

FUNCTIONAL OUTCOME OF FLEXIBLE TITANIUM NAILS IN PAEDIATRIC WITH FEMORAL SHAFT FRACTURES

Original Research

Syed Baqir Hussain Jafree¹, Shafqat Waseem¹, Muhammad Qasim², Shoaib Saleem³, Hafiz Muhammad Shiraz², Shuja Uddin^{2*}

¹Assistant Professor of Orthopedic Surgery, Jinnah Hospital, Lahore, Pakistan.

²Consultant Orthopedic Surgeon, LGH (Lahore General Hospital), Lahore, Pakistan.

³Senior Registrar, Continental Medical College, Lahore, Pakistan.

Corresponding Author: Shuja Uddin, Consultant Orthopedic Surgeon, LGH (Lahore General Hospital), Lahore, Pakistan. Drshujauddin111@gmail.com

Conflict of Interest: None

Grant Support & Financial Support: None

ABSTRACT

Background: Femoral shaft fractures are among the most common long bone fractures in the pediatric population, with a higher incidence in boys and typically resulting from falls, accidents, or trauma. Effective treatment aims to maintain bone length and alignment while minimizing discomfort for the patient and inconvenience for the family. Flexible intramedullary nailing has emerged as a preferred method for pediatric femoral fractures due to its simplicity, favorable healing rates, and low complication risk.

Objective: This study aimed to assess the functional outcomes of pediatric femoral shaft fractures treated with flexible titanium intramedullary nails.

Methods: A descriptive case series was conducted in the Orthopaedic Surgery Unit-II at Jinnah Hospital, Lahore, Pakistan, over six months from September 16, 2021, to March 16, 2022. A total of 60 pediatric patients, aged 4-11 years with femoral shaft fractures, underwent retrograde intramedullary nailing using two nails of identical diameter under image guidance. Patients were monitored in three-week intervals until radiological union was confirmed. Data analysis was performed with SPSS 25.0, stratified by gender and age, with statistical significance determined by a Chi-square test at $p \leq 0.05$.

Results: The final sample included 46 male (76.7%) and 14 female (23.3%) patients, with a mean age of 7.18 years ($SD \pm 2.259$). Based on Flynn's criteria, 96.7% (58 patients) demonstrated satisfactory functional outcomes, with 60.0% (36 patients) rated as "excellent," 30.0% (18 patients) as "good," and 6.7% (4 patients) as "fair," while only 3.3% (2 patients) had "poor" outcomes.

Conclusion: Flexible intramedullary nailing is an effective method for treating simple pediatric femoral shaft fractures, providing strong functional outcomes with minimal complications, supporting its role as a reliable treatment option in pediatric orthopedics.

Keywords: Bone fractures, Femoral fractures, Intramedullary nailing, Pediatrics, Shaft fractures, Titanium, Treatment outcomes.

INTRODUCTION

Femoral shaft fractures in children are a significant clinical concern, with an incidence of 19.15 per 100,000 children annually, making them the second most common long bone fractures in this age group (1). Representing nearly 2% of all pediatric bone injuries, femoral fractures occur more frequently in boys than in girls, with primary causes including falls from heights, vehicular accidents, and, in some instances, child abuse (2). The primary objectives in managing femoral shaft fractures in children include the preservation of bone length and alignment, as well as minimizing discomfort and disruption for both the child and their family (3). Historically, treatment regimens for these fractures have often involved conservative approaches such as spica casting or traction, subsequently followed by cast immobilization. However, surgical options, including external fixation, compression plating, and screw fixation, have been integrated into therapeutic practices over the past two decades, especially in cases requiring enhanced stability and expedited recovery.

In recent years, antegrade intramedullary nailing and retrograde flexible or elastic stable intramedullary nailing (FIN/ESIN) have gained popularity, particularly among children aged 5 to 15 years, due to their advantages over traditional methods. These methods reduce the risk of malunion, facilitate shorter hospital stays, promote early mobilization, and are cost-effective alternatives in treating femoral fractures (3,4). Retrograde flexible nailing, specifically, is noted for its simplicity, shorter operative times, and favorable outcomes in terms of both functional recovery and bone healing, making it a preferred option in resource-limited settings and public healthcare systems (5,6). Using two diverging flexible intramedullary nails provides adequate fixation along the femoral shaft, allowing one nail to stabilize against the cortical wall while the other counterbalances, thereby creating trifocal buttressing within the medullary cavity. This configuration encourages micro-movement at the fracture site, which stimulates callus formation and facilitates healing through a minimally invasive approach (7,8). Closed reduction further preserves the fracture hematoma, which is beneficial to the healing process (1).

