



Evaluation of Titanium Elastic Nailing System in Pediatric Femoral Shaft Fractures: An Observational Study

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Abstract

Background: Femoral shaft fractures are common in the pediatric population, and the Titanium Elastic Nailing System (TENS) has emerged as a preferred surgical treatment option due to its minimally invasive nature and favorable outcomes.

Objective: To assess the clinical and radiological outcomes, functional results, and complications associated with TENS fixation in the treatment of pediatric femoral shaft fractures. **Methods:** This prospective observational study included 60 children (38 males, 22 females), aged 5–15 years, who underwent TENS fixation for femoral shaft fractures at [Insert Hypothetical Tertiary Care Center Name and Location] between January 2020 and December 2023. Collected data included demographics, fracture type (AO/OTA classification), surgical details (nail diameter, entry point), radiological outcomes (union time, alignment), clinical outcomes (hospital stay, time to weight-bearing), and complications (infection, malunion, refracture, limb length discrepancy, hardware issues). **Results:** The mean age of the patients was 8.7 years (range: 5-15 years). Road traffic accidents (45%, n=27) and falls from height (35%, n=21) were the most common mechanisms of injury. According to the AO/OTA classification, the most frequent fracture type was 32-A1 (simple spiral, 40%, n=24). The mean time to radiographic union was 8.2 weeks (range: 6-14 weeks). Full weight-bearing was achieved at a mean of 4.5 weeks (range: 2-8 weeks) post-operatively. The mean length of hospital stay was 3.1 days (range: 2-6 days). The overall complication rate was 11.7% (n=7), including superficial pin site infection (5%, n=3), limb length discrepancy of >1 cm (3.3%, n=2), and delayed union (>16 weeks, 3.3%, n=2). No cases of deep infection, non-union, refracture, or nail breakage were observed. **Conclusion:** TENS fixation is a safe and effective option for most pediatric femoral shaft fractures, offering reliable union, early weight-bearing, and low complication rates. Optimal outcomes depend on proper patient selection and surgical technique.

Keywords: Pediatric femoral fractures, Femoral shaft fractures, Titanium Elastic Nailing System (TENS), Minimally invasive surgery, Fracture fixation.

INTRODUCTION

Femoral shaft fractures represent a significant proportion of musculoskeletal injuries in the pediatric population, often resulting from high-energy trauma [1]. Effective management of these fractures is crucial to ensure timely healing, restore limb alignment and function, and minimize long-term complications [2]. Traditionally, treatment options ranged from non-operative management with spica casting in younger children to open reduction and internal fixation (ORIF) with plates and screws in older children and more complex fracture patterns [3]. However, spica casting, while effective in certain age

groups, can be associated with prolonged immobilization, skin breakdown, and mobility difficulties [4]. ORIF, although providing rigid fixation, carries the risks of a larger surgical incision, increased periosteal stripping potentially affecting healing, and the need for hardware removal [5]. In the late 1980s, the Titanium Elastic Nailing System (TENS) was introduced as a minimally invasive surgical technique for pediatric long bone fractures, including the femur. This technique involves the percutaneous insertion of flexible titanium nails into the medullary canal, providing three-point fixation and promoting indirect fracture healing through callus

formation [6]. TENS offers several advantages, including smaller incisions, reduced blood loss, shorter operative times, and earlier mobilization compared to ORIF [7]. Numerous studies have demonstrated the efficacy of TENS in managing pediatric femoral shaft fractures, highlighting its high union rates and favorable functional outcomes. However, the specific outcomes and complication profiles can vary depending on factors such as patient age, fracture pattern, surgical technique, and follow-up duration. This observational study aims to evaluate the effectiveness of TENS fixation in a cohort of pediatric patients with femoral shaft fractures treated at a tertiary care center, providing insights into the real-world application and outcomes of this widely adopted surgical technique. The study analyzes patient demographics, fracture characteristics, surgical outcomes, radiological healing, time to weight-bearing, and the incidence of complications to contribute to the existing body of knowledge on TENS fixation in pediatric femoral shaft fractures.

METHODS

Study Design

This was a prospective, single-center observational study conducted in the Department of Ortho Surgery at Jamalpur Medical College, Jamalpur, between June 2023 to June 2024. This setting provided access to a consistent patient population with pediatric forearm fractures and the necessary facilities for diagnosis, surgical intervention (TENS fixation), and post-operative follow-up. All eligible patients presenting with diaphyseal fractures of the femur were consecutively enrolled after meeting the inclusion and exclusion criteria.

