



Original Article



The Functional Outcomes of Flexible Intramedullary Nails in the Management of Femoral Diaphyseal Fracture in Children

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ABSTRACT

About 20-25 children per 100,000 experience femoral shaft fractures annually. Intervention varied by age, type of fracture, and resources. Flexible intramedullary nailing (FIN) is a popular minimally invasive treatment of choice, allowing early mobility with the least complications. **Objectives:** To evaluate the clinical effectiveness of using FIN for pediatric diaphyseal femur bone fracture treatment. **Methods:** This cross-sectional study was conducted at Ghurki Trust Teaching Hospital, Lahore, from February 2021 to August 2021, including 145 pediatric patients aged 5-12 years with closed femoral diaphyseal fractures treated with flexible intramedullary nailing (FIN). Patients with multiple fractures or metabolic bone diseases were excluded. Clinical assessments were carried out at the 3rd, 6th, 9th, and 12th postoperative weeks. Functional outcomes were examined using Flynn's criteria, and data were analyzed via SPSS version 22. **Results:** Out of the total 145 patients, 101 (69.4%) were male, while 44 (30.6%) were female. The mean age of the children was 8.32 ± 2.23 years. The time between injury and surgery was 4.27 ± 3.80 days in this study. According to Flynn's criteria, 133 (91.9%) of the patients had excellent outcomes (95% CI: 86.8% to 95.7%), while 12 (8.1%) had satisfactory outcomes at 12 weeks. No statistically significant associations were found between functional outcomes and demographic variables such as gender ($p=1.000$), age group ($p=0.360$), weight group ($p=0.323$), or fracture duration ($p=0.280$). **Conclusions:** FIN is a safe and effective treatment for pediatric femoral shaft fractures, which can help patients gain early functional recovery and reduce the risk of complications. It should be applied where necessary in clinical practice.

INTRODUCTION

Femoral shaft fractures represent one of the most frequent long-bone injuries in children since they affect 20-25 out of 100,000 children every year [1]. These bone fractures most commonly emerge from high-energy incidents, yet young children show evidence of fractures through lower-energy causes, too [2]. Physicians consider diverse factors like patient age, together with fracture configuration as well as any present injuries and societal circumstances, and operational surgical capabilities to determine the treatment strategy [3]. Traditional approaches to treating pediatric femoral fractures consist of four methods: spica casting, traction, external fixation,

and internal fixation techniques. Conservative care through hip spica casting benefits young children younger than five because their bones possess strong healing properties and remodelling capacity [4]. Spica casting entails various complications, including malunion together with joint stiffness and angulation, and limb length disparities that affect children's functional outcomes and reduce their quality of life during healing [5]. Open or severely comminuted fractures require external fixation as an alternative treatment, but users experience significant risks of pin tract infections as well as infection re-fractures along with patient discomfort [6]. Elastic Stable

Intramedullary Nailing (ESIN) now serves as the leading treatment option for femoral shaft fractures among children between 5 to 12 years of age. ESIN delivers minimally invasive stabilization that enables early mobility and smaller hospitalization times, and better outcomes than traditional non-operative treatment approaches [7]. The surgical method requires flexible intramedullary nails to be inserted from the metaphysis of the distal femur into the distal end thus providing three-point fixation and controlled bone movement, which enhances fracture healing [8]. Research demonstrates that ESIN stands as the recommended treatment option for transverse and short oblique fractures in growing patients because it upholds proper bone alignment without causing substantial effects on the developing joint area [9]. Research evidence indicates that ESIN shows outstanding results when treating pediatric femoral fractures. Tamrakar *et al.* documented that 80% of treated patients achieved excellent functional outcomes, yet 20% received satisfactory results as per Flynn's criteria [10]. ESIN provided superior treatment outcomes to spica casting since children experienced swifter recovery of function and reduced stay duration alongside accelerated return to regular activities, according to studies in reference [11]. ESIN provides various benefits, though it entails a range of complications in application. Problems within ESIN treatment frequently involve misalignment of leg positions either in a varus or valgus direction, as well as differences in limb lengths and implant wearer discomfort and hardware issues [12]. Current research in pediatric orthopedic surgery focuses on developing ESIN techniques to reduce surgery-related issues. The success of ESIN relies upon three key factors, which include selecting the right nail size and determining a precise entry point assisted by intraoperative fluoroscopy [13]. The use of ESIN produces better lasting functional results than plating when combined with less tissue damage and intact periosteal layers that naturally repair the structure [14].