The advantages of flexible intramedullary nails, especially titanium variants, include not only faster union and recovery but also minimal scarring, simpler implant removal, and a high rate of patient satisfaction. Titanium nails, in particular, exhibit a low risk of infection, as evidenced by studies in animal models. The treatment approach—whether conservative or surgical—is carefully determined based on factors such as patient age, fracture pattern, severity, and whether the injury is isolated or part of a polytrauma scenario (9). Treatment protocols also consider the natural remodeling potential of the pediatric skeleton, with infants tolerating greater deformities compared to adolescents nearing skeletal maturity, where strict criteria for alignment and length discrepancies are applied. This study aims to evaluate the functional outcomes of pediatric femoral shaft fractures managed with flexible titanium intramedullary nails, contributing to the understanding of optimal treatment approaches in terms of efficacy, recovery time, and patient quality of life. This approach underscores the need for evidence-based management strategies tailored to pediatric bone physiology and fracture characteristics, ensuring the best possible functional results for young patients.

METHODS

This descriptive case series was conducted at the Orthopaedic Surgery Unit-II of Jinnah Hospital, Lahore, from September 16, 2021, to March 16, 2022. The study utilized non-probability consecutive sampling and included 60 pediatric patients, with a 95% confidence level, a 7% margin of error, and an anticipated 93% satisfactory outcome for flexible intramedullary nailing in cases of femoral shaft fractures (9). Eligible participants included boys and girls aged 4 to 11 years with isolated femoral shaft fractures. Patients presenting with pathological fractures, compound fractures, other lower limb fractures, neuromuscular diseases, metabolic disorders, or comminuted fractures (Winqvist type III and type IV) were excluded from the study to maintain a focused sample. Pediatric patients meeting the selection criteria were recruited from the Trauma Centre of the Orthopaedics Department at Jinnah Hospital. Following initial assessment, a detailed history was recorded, and each patient underwent a thorough physical and radiological examination. The surgical procedure was performed under general anesthesia after preoperative anesthesia assessment and prophylactic intravenous antibiotic administration. Standard-length elastic titanium nails (440 mm, with diameters ranging from 2.0 to 4.0 mm) were used for the retrograde intramedullary nailing. The diameter of each nail was calculated using Flynn's formula: the diameter of the nail was determined as 0.4 times the width of the narrowest point of the medullary canal on anteroposterior (AP) and lateral radiographs.

To facilitate future removal, the distal ends of the nails were positioned to protrude by approximately 0.5 to 1 cm. Postoperative radiographs were taken the following day to confirm the positioning of the nails. Patients were instructed to perform quadriceps and hamstring exercises, along with active and passive knee movements, to encourage recovery. They were followed up every three weeks until radiological union was confirmed, at which point a functional assessment was conducted. To reduce bias, data collection was standardized, with the principal investigator using a pre-designed proforma to systematically gather information. Data analysis was carried out using SPSS version 25.0. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were generated. The data was stratified by gender and age to account for potential effect modifiers. Associations were analyzed using the Chi-square test, with statistical significance set at a p-value of ≤ 0.05 .

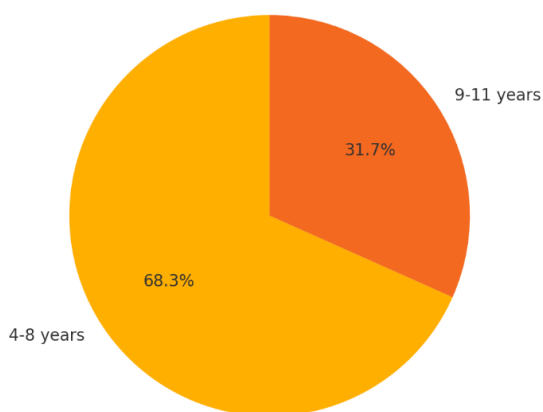
RESULTS

The participants' ages ranged from 4 to 11 years, with a mean age of 7.18 years (SD \pm 2.259). Among the 60 pediatric patients, 68.3% (41 patients) were between 4 to 8 years old, while the remaining 31.7% (19 patients) were aged between 9 and 11 years. Functional outcome assessments revealed that 60% (36 patients) demonstrated an "excellent" outcome, while 30% (18 patients) achieved a "good" outcome. A smaller portion of patients exhibited less favorable results, with 6.7% (4 patients) categorized as having a "fair" outcome, and only 3.3% (2 patients) classified as having a "poor" outcome.

