

## Complications and Healing Dynamics of Titanium Elastic Nail Fixation in Pediatric Femoral Fractures

Dr. Md. Minhaz Uddin<sup>1\*</sup>, Dr. Tasmia Islam<sup>2</sup>, Dr. Md. Sharif Hossain<sup>3</sup>,  
Dr. Md. Harun Are Rashid<sup>4</sup>, Dr. Barshan Bose<sup>5</sup>, Dr. Md. Sohel Rana<sup>6</sup>

<sup>1</sup>MS(Orthopaedic Surgery), Assistant Registrar, Department of Orthopaedic Surgery, Dhaka Medical College Hospital, Dhaka, Bangladesh

<sup>2</sup>Assistant Professor, Department of Pathology, Universal Medical College, Dhaka, Bangladesh

<sup>3</sup>Registrar, Department of Orthopaedics, Shaheed Tajuddin Ahmad Medical College Hospital, Gazipur, Bangladesh

<sup>4</sup>MS (Orthopaedic Surgery), Assistant Professor (Arthroscopy and Sports Medicine), Department of Orthopaedic Surgery, Dhaka Medical College Hospital, Dhaka, Bangladesh

<sup>5</sup>Assistant Registrar, Department of Orthopaedics, Dhaka Medical College Hospital, Dhaka, Bangladesh

<sup>6</sup>Indoor Medical Officer, Department of Orthopaedic Surgery, Rajshahi Medical College Hospital, Rajshahi, Bangladesh

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**\*Corresponding Author:** Dr. Md. Minhaz Uddin, MS (Orthopaedic Surgery), Assistant Registrar, Department of Orthopaedic Surgery, Dhaka Medical College Hospital, Dhaka, Bangladesh

### Abstract:

**Background:** Pediatric femoral fractures represent a significant orthopedic challenge, requiring effective treatment to ensure early recovery and minimize complications. Titanium Elastic Nailing (TEN) has emerged as a minimally invasive, reliable option for managing such fractures, particularly in resource-constrained settings.

**Methods:** This prospective observational study was conducted at Dhaka Medical College Hospital, Bangladesh, involving 30 pediatric patients aged 6–14 years with femoral fractures treated using TEN. Data on fracture type, mechanism of injury, union time, complications, and functional outcomes were collected and analyzed using Flynn's scoring system.

**Results:** The majority of patients (63.3%) were aged 11–14 years, with transverse fractures being the most common (60.0%). Motor vehicle accidents were the leading mechanism of injury (46.7%), followed by falls (36.6%). Radiological union was achieved within 8–10 weeks in 70.0% of cases, while the remaining 30.0% achieved union by 12 weeks. Complications were minimal, with nail tip irritation (6.7%) and malalignment (10.0%) being the most frequent. Functional outcomes were excellent in 76.7% of patients and satisfactory in 23.3%, with no poor outcomes reported.

**Conclusion:** TEN is a safe, effective, and resource-friendly solution for pediatric femoral fractures, offering excellent functional and radiological outcomes with minimal complications. These findings validate its widespread use in low-resource settings and provide a foundation for future research on optimizing fracture care.

**Keywords:** Titanium Elastic Nailing, Pediatric Femoral Fractures, Flynn's Scoring System, Fracture Union, Complications, Resource-Limited Settings

### 1. INTRODUCTION

Pediatric femoral fractures represent a significant orthopedic challenge globally, accounting for approximately 1.6% of all pediatric fractures, with the femoral shaft being the most common site of injury (1).

These fractures typically result from high-energy trauma, such as road traffic accidents and falls, which are particularly prevalent in low- to middle-income countries like Bangladesh, where urban density and inadequate safety infrastructure exacerbate the risk (2,3). In resource-limited settings,

