

Original Research Article

Clinical, radiological and functional outcomes of pediatric diaphyseal long-bone fractures treated with Titanium Elastic Nailing System: a prospective study

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ABSTRACT

Background: Diaphyseal fractures of long bones represent a substantial proportion of paediatric skeletal injuries. The Titanium Elastic Nailing System (TENS) has emerged as a minimally invasive, biologically favourable method of internal fixation that facilitates early mobilization and fracture healing in children. The aim of the study is to assess the clinical, radiological, and functional outcomes of closed diaphyseal long-bone fractures in children aged 5–16 years treated surgically using TENS.

Methods: A prospective interventional study was carried out between July 2020 and August 2022 at Government Medical College, Amravati, Maharashtra, India. Twenty-four children with 31 closed diaphyseal fractures of long bones underwent fixation using titanium elastic nails. Patients were followed at 3, 6, 12, and 24 weeks, and at 9 months postoperatively. Fracture union, alignment, complications, and functional outcomes were evaluated. Final outcomes were graded using Flynn's scoring criteria (5).

Results: The mean patient age was 12.20 ± 2.58 years. The femur was the most frequently involved bone (37.5%), followed by both-bone forearm fractures (29.17%). The mean time to fracture union was 15.12 ± 8.08 weeks, with 54.84% of fractures uniting by 12 weeks. Based on Flynn's criteria (5), excellent outcomes were observed in 90.32% of fractures, satisfactory outcomes in 6.45%, and a poor outcome in 3.23%. Complications were minimal (9.68%), consisting mainly of entry-site irritation and one case of delayed union. No deep infections or implant failures were encountered.

Conclusions: Titanium elastic nailing is a safe and effective treatment modality for paediatric diaphyseal long-bone fractures, providing reliable fracture stabilization, early union, favourable functional outcomes, and a low complication rate.

Keywords: Paediatric fractures, Diaphyseal fractures, Titanium elastic nailing, TENS, Flynn criteria

INTRODUCTION

Fractures in the paediatric population account for nearly one-quarter of all childhood injuries, with long-bone fractures constituting a major proportion.^{1,2} The increasing incidence of road traffic accidents, sports-related trauma,

and high-energy injuries has led to a rising burden of paediatric fractures worldwide.¹

Management of diaphyseal fractures in children aims to achieve stable fixation while preserving periosteal blood supply and protecting the growth plates, thereby allowing

early mobilization and minimizing long-term morbidity. Flexible intramedullary fixation using the Titanium Elastic Nailing System (TENS) provides load-sharing stabilization and functions as an internal splint.³⁻⁶ The elastic properties of titanium nails permit controlled micromotion at the fracture site, which promotes callus formation and accelerates fracture union without compromising physeal integrity.^{5,6} The present study was undertaken to evaluate the clinical, radiological, and functional outcomes of paediatric diaphyseal long-bone fractures treated using TENS in a rural tertiary care setting.

METHODS

This prospective interventional study was conducted in the Department of Orthopaedics at Government Medical College, Amravati, Maharashtra, India from July 2020 to August 2022. Approval was obtained from the Institutional Ethics Committee prior to initiation of the study, and informed written consent was obtained from the parents or legal guardians of all participants.

Inclusion criteria

Children aged 5-16 years with open physis. Closed diaphyseal fractures of long bones. Patients medically fit for surgery. Consent for operative intervention.

Exclusion criteria

Polytrauma patients. Open (compound) fractures.

Sample size

$$n = Z^2 \times p \times q / d^2$$

Where: $p=0.90$ (based on Flynn et al.)⁵, $q=0.10$, $d=0.12$, $Z=1.96$. The calculated sample size was 24. A total of 24 patients with 31 diaphyseal long-bone fractures met the inclusion criteria and were enrolled in the study.

Sampling technique: A convenient sampling technique was used.

Surgical technique and postoperative management

All patients underwent detailed preoperative clinical evaluation and radiographic assessment using anteroposterior and lateral views of the involved limb. The diameter of the titanium elastic nail was selected as approximately 40% of the narrowest medullary canal diameter.⁵ Fracture reduction was attempted by closed methods under image intensifier guidance, with open reduction reserved for cases in which closed reduction was unsuccessful. Titanium elastic nails were inserted through standard entry points appropriate for each bone, taking care to avoid physeal injury. The nails were cut and bent externally to facilitate later removal.

Postoperatively, patients received intravenous antibiotics for three days, followed by oral antibiotics. Limb

immobilization was provided for approximately three weeks, depending on the bone involved. Gradual mobilization of adjacent joints was initiated after immobilization, and weight-bearing was progressed based on radiological evidence of fracture healing.