The evidence behind ESIN continues to expand, but local researchers have yet to establish thorough assessments of its functional performance in treating pediatric femoral diaphyseal fractures. This research investigates the functional outcomes of ESIN for femoral shaft fractures in children by applying Flynn's criteria. The outcomes of treated patients will be evaluated for fracture healing duration and functional mobility, and complication incidence to provide valuable knowledge about ESIN suitability in pediatric care. This study aims to evaluate the clinical effectiveness of using FIN for pediatric diaphyseal femur bone fracture treatment.

METHODS

This cross-sectional study was conducted at Ghurki Trust Teaching Hospital, Lahore, from February 2021 to August 2021. Ethical approval was obtained (Ref. No. 1038/ERC/GTTH) from the institutional review board of Ghurki Trust Teaching Hospital, Lahore. Participants were included in the research after they provided their informed consent. A total of 145 patients (aged between 5 and to 12 years) with closed diaphyseal femoral fractures according to AO pediatric comprehensive classification of long bone fracture (AO-PCCF) as 32-D/4.1 (simple transverse) and 32-D/5.1 (simple short oblique) were included. Patients were excluded from the research if they had open fractures or underwent complex injuries with multiple closed lower limb fractures, or possessed metabolic bone disorders or pathological fractures. Two flexible intramedullary nails were surgically inserted in a retrograde direction following general anesthesia while performing the procedure in a supine position. No fracture table was used. Each patient received their prophylactic antibiotic medication based on their individual body weight. A priori sample size calculation was performed using G*Power software (version 3.1). For a Chi-square test, with an effect size (w) of 0.3 (medium), an alpha error probability of 0.05, and power ($1-\beta$) of 80%, the minimum total sample size required was 120. To account for potential dropouts, we aimed to enroll 150 patients. A total of 145 patients who met the inclusion criteria were finally enrolled during the study period. All patients received immobilization in an above-knee posterior slab after the surgeons used fluoroscopic guidance to perform the reduction. Physiotherapy professionals supervised our patient with strengthening exercises for the quadriceps, along with knee/hip motion exercises. The first-day postoperative evaluations included X-ray examinations to check the alignment and placement of nails. The rehabilitation program started with non-weight-bearing crutch walking either on the first or second day, based on the patient's pain level. The subjects received follow-up examinations at weeks 3, 6, 9, and 12 after their operations. Flynn's criteria for titanium elastic nail (TEN) outcome served as the assessment tool for functional results. The preoperative assessment of each participant included planning their medical background alongside pain symptom monitoring, in addition to X-ray imaging of the fracture. The assessment of patient muscle strength, together with neurological tests and lower limb function, helped determine eligibility for this surgical procedure before surgery. Clinical evaluations of patients occurred at pre-determined times of 3 weeks, followed by 6 weeks and 9 weeks, and finishing with 12 weeks. Follow-up evaluations evaluated both outcomes, including the pain levels through examination and recorded changes in

movement and function, together with detected surgical complications. The researchers used descriptive statistics to present patient demographic information along with their age group and gender identities, as well as their weight measurements and time since the fracture occurred. IBM-SPSS version 22 served to evaluate the functional outcomes. The report used frequencies with percentages for categorical data, which included gender and functional outcome categories, while it analyzed numerical data such as age and weight through means and standard deviations. To determine the association between different variables and functional outcomes, chi chi-square test was utilized, with p p-value of $p \leq 0.05$ considered statistically significant.

RESULTS

The results were collected for a total of 145 patients. The research participants had an average age of 8.32 ± 2.23 years within an age range between 5 to 12 years. One hundred one of the subjects were male participants (69.4%) while 44 participants were female (30.6%). These patients underwent treatment after their fractures healed for an average of 4.27 ± 3.80 days within a 1-to-18-day period. The average weight in kg was 23.69 ± 5.09 (Table 1).

Table 1: Baseline Characteristics of the Study Population

Variables	Frequency/Mean \pm SD
Number of Patients	145
Age (years)	8.32 ± 2.23
Gender (Male/Female)	101 (69.4%) / 44 (30.6%)
Weight (kg)	23.69 ± 5.09
Duration of Fracture (days)	4.27 ± 3.80

Postoperative functional outcomes were assessed at 12 weeks using Flynn's criteria. The results indicated that 91.9% (133 patients) achieved an excellent outcome (95% CI: 86.8% to 95.7%), while 8.1% (12 patients) had a satisfactory outcome. No patient experienced poor outcomes (Table 2).