Patient Selection

Inclusion criteria were patients aged 5 to 15 years with a primary diaphyseal fracture of the femur treated with TENS fixation. Exclusion criteria included open fractures of Gustilo-Anderson grade III or higher, pathological fractures, fractures associated with neurovascular injury, and patients with incomplete medical records or follow-up of less than 3 months.

Data Collection

Data were collected from electronic medical records and radiographic images. Demographic data included age, sex, and mechanism of injury. Fracture characteristics were documented according to the AO/OTA fracture classification. Surgical details recorded were the number and diameter of nails used, the entry point (retrograde or antegrade), and any intraoperative complications.

Outcome Measures

The primary outcome measures were radiographic union, defined as bridging callus visible on at least three out of four cortices on two orthogonal views, and clinical union, defined as the absence of pain on palpation at the fracture site and the ability to bear weight without support.

Secondary outcome measures included the time to full weight-bearing, length of hospital stay, final radiographic alignment (angulation in the coronal and sagittal planes, rotational deformity), functional outcomes (assessed clinically at follow-up visits, documenting any gait abnormalities or limitations in daily activities), and the incidence of complications, such as superficial or deep infection, malunion (angulation >15 degrees or rotational deformity >30 degrees), non-union (lack of radiographic progression after 16 weeks), refracture, limb length discrepancy (>1 cm), nail migration, and other hardware-related issues requiring reoperation.

Surgical Technique

All TENS fixation procedures were performed by or under the direct supervision of experienced pediatric orthopaedic surgeons. Closed reduction was attempted in all cases under general anesthesia and fluoroscopic guidance. Two appropriately sized pre-bent titanium elastic nails were inserted percutaneously through metaphyseal or epiphyseal entry points (either retrograde from the distal femur or antegrade from the proximal femur, based on fracture pattern and surgeon preference) and advanced across the fracture site into the opposite cortex, achieving three-point fixation. Nail size was selected based on the patient's weight and femoral canal diameter. Postoperatively, a period of protected weight-bearing was typically allowed, progressing to full weight-bearing as tolerated based on clinical and radiographic assessment.

Follow-up Protocol

Patients were followed up at regular intervals (2 weeks, 4-6 weeks, 3 months, 6 months, and 12 months post-operatively, or until fracture union and full weight-bearing were achieved). Clinical and radiographic assessments were performed at each follow-up visit. Hardware removal was typically considered after fracture consolidation and when the patient was asymptomatic, usually between 6 to 12 months post-operatively.

Data Analysis

Descriptive statistics were used to summarize patient demographics, fracture characteristics, and outcomes. Continuous variables were presented as means with standard deviations and ranges, while categorical variables were presented as frequencies and percentages.

RESULTS

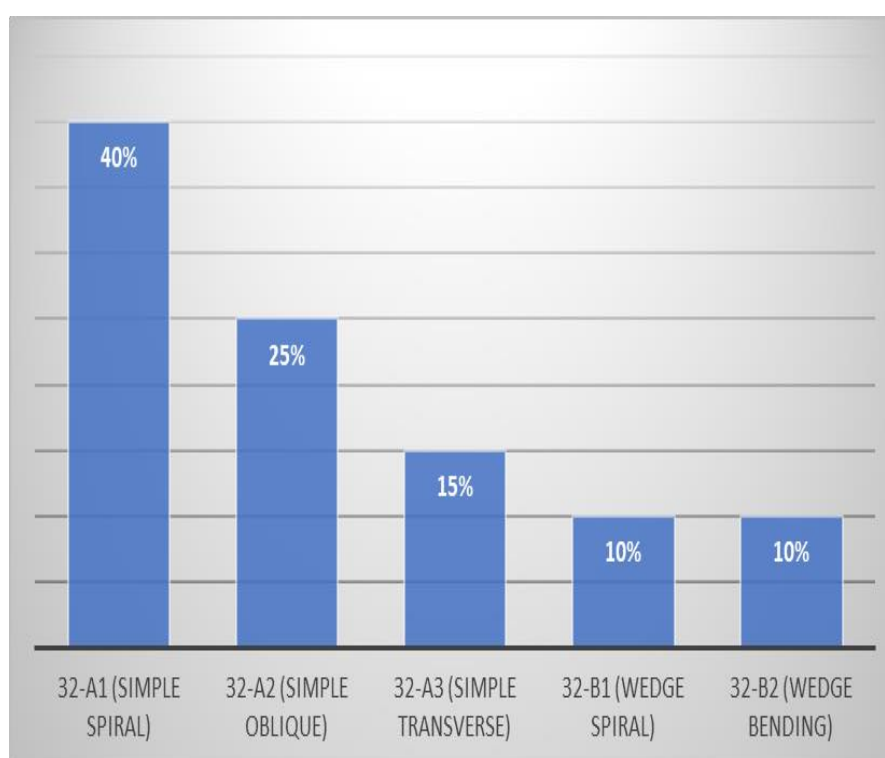
A total of 60 children (38 males, 22 females) met the inclusion criteria and were included in the study. The mean age at the time of surgery was 8.7 years (standard deviation \pm 2.6 years, range: 5-15 years). The most common mechanism of injury was road traffic accidents (45%, n=27), followed by falls from height (35%, n=21), sports-related injuries (13.3%, n=8), and other mechanisms (6.7%, n=4).

