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FUNCTIONAL OUTCOMES OF TITANIUM ELASTIC NAILING IN THE TREATMENT OF FEMORAL SHAFT FRACTURES AMONG CHILDREN LESS THAN 8 YEARS OF AGE

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ABSTRACT

BACKGROUND: Femoral shaft fractures are one of the most common in young children which often necessitate operative stabilization to ensure proper alignment and early mobilization. Titanium elastic nailing has gained acceptance in pediatric orthopedics due to its minimally invasive nature and ability to provide stable fixation. This method provides the benefit of rapid fracture healing and reduced complication rates.

OBJECTIVE: To determine the functional outcomes of Titanium Elastic Nailing in the treatment of femoral shaft fractures among children under 8 years of age.

METHODOLOGY: This descriptive study was conducted on 128 children aged 01-07 years with femoral shaft fractures from May 25, 2025 to November 25, 2025 at department of orthopedic surgery of Lady Reading Hospital, Peshawar. All the patients underwent surgical fixation with titanium elastic nails. Functional outcomes were assessed at 12th week using Flynn's criteria and categorized as excellent, good, fair, and poor. Functional outcomes were stratified with time to surgery, malunion, limb length deficiency (LLD), infection, and nail irritation using chi square test, P value ≤ 0.05 was considered significant.

RESULTS: Mean age of the 128 patients was 4.98±1.46 years. Male patients were 84 (65.6%). Functional outcomes were excellent in 65.6% (n = 84) cases and good in 22.7% (n = 29). A statistically significant association was found between shorter time to surgery and excellent outcomes ($p < 0.001$). Early weight bearing was associated with excellent outcomes ($p < 0.001$). All patients with a poor outcome had malunion ($p < 0.001$), and a majority 83.3% had an infection ($p < 0.001$). LLD (>2 cm) was associated with poor outcomes ($p < 0.001$).

CONCLUSION; Titanium elastic nailing demonstrated excellent or good functional outcomes in 88.3% (n=113) of the children. Excellent functional outcomes were significantly associated with early surgical intervention, early post-operative weight bearing, and the absence of complications such as malunion, infection, and limb length discrepancy.

KEYWORDS: Pediatric trauma, Flynn's criteria, minimally invasive fixation, Fracture union, Post-operative complications

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INTRODUCTION

Femoral shaft fractures are one of most prevalent long bone injuries in children worldwide. They present the unique challenge due to the potential for long term functional impairment. Conservative management such as traction followed by spica casting is considered the mainstay for young children due to concerns regarding the interference with growth plates. Conservative management usually involves delayed mobilization along with risks including malunion which can considerably impair quality of life and developmental process. [1-4] The introduction of flexible intramedullary fixation utilizing Titanium Elastic Nailing System (TEN) has revolutionized the treatment of pediatric femoral diaphyseal fractures. TEN offers stable internal fixation alongside the preservation of biological environment, facilitating early mobilization and supporting efficient healing. [5,6]

A study conducted in Pakistan involving 70 children managed with flexible intramedullary nails reported a mean radiological union time of 8.57 ± 1.05 weeks demonstrating excellent outcomes of 88.5% of cases with only 1.4% had poor outcomes. [7] Another study found that children treated with TEN attained fracture union within approximately 15 weeks with 84% presenting excellent anatomical outcomes.[8] A retrospective study analyzed 32 children with femoral fracture, and reported excellent functional outcome in 90.62% of cases. [9]

Additional evidence from a study on pediatric femoral shaft fractures treated with TEN observed that the bone union was accomplished at mean of 10 weeks while early weight bearing was recorded around 9.5 weeks, and excellent outcome was seen within 92.3% of cases. [10] An earlier long term follow up study even included children under six years and validated that within 79.2% of patients, complete functional recovery was accomplished with minimal limb length discrepancy and no instances of non-union were recorded. [11]

Despite this encouraging body of evidence, majority of studies focus on children with mixed pediatric age ranges. There remains a notable paucity of data specifically addressing the functional outcomes of TEN in children under 8 years. Age group with potentially greater bone remodeling capacity, narrower

medullary canals and unique biomechanical and growth considerations. This gap is especially relevant in low- and middle-income settings where resource constraints, socio-economic factors and differing injury patterns may influence outcomes differently than in more resourced contexts. By documenting functional recovery, such an investigation would fill an important knowledge gap and guide surgical decision. That would ultimately lead to enhanced patient outcomes along with better long-term quality of life for pediatric population in regions like ours.

METHODOLOGY:

This descriptive study was conducted in the Department of Orthopedic Surgery, Lady Reading Hospital, Peshawar. One hundred and twenty-eight children were included in the study via consecutive non-probability sampling. The sample was calculated using the WHO sample size calculator based on previously reported poor functional outcome of TEN 3.3%,[12] margin of error 3.1% and confidence interval 95%. Included patients were aged between one to seven years, of either gender presented with a radiologically confirmed femoral shaft fracture. Radiographic confirmation showing fracture line, and angulation in children, with symptoms such as deformity, swelling, pain, and inability to move the leg. Children with open fractures, neuromuscular diseases, and metabolic bone disorders were excluded.