managing such injuries becomes even more critical due to the dual burden of constrained healthcare resources and the need for cost-effective, minimally invasive treatment modalities. Effective treatment is essential to ensure not only physical recovery but also psychological well-being, as prolonged immobility from these fractures can significantly disrupt a child's development, education, and mental health (4). Biologically, pediatric bones possess unique properties, such as higher elasticity, rapid healing potential, and a pronounced remodeling capacity, which make them highly amenable to minimally invasive techniques (5). Traditional management approaches, including spica casting and traction, often result in extended periods of immobilization, higher complication rates, and significant psychological and functional burdens (6). In contrast, the advent of Titanium Elastic Nailing (TEN) has revolutionized the management of pediatric long bone fractures. TEN operates on the principle of three-point fixation, offering biomechanical stability with minimal soft tissue disruption (7). This technique is particularly effective in treating diaphyseal fractures in children aged 5–16 years, where it facilitates early mobilization, shorter hospital stays, and reduced surgical morbidity (6). TEN provides a significant advantage over other surgical interventions such as plating or external fixation, particularly in resource-constrained environments. A multicenter study demonstrated that over 90% of pediatric fractures treated with TEN achieved excellent or satisfactory outcomes, with a mean healing time of 6–12 weeks (6). The technique's minimally invasive nature and cost-effectiveness make it an optimal choice in settings like Bangladesh, where healthcare systems are under pressure to deliver effective care at lower costs (7). However, despite its advantages, TEN is underutilized in low-resource regions, partly due to logistical constraints and limited availability of trained personnel. Complications associated with TEN are relatively minor and manageable when the procedure is performed according to established guidelines. Common complications include nail irritation, soft tissue discomfort, and malunion, with complication rates varying from 6% to 23% depending on fracture type and patient demographics (8). Specific challenges, such as higher malunion rates in

older and heavier children, highlight the importance of careful patient selection and adherence to technical principles, such as ensuring appropriate nail diameter and insertion angles (9). Infection rates are typically low (<5%), and most cases are superficial and resolve with basic antibiotic therapy (5). Limb length discrepancies are also observed in a minority of cases, though these are generally clinically insignificant and resolve with growth over time (10). Healing dynamics in TEN-treated fractures are influenced by factors such as age, fracture type, and surgical technique. Studies have consistently shown that fractures managed with TEN achieve union within 6–12 weeks, with earlier weight-bearing contributing to faster functional recovery (11). The dynamic axial stability offered by the titanium nails minimizes the risk of rotational deformities, ensuring better long-term outcomes (Flynn et al., 2001). Furthermore, TEN's ability to reduce hospital stays and facilitate quicker returns to normal activities underpins its value in pediatric orthopedic care globally (12). In Bangladesh, where road traffic accidents are a leading cause of pediatric trauma, the need for effective and scalable solutions like TEN is paramount. This study aims to evaluate the complications and healing dynamics of TEN in pediatric femoral fractures within this context, addressing the unique challenges posed by resource limitations and high trauma prevalence. By providing statistically robust data and contextual insights, the findings of this research will contribute to optimizing pediatric fracture management in Bangladesh and similar healthcare settings.

## 2. METHODS

This study employed a prospective observational design to evaluate the complications and healing dynamics of Titanium Elastic Nailing (TEN) in pediatric femoral fractures. The study was conducted at the Department of Orthopaedics and Traumatology, Dhaka Medical College Hospital, Bangladesh, over a period of 24 months, from July 2017 to June 2019. The study population included children aged 6 to 14 years with closed, mid-diaphyseal transverse, short oblique, or short spiral femoral fractures with minimal comminution. A purposive sampling technique was used, and a total of 30 patients meeting the inclusion criteria were enrolled. Patients with open

fractures, pathological fractures, infections, or other injuries were excluded. After obtaining written informed consent from the guardians, clinical history and radiographic evaluation were performed preoperatively. Under general or spinal anesthesia, closed reduction and internal fixation with Titanium Elastic Nails were performed using fluoroscopic guidance (C-Arm). Postoperative management included early mobilization with isometric quadriceps exercises initiated on day one, followed by progressive weight-bearing as tolerated. Antibiotics were administered for 3 days

intravenously and transitioned to oral for 7 days, while sutures were removed on postoperative days 12–14. Patients were followed up at 4, 8, 12, and 16 weeks and up to 6 months. Functional and radiological outcomes, including union time, malalignment, limb length discrepancies, and complications, were assessed using Flynn’s scoring system. Data were systematically recorded in pre-designed data sheets and analyzed using SPSS software, with p-values <0.05 considered statistically significant.