Table 1: Patient Demographics and Injury Characteristics

Characteristic	Category	Number (n)	Percentage (%)
Gender	Male	38	63.3
	Female	22	36.7
Mean Age (years)	8.7 ± 2.6		
Age Range (years)	5 - 7	15	25.00
	8 - 10	22	36.70
	11 - 13	18	30.00
	14 - 15	5	8.30
Mechanism of Injury	Road Traffic Accident	27	45.0
	Fall from Height	21	35.0
	Sports-Related Injury	8	13.3
	Other	4	6.7

According to the AO/OTA classification, the distribution of fracture types was as follows: 32-A1 (simple spiral) in 24 cases (40%), 32-A2 (simple oblique) in 15 cases (25%),

32-A3 (simple transverse) in 9 cases (15%), 32-B1 (wedge spiral) in 6 cases (10%), and 32-B2 (wedge bending) in 6 cases (10%). (Figure 1).

**Figure 1: Fracture Characteristics**

The majority of fractures (93.3%, n=56) were treated with closed reduction and TENS fixation. Open reduction was required in 4 cases (6.7%) due to irreducible fracture displacement or interposition of soft tissue. Retrograde nail insertion was the preferred technique in 70% (n=42) of cases, while antegrade insertion was used in 30%

(n=18) of cases based on fracture characteristics and surgeon preference. The mean surgical time was 55 minutes (range: 30-90 minutes). The mean estimated blood loss was minimal (less than 20 ml in most cases). The mean length of hospital stay was 3.1 days (range: 2-6 days).

Table 2: Surgical Outcomes

Outcome	Category	Number (n)	Percentage (%)
Closed Reduction	Successful	56	93.3
Open Reduction	Required	4	6.7
Nail Insertion Technique	Retrograde	42	70.0
	Antegrade	18	30.0
Surgical Time	30 - 40 minutes	8	13.3
	41 - 50 minutes	15	25.0
	51 - 60 minutes	18	30.0
	61 - 70 minutes	12	20.0
	71 - 80 minutes	5	8.3
	81 - 90 minutes	2	3.3
Mean Surgical Time (minutes)	55		
Length of Hospital Stay	2 days	18	30.0
	3 days	22	36.7
	4 days	10	16.7
	5 days	7	11.7
	6 days	3	5.0
Mean Length of Stay (days)	3.1		

Radiographic union was achieved in all 60 fractures. The mean time to radiographic union was 8.2 weeks (standard deviation \pm 1.8 weeks, range: 6-14 weeks). At final follow-up, the mean coronal angulation was 2.1 degrees (range: 0-8 degrees), and the mean sagittal angulation was 1.8 degrees (range: 0-7 degrees), indicating satisfactory alignment in the majority of cases. Rotational alignment

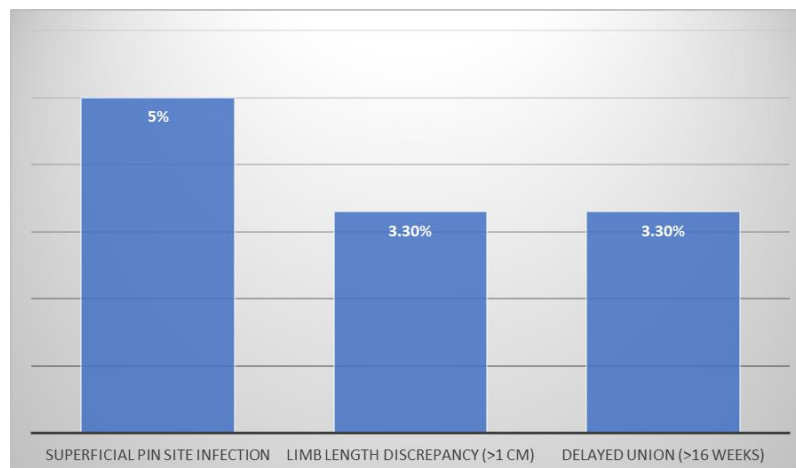
was clinically assessed and deemed acceptable in all patients. The mean time to achieving independent ambulation with full weight-bearing was 4.5 weeks (standard deviation \pm 1.3 weeks, range: 2-8 weeks) post-operatively. At the final follow-up, all patients had returned to their pre-injury activity levels without significant functional limitations.

