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Original Article

Application of Titanium Elastic Nails for Treating Pediatric Tibial Shaft Fractures

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ABSTRACT

Background: Pediatric tibial shaft fractures are among the most common long bone injuries, particularly in developing countries, often requiring effective surgical management for optimal outcomes. Aim of the study to evaluate the effectiveness and clinical outcomes of Titanium Elastic Nailing in pediatric tibial shaft fractures**. Methods & Materials**: This prospective observational study was conducted over one year at the Department of Orthopedic & Spine Surgery, Ad-Din women's Medical College Hospital and Barak PRP Medical Centre & General Hospital, Dhaka, Bangladesh, Dhaka, Bangladesh. A total of 15 pediatric patients aged 5–15 years with tibial shaft fractures were treated using Titanium Elastic Nails. Demographic data, fracture characteristics, operative details, and postoperative outcomes were recorded. Functional outcomes were assessed using Flynn criteria, and radiological parameters were evaluated for alignment and limb length discrepancy. Statistical analysis was performed using SPSS version 26 with descriptive statistics. **Result**: The mean age was 10.4±2.9 years, with male predominance (73.33%). Road traffic accidents (40%) were the most common cause. The mean time to union was 9.8±2.1 weeks, with most cases (86.67%) achieving union within 12 weeks. Complications were minimal, with 73.33% having no complications. Functional outcomes were excellent in 66.67% and good in 26.67% of patients. Radiologically, 86.67% had <5° angular deformity, and 93.33% had <1 cm limb length discrepancy. **Conclusion**: Titanium Elastic Nailing is an effective and reliable treatment for pediatric tibial shaft fractures, providing excellent functional and radiological outcomes with minimal complications.

Keywords: *Pediatric tibial fracture, Titanium elastic nail, TENS, Flynn criteria, fracture union, minimally invasive surgery.*

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INTRODUCTION

Pediatric tibial shaft fracture refers to a discontinuation of the tibial diaphysis in skeletally immature patients, typically caused by trauma, such as falls, road traffic accidents or sports-related injuries. Tibia is also especially susceptible to injuries because it is subcutaneous in structure and is covered by a scanty amount of soft tissues [1]. One of the most frequent long bone injuries in children is tibial shaft fractures, which constitute a large percentage of orthopedic injuries in children [2,3]. Pediatric long bone fractures have grown in the world over the past decades as a result of high rates of urbanization, motorization and recreational activities. In children and adolescents, lower leg fracture is the most common cause of morbidity and mortality caused by traumatic injuries of long bones shaft fractures, with the majority of the burden of the disease being carried by the low- and middle-income nations, especially in developing world [4]. Hospital-based reports in Bangladesh show that there is an increasing trend in the number of pediatric fracture admissions, especially in cases of road traffic injuries and falls, which are a result of the changing socioeconomic and environmental conditions [5]. Historically, the conventional approach to management, which involved casting, was the most common treatment approach. Despite its success in numerous instances, this approach to treatment is filled with numerous complications and psychological, social, educational, and economic challenges [6]. To address these, surgical fixation has been widely embraced, especially in unstable or displaced fractures [7]. Elastic Stable Intramedullary Nailing (ESIN), often referred to as the Titanium Elastic Nailing System (TENS) has become a popular surgical method used to treat long bone fractures in children. This is a minimally invasive surgery whereby flexible titanium nails are inserted into the medullary canal to offer internal fixation that is stable and does not damage the periosteal blood supply and growth plate integrity [8]. Titanium elastic nails offer biomechanical stability by elastic fixation with controlled micro-motion to enhance early bone healing [9]. Titanium elastic nailing is important as it is able to support fracture alignment and early mobilization which is important in shortening hospital stay and rehabilitation time [10]. The benefits of this method are low levels of soft tissue disturbance, less time spent in the operating room, earlier weight-bearing, and quicker functional restoration than the traditional approaches to immobilization [11]. Although these are the advantages, some complications like nail irritation, infection, malalignment, and the necessity to perform second operations to remove the implants are reported [12]. Tibial shaft fractures in children are becoming more prevalent, especially in the developing nations. Despite the popularity of Titanium Elastic Nailing System (TENS), differences in outcomes and insufficient evidence on the topic are still a problem in Bangladesh and needs to be considered for effectiveness. This study aims to assess the effectiveness and clinical outcomes of Titanium Elastic Nailing System (TENS) in the treatment of pediatric tibial shaft fractures, specifically in terms of fracture healing, functional recovery, complication rates, and overall treatment success.

