
Fracture displacement			
Non-displaced	3	0	
Displaced	7	4	0.078

Treatment time			
<24 h	6	1	
⩾24 h	5	3	1.0
Type of reduction			
Open	2	1	
Closed	10	2	0.609

DISCUSSION

A femoral neck fracture is rare in children. The child/adult ratio for femoral neck fractures is reported to be 1/130 [4]. Several factors distinguish femoral neck fractures in children from fractures in adults, and two of the most important should be mentioned. First, high-energy trauma is the main etiological factor, as the proximal femoral bone excluding the physis is very strong in children and requires considerable force to break it, while minor trauma is the main etiological factor in adults [2]. This is the main reason why femoral neck fractures are rare injuries in children. The results of this study supported these findings, as nearly 85% of fractures were caused by major trauma. Second, the blood supply to the femoral head is different. The adult hip has intraosseous blood vessels that supply the femoral head. However, vessels cannot pass through the open physis, and therefore the blood supply to the femoral head is critical and can be easily compromised by a hip fracture in children [2]. Thus, AVN is the most common and damaging complication of femoral neck fractures in children. The reported overall complication rate after treatment of femoral neck fracture is approximately 33%.[17] Osteonecrosis is the most common complication; other complications include premature physeal closure, coxa vara deformity, need for revision surgery, nonunion, surgical site infection, septic arthritis, posttraumatic slipped capital femoral epiphysis (SCFE), and femoral neck overgrowth.[7,17]

The most extensive microscopic necrotic changes in AVN are visible during the first year after the injury, and therefore the risk of femoral head collapse increases during this period [5]. It is a well-known fact that the treatment of AVN is unsuccessful and does not change the natural course of femoral neck fractures in children [1]. However, it has recently been suggested that intertrochanteric osteotomy could have a biological role in restoring the viability of the uncollapsed femoral head with AVN seen after femoral neck fractures [6]. Ratliff [4] mentioned that the presence of AVN usually adversely affected the prognosis. The results of this study showed that the development of AVN significantly affects clinical and radiological outcomes, as all patients with unsatisfactory outcomes had AVN. However, Leung and Lam [7] noted that the clinical and radiological outcomes of the same hips in pediatric femoral neck fractures can change significantly over several years.

It has been previously reported that a better outcome in femoral neck fractures in children was correlated with the absence of AVN during follow-up, patient age (< 8 years), fracture type (cervicotrochanteric and nondisplaced fractures), and proper initial treatment (early, anatomical, stable internal fixation), decompression of intra-articular fracture hematoma and application of postoperative immobilization [1, 4, 7–19]. This study has a satisfactory result of 73.3%. Transcervical fractures have a lower rate of satisfactory outcomes compared to cervicotrochanteric fractures. In addition, the nondisplaced fracture group has slightly better outcomes.