**3. RESULTS**

**Table1.** Age Distribution among the participants (N=30)

Age group (years)	Number of patients	Percentage (%)
6–10	11	36.7
11–14	19	63.3
Mean±SD	11.1±1.8	

The study population consisted of children aged 6–14 years. The majority of patients (63.3%) were in the 11–14 age group, while 36.7% were aged 6–10 years. The mean age of

the patients was 11.1±1.8 years, indicating that older children within the studied age range were more commonly affected.

**Table2.** Type of Fracture among the participants (N=30)

Type of fracture	Number of patients	Percentage (%)
Transverse	18	60.0
Oblique	10	33.3
Spiral	2	6.7

Among the patients, transverse fractures were the most common, accounting for 60.0% of cases. Oblique fractures were observed in 33.3% of patients, while spiral fractures were

the least common, comprising only 6.7% of the cases. These findings highlight that simple transverse fractures are predominant in pediatric femoral fractures.

**Table3.** Mechanism of Injury among the participants (N=30)

Mechanism of Injury	Number of patients	Percentage (%)
Motor vehicle accident	14	46.7
Fall from height	11	36.6
Pedestrian hit by motor vehicle	5	16.7

The most frequent cause of injury was motor vehicle accidents, which accounted for 46.7% of cases, followed closely by falls from height at 36.6%. Pedestrian accidents, where children

were hit by motor vehicles, were reported in 16.7% of cases. This distribution reflects the significant contribution of high-energy trauma as a major cause of pediatric femoral fractures.

**Table4.** Duration of Hospital Stay among the participants (N=30)

Duration of hospital stay (weeks)	Number of patients	Percentage (%)
1–2 weeks	7	23.3
2–3 weeks	23	76.7

The majority of patients (76.7%) stayed in the hospital for 2–3 weeks following surgery, while 23.3% had a shorter hospital stay of 1–2 weeks. The relatively short duration of

hospitalization indicates the effectiveness of Titanium Elastic Nailing (TEN) in enabling early mobilization and discharge.

**Table5.** Union Time among the participants (N=30)

Union time (weeks)	Number of patients	Percentage (%)
8–10 weeks	21	70.0
11–12 weeks	9	30.0

Radiological union was achieved in most cases within 8–10 weeks, accounting for 70.0% of patients. The remaining 30.0% of patients

showed fracture union between 11–12 weeks. These findings emphasize the efficiency of

TEN in promoting early fracture healing in pediatric patients.

**Table6.** Complications among the participants (N=30)

Complications	Number of patients	Percentage (%)
Nail tip irritation	2	6.7
Superficial infection	1	3.3
Malalignment	3	10.0
Limb length discrepancy	1	3.3

Complications were observed in a minority of patients. Nail tip irritation was the most common issue, occurring in 6.7% of cases. Malalignment was noted in 10.0% of patients, while superficial infection and limb length

discrepancies each occurred in 3.3% of cases. These complications were minor and manageable, highlighting the safety and reliability of TEN as a treatment method.

**Table7.** Outcome Based on Flynn's Score among the participants (N=30)

Flynn's Score	Number of patients	Percentage (%)
Excellent	23	76.7
Satisfactory	7	23.3
Poor	0	0.0

According to Flynn's scoring system, the majority of patients (76.7%) achieved excellent outcomes, while 23.3% had satisfactory results. Importantly, no patient had a poor outcome, demonstrating the overall success of Titanium Elastic Nailing in achieving functional and clinical recovery for pediatric femoral fractures.

lower limb fractures, particularly in urban environments, while Macha et al. highlighted falls as a major contributing factor in their study conducted in Tanzania(14,15). These results suggest that both high-energy and low-energy mechanisms significantly contribute to pediatric femoral fractures, depending on regional factors such as infrastructure, safety measures, and socioeconomic conditions. The duration of hospital stay observed in our study was relatively short, with 76.7% of patients discharged within 2–3 weeks. This is comparable to findings from Kumar et al., who reported a mean hospital stay of 8.8 days for patients treated with TEN(16). Similarly, Nascimento et al. observed an average hospitalization period of 9.4 days, further emphasizing TEN's role in enabling early mobilization and reducing healthcare burdens(17). These shorter stays are particularly significant in low-resource settings like Bangladesh, where prolonged hospitalization can impose financial strains on families and healthcare systems. The fracture union times observed in this study (8–10 weeks for 70% of patients) are in line with those reported in existing literature. Warade et al. demonstrated union times ranging from 6 to 15 weeks, with most fractures healing within 9 weeks(18). Similarly, Kayaokay and Aktuglu reported a mean union time of 9.0 weeks, reinforcing the consistency of TEN in achieving early radiological union(10). Imam et al. further confirmed that TEN outperformed spica casting in terms of union time, functional recovery, and overall outcomes, supporting its widespread adoption as the gold standard for treating pediatric femoral fractures(19). The complications in this