METHODS & MATERIALS

This prospective observational study was conducted at the Department of Orthopedic & Spine Surgery Ad-Din women's Medical College Hospital and Barak PRP medical Centre & General Hospital, Dhaka, Bangladesh, Dhaka, Bangladesh over a

period of 1 year from January 2025 to December 2025. The study included pediatric patients diagnosed with tibial shaft fractures who were managed with Titanium Elastic Nailing (TEN). A purposive sampling technique was employed, and a total of **15 patients (N = 15)** were enrolled, forming a clearly defined study cohort.

The patients were selected based on predefined inclusion and exclusion criteria to ensure clinical relevance and homogeneity. All enrolled cases underwent surgical management using Titanium Elastic Nails, and outcomes were assessed through clinical and radiological follow-up.

Inclusion Criteria

- Patients aged between 5–15 years.
- Closed tibial shaft fractures or open fractures (Grade I).
- Displaced or unstable fractures requiring surgical intervention.
- Patients presenting within a reasonable time frame after injury.
- Consent obtained from guardians/parents.

Exclusion Criteria

- Patients with open fractures Grade II and III.
- Pathological fractures.
- Associated neurovascular injury.
- Polytrauma patients requiring alternative priority management.
- Previous fracture or deformity in the same limb.
- Patients unfit for anesthesia or surgery.

Data Collection

Data were systematically collected using a structured and pre-tested data collection sheet. Variables recorded included demographic characteristics (age, gender, side of fracture), mechanism of injury (road traffic accident, fall from height, sports injury, others), fracture characteristics (type and pattern), and operative details such as time to surgery, duration of surgery, blood loss, use of fluoroscopy, and type of reduction (closed or open).

Postoperative parameters included time to union, duration of hospital stay, and complications (entry site irritation, infection, delayed union). Functional outcomes were assessed using the Flynn criteria at final follow-up. Radiological evaluation included assessment of angular deformity and limb length discrepancy.

All patients underwent surgical fixation under general or regional anesthesia using standard Titanium Elastic Nail technique. Closed reduction was attempted initially in all cases, with open reduction performed when necessary. Postoperatively, patients were followed up regularly with clinical and radiological assessments until fracture union and functional recovery were achieved.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 26). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Due to the descriptive nature and small sample size of the study, primarily descriptive statistics were applied. Results were presented in tables for clear interpretation.

RESULT

Among 15 patients, the mean age was 10.4 ± 2.9 years, with the majority aged 9–12 years (46.67%), followed by 5–8 and 13–15 years (26.67% each). Males predominated (73.33%), and right-sided fractures were more common (60.00%) *Table I.*

Table I
Baseline Demographic Characteristics of Patients (*n* = 15).

Characteristics	Frequency (n)	Percentage (%)
Age (years)		
5–8	4	26.67
9–12	7	46.67
13–15	4	26.67
Mean ± SD	10.4 ± 2.9	
Gender		
Male	11	73.33
Female	4	26.67
Side of fracture		
Right	9	60.00
Left	6	40.00

Regarding injury characteristics, road traffic accidents were the most common mechanism (40.00%), followed by falls from height (33.33%) and sports-related injuries (20.00%). The majority of fractures were closed (86.67%), with only 13.33% being open (Grade I). In terms of fracture configuration, transverse fractures were most frequent (40.00%), followed by oblique (33.33%), spiral (20.00%), and comminuted types (6.67%) *Table II.*

Table II
Mechanism and Pattern of Injury (*n* = 15).