Written consent was taken from the parents or guardian of the patients. The surgical procedure was performed under general or spinal anesthesia with the patient positioned on a fracture table. A linear incision was made, the fascia was opened, and the muscle fibers were traversed, resulting in the creation and enlargement of a hole in the bone. Afterwards, each titanium elastic nail was inserted retrogradely through the distal portion of the femur. The diameter of each nail constituted 40% of the canal length at the narrowest point of femoral shaft. Reduction and fixation were performed using a C-arm image intensifier.

Functional outcomes were evaluated twelve weeks post-operatively using Modified Flynn's criteria. For this study, outcomes were categorized as excellent (0-5° loss of carrying angle and 0-5° loss of motion), good (6-10° loss of carrying angle and 6-10° loss of motion), fair (11-15° loss of carrying angle and 11-15° loss of motion), and poor (>15° loss of carrying angle and >15° loss of motion). All follow-up assessments were conducted under the supervision of a consultant orthopedic surgeon. Data regarding demographics, treatment timelines, and functional outcomes were recorded on a proforma. Time to surgery was defined as the time in hours from the time of injury to the beginning of the surgical intervention. Malunion was defined as the presence of bony angulation more than 10° in any plane, assessed on follow-up radiographs. Limb length deficiency was measured in centimeters from the anterior superior iliac spine to the medial malleolus and categorized for analysis. Nail irritation was defined as localized pain, tenderness, or erythema at the insertion site, which required symptomatic management. Infection was defined as erythema, warmth, purulent discharge, or wound dehiscence, occurring during the 12-week post-operative period. Full weight bearing was defined as the number of postoperative weeks, until the patients could support full body weight on the operated limb without any aids.

Statistical analysis was performed with SPSS 25. Age, times to surgery and hospital stay were presented as mean and standard deviation. Functional outcomes, side of fracture, type of fracture, and gender were presented as frequencies and percentages. Functional outcomes were stratified with malunion, time to surgery, infection, limb length deficiency, nail irritation and weight bearing, using chi square test, P value ≤ 0.05 considered significant.

Ethical approval with reference number 126/LRH/MTI was obtained from Ethical Review Board of Lady Reading Hospital, Peshawar, Pakistan .

RESULTS

The study included 128 patients; their mean age was 4.98 ± 1.46 years. Their mean hospital stay was 4.51 ± 1.11 days, and their mean time to surgery was 29.06 ± 13.23 hours. Regarding gender distribution, majority were male patients 84 (65.6%) (Figure 1). Fracture types are presented in table no 1.

Functional outcomes were excellent in 84 (65.6%) cases, good in 29 (22.7%), fair in 9 (7.0%), and poor in 6 (4.7%) cases (Table 2). Among those patients, who underwent surgery within 24 hours 61.9% achieved an excellent outcome, and 83.3% patients with surgery delayed beyond 48 hours experienced a poor outcome ($p < 0.001$). Early weight bearing at 3 to 4 weeks was statistically associated with better functional results ($p < 0.001$). The presence of malunion showed a significant relation with poorer outcomes ($p < 0.001$). Infection was present in 83.3% of the poor outcome group ($p < 0.001$). Limb length deficiency less than 0.5 cm was observed in majority of the patients in excellent group, while a deficiency exceeding 2 cm was found in majority of the poor outcome cases. Nail irritation was reported in majority of the poor outcome cases. ($p < 0.001$) (Table 3).

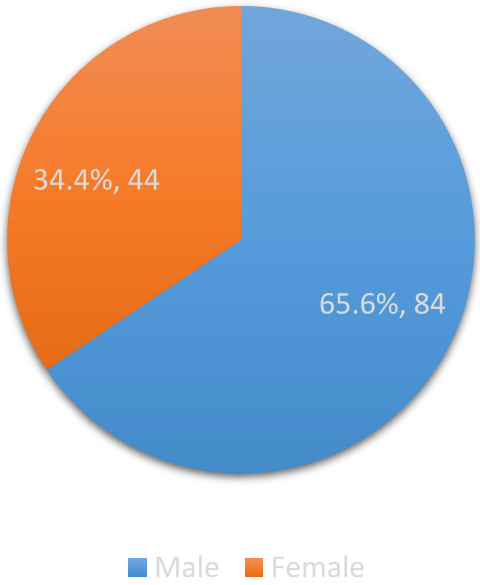

Figure 1: Gender distribution

Table I: Clinical presentation of the patients

Clinical presentation		n	%
Gender	Male	84	65.6%
	Female	44	34.4%
Fracture type	Transverse	71	55.5%
	Oblique	31	24.2%
	Spiral	17	13.3%
	Comminuted	9	7.0%
Side of fracture	Right	70	54.7%
	Left	58	45.3%