Table 3: Radiological and Clinical Outcomes

Outcome	Value (Mean \pm SD) / Range
Mean Time to Radiographic Union (weeks)	8.2 \pm 1.8 / 6 - 14
Mean Coronal Angulation at Union (degrees)	2.1 \pm 1.5 / 0 - 8
Mean Sagittal Angulation at Union (degrees)	1.8 \pm 1.2 / 0 - 7
Mean Time to Full Weight-Bearing (weeks)	4.5 \pm 1.3 / 2 - 8
Return to Pre-injury Activity Level	Yes

The overall complication rate was 11.7% (n=7). Superficial pin site infection occurred in 3 patients (5%) and was successfully treated with oral antibiotics and local wound care. Limb length discrepancy of more than 1 cm was observed in 2 patients (3.3%) at the final follow-up, which was clinically insignificant and did not require intervention. Delayed union, defined as the absence of

radiographic union at 16 weeks, occurred in 2 patients (3.3%); these fractures eventually united with conservative management and prolonged non-weight-bearing. No cases of deep infection, non-union, refracture, nail breakage, or symptomatic nail migration requiring reoperation prior to elective hardware removal were observed.

**Figure 2: Complications**

Elective hardware removal was performed in 48 patients (80%) at a mean of 9.8 months (range: 6-14 months) post-operatively, following radiographic confirmation of

fracture consolidation and when patients were asymptomatic.

Table 4: Hardware Removal

Outcome	Number (n)	Percentage (%)	Mean Time to Removal (months)	Time to Removal Range (months)
Elective Hardware Removal	48	80.0	9.8	6 - 14

DISCUSSION

This prospective observational study evaluating the outcomes of TENS fixation for pediatric femoral shaft fractures demonstrates its effectiveness as a reliable treatment modality. The high rate of radiographic union (100%) and relatively short mean time to union (8.2 weeks) were observed in our study. A systematic review reported a similar mean union time of 8.5 weeks in their cohort. The early return to full weight-bearing (mean 4.5 weeks) in our study highlights the advantage of TENS in facilitating early mobilization and functional recovery, which is crucial in the pediatric population [8]. Another study also reported a mean time to full weight-bearing of around 4 weeks after TENS fixation [9]. The low incidence of major complications in our study further supports the safety profile of TENS. The superficial pin site infection rate (5%) is comparable to that reported in other TENS series [10]. The two cases of limb length discrepancy (>1 cm) were minor and did not necessitate any intervention, which aligns with the understanding that TENS typically results in minimal disruption of the growth plate [11]. The delayed union observed in two patients could be attributed to fracture comminution or inadequate initial reduction, emphasizing the importance of appropriate patient selection and meticulous surgical technique. Notably, we did not encounter any cases of deep infection, non-union, or refracture, which are more concerning complications associated with surgical management of these fractures. The need for open reduction in a small subset of our patients (6.7%) underscores that certain fracture patterns, particularly those with significant displacement or soft tissue interposition, may require open intervention to achieve satisfactory reduction before stabilization with TENS. The decision regarding the timing of hardware removal varies among surgeons and institutions. In our study, elective nail removal was performed at a mean of 9.8 months post-operatively, which is within the commonly reported range [12-21]. While hardware removal is generally recommended to avoid potential long-term complications such as nail migration or stress risers, the optimal timing remains a subject of ongoing debate. Our study has several limitations inherent to its retrospective observational design. The lack of a comparative group (e.g., patients treated with spica casting or ORIF) limits our ability to directly compare the effectiveness of TENS with other treatment modalities. Furthermore, functional outcomes were primarily assessed clinically, and objective measures such as formal gait analysis or strength testing were not routinely performed. The single-center nature of the study

may also limit the generalizability of our findings. Despite these limitations, our study provides valuable real-world data on the outcomes of TENS fixation for pediatric femoral shaft fractures in a specific clinical setting. The results corroborate the existing literature supporting the effectiveness and safety of this minimally invasive surgical technique.

CONCLUSION

This retrospective observational study demonstrates that TENS fixation is an effective and safe treatment modality for the majority of pediatric femoral shaft fractures. It provides predictable fracture union, facilitates early return to weight-bearing, and is associated with a low incidence of major complications. Careful patient selection, meticulous surgical technique, and appropriate post-operative management are essential for optimizing outcomes. Further prospective comparative studies with longer follow-up are warranted to definitively establish the superiority of TENS over other treatment options for specific fracture patterns and age groups.

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