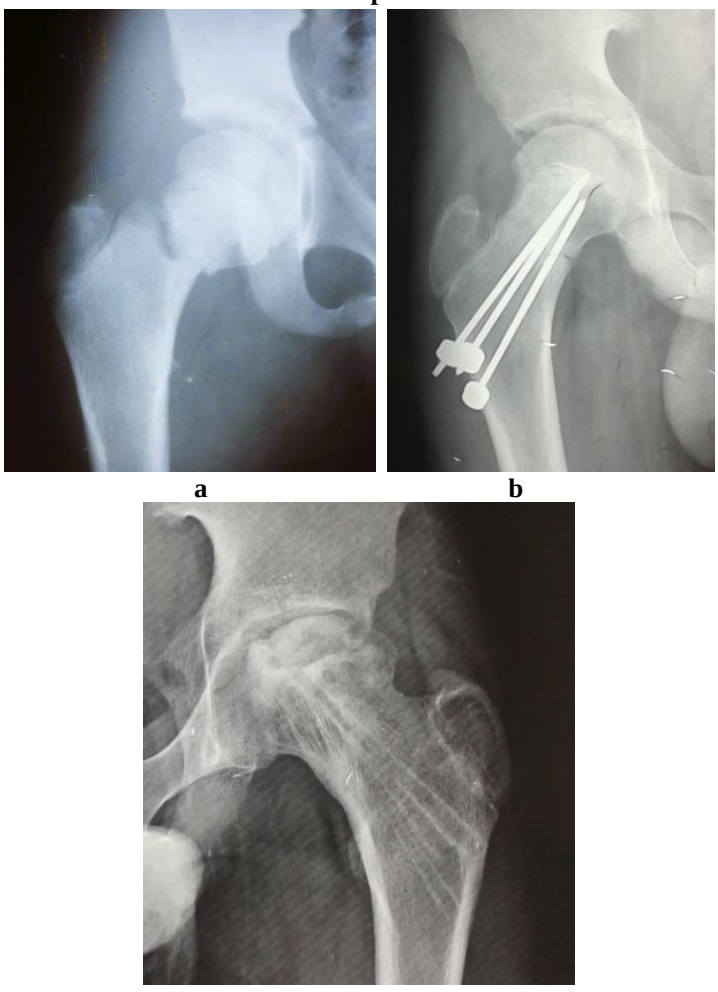
The reported incidence of AVN due to femoral neck fractures in children ranges from 0 to 92% [20]. Several factors may correlate with the development of AVN; however, a recent meta-analysis reported that fracture type and patient age were the two most significant variables. The risk of AVN was found to be 15-fold, six-fold, and four-fold higher in transepiphyseal, transcervical, and cervicotrochanteric fractures than in intertrochanteric fractures. In addition, older children were considered to be at higher risk of developing AVN and this risk was found to increase 1.14 times for each year of increasing age [20]. The current study has an AVN rate of 13.33%. The incidence of AVN is higher in transcervical fractures than in cervicotrochanteric fractures. In addition, the nondisplaced fracture group has only one AVN that resolved without any sequelae. Ratliff [4] previously reported that severe AVN (type I and II) always had a good or poor outcome, whereas type III AVN have good outcomes. The results of this study seem to support this observation, as the majority of AVNs were type II, and all had unsatisfactory outcomes.

The reported rate of iatrogenic infection is 1% for femoral neck fractures in children [1]. Compared to classical knowledge, the infection rate appears to be higher in this set (6.6%). One case had infectious arthritis of the hip and developed significant joint damage.

The current series includes 15 cases with a minimum follow-up of one year. Fractures of the femoral neck are rare injuries, and compared to previously published case reports in the literature, the number of cases in this study is comparable, but the average follow-up is not as long, which can be considered a weakness of the study. However, it has been previously reported that a radiographic diagnosis of AVN can be made within one year of injury [4]. Thus, the minimal case follow-up of this study appears to be sufficient to comment on AVN. This study did not include any transepiphyseal fractures, which can be considered another shortcoming of the study, as it is not possible to draw stronger conclusions about this type of fracture. However, this type is not as common

as the transcervical fracture, which accounts for almost 65–85% of the entire femoral neck fracture population in children [1]. In addition, the number of cases in the "displaced fracture" and "open reduction" groups can be considered small to allow stronger conclusions about these variables.

Figure 3: Anteroposterior hip radiographs of an 11-year-old girl who had a right displaced transcervical femur neck fracture due to a traffic accident. a Preoperative. b At 6 months follow up. c At 2 years follow-up showing union with the removal of Moore's pins done



We believe that obtaining radiographically verified intraoperative anatomical reduction by closed or open methods and maintaining this reduction with internal fixation accompanied by a hip spica set are two important key points in the successful treatment of femoral neck fractures in children. In our opinion, two or three Moore's pins seem to be the most appropriate method of internal fixation for children. In addition, it may be better to apply a postoperative hip cast in children younger than 7 years. Based on our results, we can state that the presence or absence of AVN is the main determinant of clinical and radiographic outcomes in femoral neck fractures in children, and the development of this complication should not be underestimated. AVN cannot be completely prevented or effectively treated, but its incidence can be reduced by carrying out appropriate treatment as mentioned above. This series does not include transepiphyseal fractures; however, with the numbers available in this study, AVN is commonly seen in transcervical femoral neck fractures, leading to a higher rate of unsatisfactory outcomes in such fractures. Although not statistically proven, fracture displacement may also have some adverse effects on the outcome. Therefore, in the future, parents' of children with this type of femoral neck fracture should be initially warned about the possible development of serious complications and unsatisfactory outcomes.

CONCLUSION

In our opinion, internal fixation with two or three Moore's pins seems to be the most convenient method in children aged 5-13 years. Patient's age and gender, laterality, the time from the initial trauma to the definitive treatment, and performing a closed reduction without draining the intra-capsular hematoma or an open reduction leading to the drainage of the intra-capsular hematoma seem to have no significant effects on the development of AVN and the outcome.

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CONFLICT OF INTEREST STATEMENT
None.

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