Follow-up and outcome evaluation

Patients were followed up at 3, 6, 12, and 24 weeks and at 9 months postoperatively. At each visit, clinical assessment and radiographic evaluation were performed to assess fracture union, alignment, and implant position. Functional outcomes at final follow-up were assessed using Flynn's scoring criteria (5), which evaluate limb length discrepancy, malalignment, pain, and complications.

Statistical analysis

Data were compiled in Microsoft Excel and analysed using SPSS version 16.0.

RESULTS

The study population comprised 24 children (17 males and 7 females) with a mean age of 12.20 ± 2.58 years. Femoral fractures were the most common (37.5%), followed by both-bone forearm fractures (29.17%), tibial fractures (20.83%), humeral fractures (8.33%), and isolated ulnar fractures (4.17%).

Table 1: Demographic characteristics of study population.

Variables	Values
Total number of children	24
Males	17
Females	7
Mean age (years)	12.20 ± 2.58

Table 2: Distribution of fracture types.

Type of fractures	Number	%
Femoral fractures	9	29.03
Both-bone forearm fractures	14	45.16
Tibial fractures	5	16.13
Humeral fractures	2	6.45
Isolated ulnar fractures	1	3.23
Total	31	100

Table 3: Fracture union characteristics.

Parameters	Values
Mean duration of union (weeks)	15.12 ± 8.08
Union ≤ 12 weeks (%)	17 (54.84)
Union > 12 weeks (%)	7 (45.16)
Angular deformity $> 10^\circ$ (%)	1 (3.23)

Table 4: Functional outcome according to Flynn's criteria.

Outcomes	N	%
Excellent	28	90.32
Satisfactory	2	6.45
Poor	1	3.23

Table 5: Functional complication according to Flynn's criteria.

Complications	N	%
Entry-site skin irritation	2	6.45
Delayed union with mild angular deformity	1	3.23
Superficial infection	0	0
Deep infection	0	0
Implant failure	0	0
Total complications	3	9.68



Figure 1: (a) Pre-operative anteroposterior radiograph of the pelvis with bilateral femora showing a left-sided diaphyseal femoral fracture in a skeletally immature patient, (b) immediate post-operative anteroposterior radiograph demonstrating fixation of the left femoral shaft fracture using titanium elastic nails with satisfactory alignment and preservation of the growth plates and (c) follow-up anteroposterior radiograph at 6 months showing radiological union of the fracture with maintained alignment and evidence of remodelling.



Figure 2: Clinical photograph at follow-up showing the patient in supine position with equal limb length and no evidence of rotational or angular deformity.



Figure 3: Clinical photograph showing the patient sitting cross-legged at final follow-up, reflecting good functional recovery of the affected limb.

The mean duration for fracture union was 15.12 ± 8.08 weeks. Union was achieved within 12 weeks in 17 fractures (54.84%). Angular deformity greater than 10 degrees was observed in one fracture (3.23%).

According to Flynn's criteria (5), excellent outcomes were achieved in 28 fractures (90.32%), satisfactory outcomes in two fractures (6.45%), and a poor outcome in one fracture (3.23%).

Complications were observed in three fractures (9.68%). Entry-site skin irritation occurred in two cases (6.45%), while delayed union with mild angular deformity was noted in one case (3.23%). No superficial or deep infections and no implant failures were reported.

DISCUSSION

The findings of the present study demonstrate that titanium elastic nailing is an effective modality for the management of paediatric diaphyseal long-bone fractures, yielding favourable clinical, radiological, and functional outcomes.

The high percentage of excellent results according to Flynn's criteria is comparable to previous studies by Sankar et al, Furlan et al, and other investigators, who similarly reported high union rates, minimal malalignment, and excellent functional recovery following titanium elastic nailing.⁵⁻¹¹

Biomechanically, titanium elastic nails function on the principle of elastic stable intramedullary fixation. Their flexible, prebent design creates balanced opposing forces within the medullary canal, resulting in three-point fixation that stabilizes the fracture.⁵ The load-sharing nature of the construct allows controlled micromotion at the fracture site, which stimulates external callus formation and promotes secondary bone healing.⁶

CONCLUSION

Titanium elastic nailing is a safe, effective, and minimally invasive method for the treatment of paediatric diaphyseal long-bone fractures. It provides reliable fracture stabilization, promotes early mobilization, and is associated with excellent functional outcomes and a low incidence of complications in children aged 5–16 years.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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