Table II: Functional outcome

Functional outcome	n	%
Excellent	84	65.6%
Good	29	22.7%
Fair	9	7.0%
Poor	6	4.7%

Table III: Association of functional outcomes with various factors

Factors		Functional outcome				P value/ Chi Square
		Excellent	Good	Fair	Poor	
Time to surgery (Hours)	< 24	61.9%	27.6%	0.0%	0.0%	< 0.001
	24 to 48	28.6%	62.1%	66.7%	16.7%	
	> 48	9.5%	10.3%	33.3%	83.3%	45.394
Weight Bearing (days)	3 to 4 weeks	95.2%	65.5%	33.3%	0.0%	< 0.001
	> 4 weeks	4.8%	34.5%	66.7%	100.0%	51.632
Malunion	Yes	0.0%	6.9%	44.4%	100.0%	< 0.001
	No	100.0%	93.1%	55.6%	0.0%	79.927
Infection	Yes	0.0%	6.9%	33.3%	83.3%	< 0.001
	No	100.0%	93.1%	66.7%	16.7%	62.806
Limb length deficiency	< 0.5	97.6%	55.2%	11.1%	0.0%	< 0.001
	0.5 to 1 cm	2.4%	44.8%	11.1%	0.0%	
	1 to 2 cm	0.0%	0.0%	77.8%	33.3%	207.190
	> 2 cm	0.0%	0.0%	0.0%	66.7%	
Nail irritation	Yes	3.6%	20.7%	44.4%	83.3%	< 0.001
	No	96.4%	79.3%	55.6%	16.7%	39.402
						Chi square test applied

DISCUSSION

The present study provided meaningful insights regarding the management of pediatric femoral shaft fractures using titanium elastic nailing. The mean age in this study was 4.98 years, this is lower than Khan et al. and Ijaz et al., who focused on children aged 5-15 and 6-12 years.[6,13] The gender distribution, with 65.6% (n = 84) male patients, is in alignment with the male majority in pediatric femoral fractures observed in several studies, Gupta et al. and Yousaf et al., which reported male percentages of 68.6% and 64.0%.[14,15]

The fracture pattern distribution showed that, transverse fractures were the most common pattern 55.5% (n = 71), this finding aligns with observations from other studies, such as, by Wahid et al. where transverse fractures were observed 69.57% cases.[16] The slight majority of right-sided fractures 54.7% n = 70) is a minor demographic trend also noted by the aforementioned study.[16]

Majority of the patients achieved excellent to good outcomes in this study. This finding is similar to several studies, which reported excellent outcomes in majority of the patients.[6,14,15] The mean time to surgery in this study was 29 hours, this highlights a clinical priority for prompt intervention. This factor was critical, as the analysis demonstrated that patients undergoing surgery within 24 hours achieved excellent outcomes, while delays > 48 hours were linked to excellent results in fewer patients. Early weight bearing was also found significantly associated with excellent outcomes, similar observation has been reported by Ijaz et al., where they noted that TEN was associated with early weight bearing as compared to hip spica casting.[13] Khan et al. and Shemshaki et al. found that TEN significantly facilitated earlier mobilization and weight bearing compared to conservative management.[6,17]

Malunion, infection, limb length discrepancy (LLD), and nail irritation were all associated with poorer results on the Flynn criteria. The complete absence of malunion in the excellent outcome group, and its presence in all poor outcomes, emphasizes anatomical alignment as a fundamental requirement for successful treatment. The absence of infection in all excellent outcomes and its presence in majority of the poor outcomes, points towards the detrimental effect of this complication, a consistent risk factor in surgical literature. Minor discrepancies (<0.5 cm) were in more than 90% of the patients who achieved excellent outcomes, larger deficiencies (>2 cm) were common in the poor outcome group. This aligns with findings from Kayaokay et al. and Uddin et al., who noted that significant discrepancies were more likely to compromise outcome scores.[18,19] Nail irritation showed a significant association with poorer results. This indicates that even minor complications can contribute to discomfort that affects overall functional assessment, a point also observed in the complication profiles reported by Ahmed et al.[20]

The innovation of this study exists in its focused examination of these outcome predictors within a dedicated cohort of very young children. Most existing literatures, either concentrates on

older children or merges broad age ranges.[13,14] By demonstrating that early surgery, stable fixation to prevent malunion, infection control, and careful technique to minimize LLD and implant irritation are important in this younger pediatric population, this study provides age-specific evidence for clinical guidance. It affirms that the benefits of TEN, including early weight bearing and reduced complication rates, are applicable and highly relevant to children under eight years.

The study had a 12-week follow-up period, this period might have been suitable for assessing fracture union and early functional recovery, it was too brief to evaluate long-term remodeling of angular deformities or the final state of limb length inequality which can continue for years in growing children. The single-center design may restrain the generalizability of the findings, as surgical protocols and rehabilitation practices can vary between institutions. There is a limitation of observer bias in the assessment of functional outcomes. Future research should involve multicenter collaborations with extended follow-up to validate these findings, assess long-term growth patterns, and further refine the indications for TEN in the youngest pediatric patients.

CONCLUSION

In conclusion, this study demonstrated that titanium elastic nailing is an effective treatment for femoral shaft fractures in children under eight years of age, majority of the children achieved excellent functional outcomes, which were significantly associated with early surgical intervention, early post-operative weight bearing, and the absence of complications such as malunion, infection, and limb length discrepancy.

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All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

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