Characteristics	Frequency (n)	Percentage (%)
Mechanism of injury		
Road traffic accident	6	40.00
Fall from height	5	33.33
Sports injury	3	20.00
Others	1	6.67
Fracture type		
Closed	13	86.67
Open (Grade I)	2	13.33
Fracture pattern		

Transverse	6	40.00
Oblique	5	33.33
Spiral	3	20.00
Comminuted	1	6.67

Operative parameters showed a mean time to surgery of 2.6 ± 1.2 days. The average duration of surgery was 58 ± 12 minutes, with a mean intraoperative blood loss of 42 ± 15 ml. Fluoroscopy was used in all cases (100.00%), and closed reduction was successfully achieved in 86.67% of patients, while 13.33% required open reduction (*Table III*).

Table III
Operative and Intraoperative Parameters (*n* = 15).

Characteristics	Frequency (n)	Percentage (%)
Time to surgery (days), Mean ± SD	2.6 ± 1.2	
Duration of surgery (minutes), Mean ± SD	58 ± 12	
Blood loss (ml), Mean ± SD	42 ± 15	
Fluoroscopy use	15	100.00
Closed reduction	13	86.67
Open reduction	2	13.33

Postoperative outcomes indicated that most fractures united within 9–12 weeks (46.67%), while 40.00% healed within ≤8 weeks and 13.33% took more than 12 weeks, with an overall mean union time of 9.8 ± 2.1 weeks. The mean hospital stay was 4.3 ± 1.1 days. A majority of patients (73.33%) experienced no complications. Among the complications observed, entry site irritation was the most common (13.33%), followed by superficial infection and delayed union (6.67% each) *Table IV*.

Table IV
Postoperative Outcomes and Complications (*n* = 15).

Characteristics	Frequency (n)	Percentage (%)
Time to union (weeks)		
≤8 weeks	6	40.00
9–12 weeks	7	46.67
>12 weeks	2	13.33
Mean ± SD	9.8 ± 2.1	
Hospital stay (days)	4.3 ± 1.1	
Complications		
Entry site irritation	2	13.33
Superficial infection	1	6.67
Delayed union	1	6.67
No complication	11	73.33

Functional outcomes demonstrated excellent results in 66.67% of cases, good in 26.67%, and fair in 6.67%, with no poor outcomes reported (*Table V*).

Table V
Functional Outcome at Final Follow-up (*n* = 15).

Outcome (Flynn Criteria)	Frequency (n)	Percentage (%)
Excellent	10	66.67
Good	4	26.67
Fair	1	6.67
Poor	0	0.00

Radiological assessment revealed satisfactory alignment in most patients, with 86.67% having angular deformity <5° and no cases exceeding 10°. Limb length discrepancy was minimal, with 93.33% having <1 cm discrepancy and only 6.67% showing ≥1 cm difference (*Table VI*).

Table VI
Radiological Alignment and Limb Length Discrepancy (*n* = 15).

Characteristics	Frequency (n)	Percentage (%)
Angular deformity		
<5°	13	86.67
5–10°	2	13.33
>10°	0	0.00
Limb length discrepancy		
<1 cm	14	93.33
≥1 cm	1	6.67