Table 2: Functional Outcome According to Flynn's Criteria

Variables	Frequency/Mean \pm SD
Excellent	133 (91.9%)
Satisfactory	12 (8.1%)

Flynn's criteria outcomes were further analyzed based on gender, age, weight, and fracture duration. As shown in Table 3, no statistically significant associations were found with gender ($p=1.000$), age group ($p=0.360$), weight group ($p=0.323$), or fracture duration ($p=0.280$). (Table 3).

Table 3: Stratification of Functional Outcome Based on Different Variables

Categories	Excellent (%)	Satisfactory (%)	p-value
Male (n=101)	92 (90.7%)	9 (9.3%)	1.000

Female (n=44)	42 (94.7%)	2 (5.3%)	
5-8 (n=77)	68 (87.9%)	9 (12.1%)	0.360
9-12 (n=68)	66 (96.6%)	2 (3.4%)	
10-20 (n=35)	35 (100%)	0 (0%)	0.323
21-32 (n=110)	98 (89.4%)	12 (10.6%)	
1-6 (n=115)	108 (93.9%)	7 (6.1%)	0.280
7-18 (n=30)	25 (84.6%)	5 (15.4%)	

The patients recovered without encountering major postoperative medical issues. The nail insertion site caused brief pain for 4 patients (6.5%), but the symptoms disappeared within weeks. The study demonstrated no instances of infection, together with the absence of deep vein thrombosis and neurovascular injury.

DISCUSSIONS

Pediatric femoral shaft fractures commonly occur, and orthopedic specialists have developed several treatment approaches over the past years. Flexible intramedullary nailing (FIN) has become more popular because it offers minimally invasive procedures and achieves favorable results according to the prior study [8]. The authors researched to evaluate the functional results obtained from flexible intramedullary nails used to treat femoral diaphyseal fractures by applying Flynn's criteria as assessment measures. The patient sample consisted mainly of males who averaged 8.32 years in age among 145 participants. The research showed that flexible intramedullary nails delivered excellent functional results in 91.9% of patients, yet produced satisfactory results in 8.1% of cases. Similarly, another study found 80% excellent outcomes, besides a 20% satisfactory outcome through their equivalent investigation methods [10]. A previous study done in the year 2023 described that adequate axial and rotational stability from FIN treatment plays a key role in achieving success because it supports early mobilization and rapid healing without serious complications [15]. A meta-analysis was done in 2023 demonstrating superior treatment effectiveness based on its comparison against spica casting and external fixation methods for orthopedic care. Young children received spica casting in the past, but this treatment method caused malunion while delaying functional recovery, together with joint stiffness [16]. Another study identified that external fixation provides effective results in specific cases but comes with risks that involve pin tract infections and re-fractures, and prolonged periods of immobilization [17]. Early weight-bearing becomes possible with the FIN system while maintaining proper fracture stability, according to studies conducted by a prior study [18]. The current study established that demographic variables, including age, gender, weight, and fracture duration, were insignificantly associated with functional results ($p > 0.05$) [19]. This suggests that, within the studied population, the high success rate of FIN may be

consistent across different demographic subgroups. The influence of these specific factors on functional outcomes after FIN for femoral fractures has not been extensively detailed in existing literature, and our findings provide a baseline for future investigation. Moreover, the current study reported that no cases of infection, DVT, or neurovascular injury. This finding aligned with a previous case report, which states that none of the patients developed serious complications and also maintained good recovery and greater union rates with an acceptable rate of minor complications[20]. The evaluation of flexible intramedullary nailing requires additional patient-based outcome assessments combined with comparative studies of alternative treatment types to achieve a full evaluation. The treatment effect of flexible intramedullary nailing would benefit from more research into biomechanics along with improved surgical techniques. The study faces restrictions from a limited participant group, and a 12-week follow-up was sufficient for assessing early healing and mobilization; however, it was too short to evaluate long-term complications such as malunion and leg length discrepancy. Further examinations should utilize extensive follow-up phases and multiple research facilities for assessing prolonged treatment outcomes within larger-scale research.

CONCLUSIONS

Flexible intramedullary nailing (FIN) is considered a safe and effective procedure for managing femoral diaphyseal fractures in children aged 5-12 years, as it allows early mobilization, improves functional recovery, and is also associated with minimal complications. However, its application must be individualized, as spica casting is preferred in children under 5 years of age, and rigid trochanteric entry nailing might be suitable in adolescents (near to skeletal maturity). Furthermore, a longer follow-up is needed to investigate the potential late complications, including leg length discrepancy and malunion.

Authors' Contribution

Conceptualization: MA

Methodology: RA, MA, WA, IU

Formal analysis: RA, FS, IU

Writing and Drafting: MA, WA, FS, SA

Review and Editing: RA, MA, WA, FS, SA, IU

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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