Table 1: Frequency Distribution of Age Groups and Functional Outcomes

Category	Frequency (%age)
Age Groups	
4-8 years	41 (68.3%)
9-11 years	19 (31.7%)
Functional Outcome	
Excellent	36 (60.0%)
Good	18 (30.0%)
Fair	4 (6.7%)
Poor	2 (3.3%)
Total	60 (100.0%)

Age Group Distribution



Functional Outcome Distribution

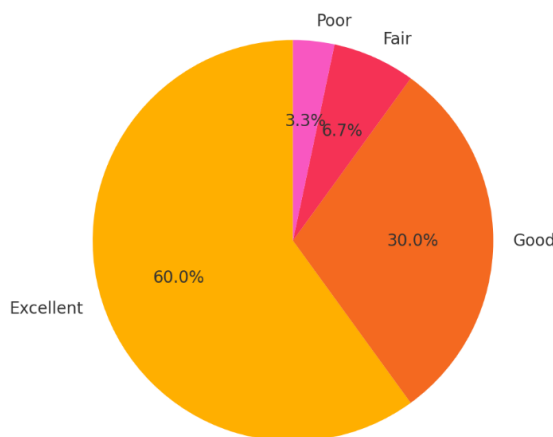


Table 2: Stratification of satisfactory functional outcome with respect to gender

Gender	Satisfactory Functional Outcome - Yes	Satisfactory Functional Outcome - No	Total	p-value
Male	44 (95.7%)	2 (4.3%)	46	0.427
Female	14 (100%)	0 (0%)	14	
Total	58 (96.7%)	2 (3.3%)	60	

Table 3: Stratification of satisfactory functional outcome with respect to age

Age Groups	Satisfactory Functional Outcome - Yes	Satisfactory Functional Outcome - No	Total	p-value
4-8 years	39 (95.1%)	2 (4.9%)	41	0.327
9-11 years	19 (100%)	0 (0%)	19	
Total	58 (96.7%)	2 (3.3%)	60	

Analyzing the association between satisfactory functional outcomes and gender showed no statistically significant difference, with male patients achieving 95.7% satisfactory outcomes compared to 100% in female patients ($p > 0.05$). Likewise, no significant association was observed between functional outcomes and age groups. Within the 4-8 year age group, 95.1% achieved satisfactory outcomes, while all patients in the 9-11 year age group reached satisfactory outcomes, with no recorded failures in the latter group ($p > 0.05$). These findings suggest that flexible intramedullary nailing yields predominantly positive functional outcomes in pediatric femoral shaft fractures, independent of age and gender variables, highlighting the technique’s overall efficacy across different demographics.

DISCUSSION

This study evaluated the functional outcomes of pediatric femoral shaft fractures treated with flexible titanium intramedullary nails in a public hospital setting in Pakistan, contributing to the growing body of evidence supporting the efficacy of surgical intervention for these injuries. Traditionally, pediatric femoral shaft fractures were managed with traction and spica casting, which effectively avoided surgery but often resulted in prolonged immobilization and rehabilitation. Over the past two decades, however, surgical treatment has gained traction, offering benefits such as enhanced mobilization, faster recovery, and reduced complication rates. Flexible intramedullary nailing, which allows controlled micromotion at the fracture site to encourage bone healing while preserving open physis, has become a favored technique for these fractures. This closed procedure minimizes infection risk and has demonstrated high union rates and favorable functional outcomes (8). Initially recommended for children aged 6 to 16, recent evidence suggests flexible nailing is also effective in children younger than 6, expanding its applicability. Previous studies reported successful union in pediatric femoral fractures with minimal complications, with one extensive study on 123 cases observing complete bone and joint union in all patients (8). Smaller studies involving 58 and 79 cases also supported these findings, showing high rates of bone healing without adverse effects. Additionally, evidence suggests that using larger nail sizes may reduce technical complications, as reported in a study of 43 cases where only one instance of hypertrophic non-union occurred, reinforcing the role of nail sizing in treatment efficacy (17).

One potential concern with flexible intramedullary nailing lies in the timing of nail removal. Early removal, sometimes performed as early as three months post-surgery, has led to both medical and rehabilitative challenges in some cases. Most clinicians advocate waiting six months to one year post-surgery to optimize outcomes, reflecting a need for standardized guidelines to ensure safe and effective nail removal protocols (19). The study’s findings align with existing literature in demonstrating high rates of successful outcomes and functional recovery, further supporting flexible intramedullary nailing as an effective treatment for pediatric femoral fractures. This study’s strength lies in its contribution to clinical data on pediatric fracture management in a public healthcare context, though it is limited by its sample size and demographic scope. Larger studies could provide more insight into potential outcome variations by age, gender, and body mass index (BMI), factors that may influence treatment responses and recovery rates. Additionally, future research might benefit from sampling children in rural and remote areas, as factors such as travel distance, food security, nutritional adequacy, and parental health literacy could impact recovery rates and bone union. These broader demographic insights could inform more tailored treatment approaches, particularly in settings with diverse socio-economic and geographic characteristics.

CONCLUSION

In conclusion, this study demonstrates that pediatric femoral shaft fractures can be effectively managed using flexible intramedullary nailing, which provides strong functional outcomes and supports efficient bone healing. This method offers a reliable treatment option that aligns with the goals of rapid recovery and minimized complication risks, making it a valuable approach in pediatric orthopedic care.

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