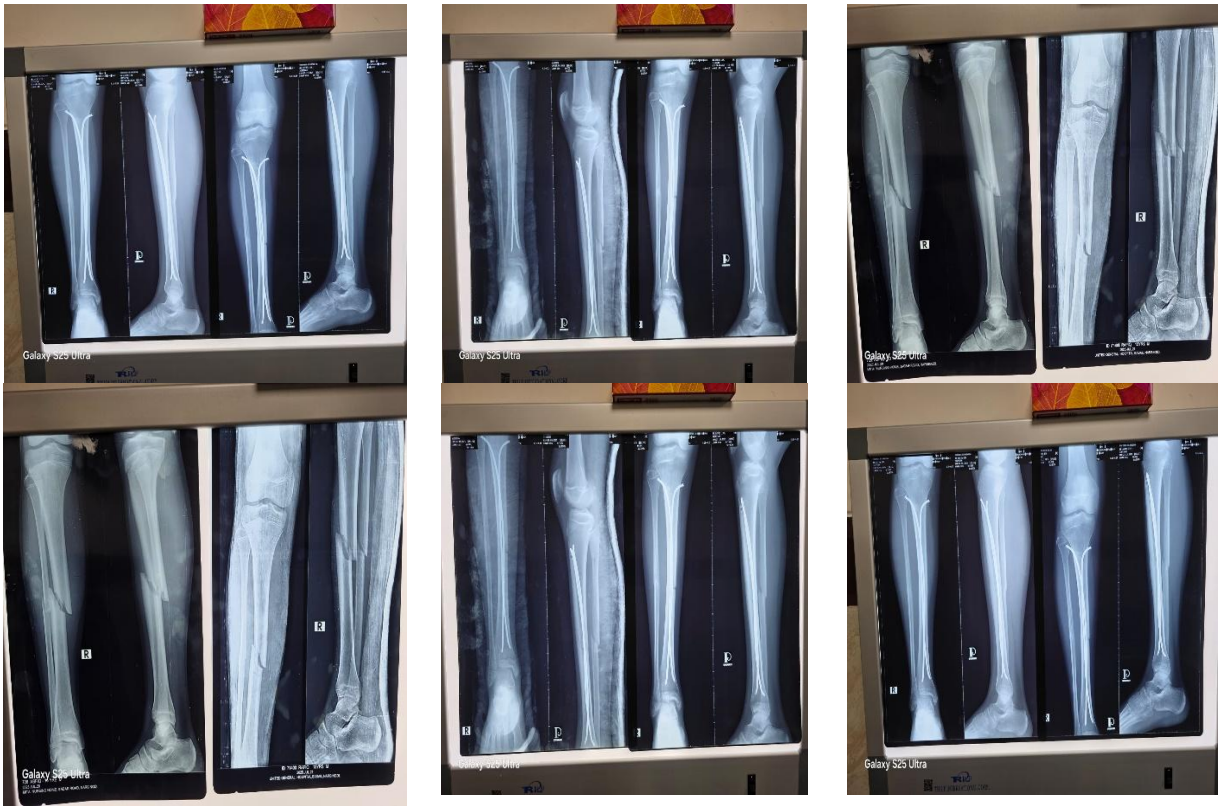

Figure 1 Radiographic Evaluation of Pediatric Tibial and Fibular Shaft Fractures Managed with Titanium Elastic Nailing System (TENS).

The X-rays demonstrate a displaced mid-shaft fracture of the right tibia and fibula in a patient, showing successful internal fixation with elastic nails and progressive callus formation indicating healthy bone healing (*Figure 1*).