**4. DISCUSSION**

The present study aimed to evaluate the complications and healing dynamics of Titanium Elastic Nailing (TEN) in pediatric femoral fractures within a low-resource setting. The age distribution observed in this study, where 63.3% of patients were aged 11–14 years, aligns closely with the findings reported by Kayaokay and Aktuglu, who noted a similar predominance of older children in their cohort(10). This trend may be attributed to the increased risk of high-energy trauma, such as road traffic accidents, in older, more active children. Additionally, the predominance of transverse fractures (60.0%) in our study is consistent with findings from Bhuyan and Singh, who also reported transverse fractures as the most common type managed with TEN(13). This can be explained by the biomechanical properties of pediatric bones, which, being more elastic and less brittle, tend to sustain simpler fracture patterns upon impact. In terms of mechanisms of injury, motor vehicle accidents were the leading cause (46.7%), followed by falls from height (36.6%) and pedestrian accidents (16.7%). These findings reflect similar patterns reported globally and in resource-limited settings. Almansouf et al. emphasized motor vehicle accidents as the predominant cause of pediatric



study were minor and easily managed, with nail tip irritation being the most common issue (6.7%). This finding is consistent with studies by Narayanan et al. and Luhmann et al., both of which reported low complication rates associated with TEN(5,12). Narayanan et al. highlighted nail irritation and superficial infections as common complications, occurring in 4–6% of cases, while Luhmann et al. reported similar rates of malalignment and irritation. Notably, our findings align with global studies that emphasize the importance of adhering to technical principles, such as proper nail diameter selection and insertion techniques, to minimize complications (9). The functional outcomes observed in this study were highly favorable, with 76.7% of patients achieving excellent results and 23.3% achieving satisfactory results based on Flynn's criteria. This mirrors the results reported by Suggu et al., who observed excellent outcomes in 73.3% of patients and satisfactory outcomes in 26.7%(20). Similarly, Kumar et al. found superior outcomes in the TEN group compared to hip spica casting, with significantly fewer complications(16). The statistically significant success rate observed in our study ( $p < 0.05$ ) further underscores the efficacy of TEN as a treatment modality for pediatric femoral fractures. Despite the favorable outcomes, a small proportion of patients (10.0%) experienced malalignment, and 3.3% developed limb length discrepancies. These findings are consistent with those of Wall et al., who reported a malunion rate of 6–23%, emphasizing the importance of meticulous technique and appropriate patient selection to minimize such risks(8). Nonetheless, these complications were minor and did not compromise the overall functional recovery of patients. In conclusion, the findings of this study align with global evidence, demonstrating that Titanium Elastic Nailing is a highly effective, minimally invasive, and reliable treatment for pediatric femoral fractures. It promotes early mobilization, reduces hospital stays, and achieves excellent functional and radiological outcomes with minimal complications. These advantages are particularly significant in resource-limited settings, where TEN offers a cost-effective solution for managing pediatric fractures while ensuring optimal outcomes.

### 5. CONCLUSION

Titanium Elastic Nailing (TEN) has proven to be an effective and reliable treatment for pediatric femoral fractures, particularly in resource-limited settings. This study demonstrates that TEN facilitates early mobilization, shortens hospital stays, and ensures high rates of radiological union, with the majority of fractures healing within 8–10 weeks. Functional outcomes, evaluated using Flynn's scoring system, were excellent or satisfactory in all patients, highlighting the technique's clinical success. Furthermore, the low complication rates, such as minor nail tip irritation and superficial infections, emphasize its safety and practicality when performed with meticulous technique. These findings align with global standards, reinforcing TEN's role as a gold-standard treatment modality. Future research should explore strategies to further optimize its application in resource-constrained environments and address specific patient populations with complex fracture patterns.

### LIMITATIONS OF THE STUDY

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

### ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee

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