DISCUSSION

Pediatric tibial shaft fractures present a unique therapeutic challenge, where the application of titanium elastic nails has emerged as an effective modality balancing stability with minimally invasive management [13]. The present study evaluated the effectiveness of Titanium Elastic Nailing (TEN) in pediatric tibial shaft fractures, demonstrating favorable demographic distribution, satisfactory operative parameters, high union rates, and excellent functional outcomes with minimal complications. In terms of baseline demographic characteristics, the mean age in our study was 10.4 ± 2.9 years, with the majority of patients in the 9–12 years age group (46.67%), followed by 5–8 years (26.67%) and 13–15 years (26.67%). This age distribution is comparable to studies by Hayek et al., who reported a mean age of approximately 11.8 years [14]. A marked male predominance (73.33% male vs 26.67% female) was observed in our study, which is consistent with findings by Gothefors et al., who reported male preponderance (58%) due to higher physical activity levels and exposure to trauma [15]. Regarding the side of fracture, the right side (60.00%) was more commonly affected than the left (40.00%), which is in agreement with earlier observational studies, although no consistent laterality preference has been universally established [16]. Analysis of the mechanism and pattern of injury revealed that road traffic accidents (40.00%) were the most common cause, followed by fall from height (33.33%), sports injury (20.00%), and others (6.67%). This pattern is comparable to findings by Civan et al., where high-energy trauma accounted for a significant proportion of tibial fractures [17]. In our study, closed fractures accounted for 86.67%, while open (Grade I) fractures were 13.33%, which aligns with the inclusion criteria commonly used in TEN studies [13]. The fracture pattern distribution showed transverse fractures (40.00%) as most common, followed by oblique (33.33%), spiral (20.00%), and comminuted (6.67%), similar to the observations by Patel et al., where simple fracture patterns predominated [18]. Operative and intraoperative parameters in our study further support the minimally invasive nature of TEN. The mean time to surgery was 2.6 ± 1.2 days, indicating early surgical intervention, which is consistent with current recommendations [19]. The mean duration of surgery was 58 ± 12 minutes, and mean blood loss was 42 ± 15 ml, both of which are comparable to studies by Baig et al. and Zhu et al., who reported operative times of approximately 50–60 minutes and minimal blood loss [20,21]. Fluoroscopy was used in 100.00% of cases, reflecting standard intraoperative practice [22]. Closed reduction was successfully achieved in 86.67% of cases, while 13.33% required open reduction, which is consistent with previously reported rates, emphasizing the biological advantage of closed techniques in preserving periosteal blood supply [23]. Postoperative outcomes in our study demonstrated a mean time to union of 9.8 ± 2.1 weeks, with 40.00% achieving union within ≤8 weeks, 46.67% within 9–12 weeks, and only 13.33% taking >12 weeks. These findings are in close agreement with Uludağ & Tosun, who reported union times ranging from 6–20 weeks [13]. The mean hospital stay in our study was 4.3 ± 1.1 days, which is comparable to other studies demonstrating shorter hospitalization with TEN [23]. Complication rates were low, with entry site irritation (13.33%), superficial infection (6.67%), and delayed union (6.67%), while 73.33% had no complications. These findings are consistent with reports by Pogorelić et al., where minor complications such as nail irritation were most common and major complications were rare [23]. Functional outcomes assessed by Flynn criteria showed excellent results in 66.67%, good in 26.67%, and fair in 6.67%, with no poor outcomes (0.00%). These results are highly comparable to those reported by Aly et al. [24]. Radiological outcomes in our study were also highly satisfactory. Angular deformity was **<5°** in 86.67% of patients and 5–10° in 13.33%,

with no cases >10° (0.00%), which is within acceptable limits and comparable to findings by Uludağ &Tosun [13].

LIMITATIONS

This study has several limitations, including a small sample size (N=15), which limits the generalizability of the findings. The absence of a control or comparative group restricts the ability to directly evaluate superiority over other treatment modalities such as casting or plating. Additionally, the study was conducted at a single center, which may introduce selection bias. The relatively short follow-up period also limits assessment of long-term outcomes, including growth disturbances and late complications.

CONCLUSION

The present study demonstrates that Titanium Elastic Nailing is a safe, effective, and minimally invasive modality for the management of pediatric tibial shaft fractures. The majority of patients achieved timely fracture union, with a mean duration of 9.8 weeks, and excellent to good functional outcomes were observed in 93.34% of cases according to Flynn criteria. Complication rates were low and predominantly minor, with no cases of severe deformity or poor outcomes. Radiological parameters further confirmed satisfactory alignment and minimal limb length discrepancy. Overall, Titanium Elastic Nailing provides reliable stabilization, facilitates early mobilization, and ensures favorable clinical and functional recovery, making it a preferred treatment option for appropriately selected pediatric patients.

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CONFLICT OF INTEREST

None declared

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee.

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