Original Article | Journal of Orthopaedic Case Reports 2026 November:16(11):Page 373-378

Functional Outcome of Titanium Elastic Nailing in Pediatric Lower-Limb Fractures: A Prospective Study

Raja Velayudham[1], Madhavan Manjini[2], Manikandan Kumarasamy[3], Pragash Mohanen[3]

Learning Point of the Article:

Titanium elastic nailing provides safe and faster recovery with early union in pediatric age group, making it an ideal treatment option in pediatric lower-limb fractures.

Abstract

Introduction: Pediatric femoral and tibial shaft fractures are common injuries with evolving treatment trends toward operative management. Titanium elastic nailing system (TENS) has gained popularity due to its minimally invasive nature and favorable outcomes. This study evaluates the clinical and radiological outcomes of TENS in pediatric lower-limb fractures.

Materials and Methods: A hospital-based prospective analytical study was conducted on 15 children aged 5–16 years with displaced diaphyseal fractures of the femur and tibia between November 2019 and April 2021. Patients underwent TENS (retrograde for femur and antegrade for tibia). Follow-up assessments were performed at regular intervals up to 6 months, evaluating fracture union, range of motion, and complications.

Results: The mean age was 8.5 years, with a male predominance (66.7%). The average time to radiological union was 10.1 ± 1.5 weeks for femur fractures and 9.4 ± 1.5 weeks for tibial fractures, with no significant difference ($P > 0.05$). Complications were minimal, with 80% of patients showing no complications. Limb length discrepancy (1 cm), knee stiffness due to nail irritation, and malalignment were noted in a few cases. According to Flynn criteria, 80% of patients had excellent outcomes, 13.3% satisfactory, and 6.7% poor outcomes.

Conclusion: TENS is a safe, effective, and minimally invasive method for treating pediatric femoral and tibial shaft fractures. It provides stable fixation, promotes early union and mobilization, and is associated with low complication rates, making it as preferred treatment modality.

Keywords: Pediatric femoral and tibial shaft fractures, titanium elastic nails, fracture union.

Introduction

Femoral fractures in the pediatric age group account for about 1.6% of all bony injuries and are more common in males than females with an incidence of 2.6:1, respectively [1]. Pediatric tibial shaft fractures are the 2nd most common injuries after femoral fractures with their peak incidence between 10 and 14 years of age with a ratio of 2:1 for males to females, respectively [2]. For the past 2 decades, there has been an increased trend towards operative treatment in children using external fixation, locked intramedullary nailing, flexible intramedullary nails, and submuscular plate fixation for lower-limb fractures [3]. Treatment options for femoral shaft fractures for infants and up to 2 years of age are Pavlik harness, hip spica cast, and traction followed by spica cast. For children up to 5 years of age, treatment modalities are early spica cast, traction followed by spica cast, very rarely external fixation, and flexible intramedullary nails [4]. Most of the tibial diaphysis fractures were managed conservatively by applying a long leg cast. Even for completely

Access this article online

Website: www.jocr.co.in

DOI: https://doi.org/10.13107/jocr.2026.v16.i11.8502

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Dr. Raja Velayudham


Dr. Madhavan Manjini


Dr. Manikandan Kumarasamy


Dr. Pragash Mohanen

[1]Department of Orthopaedics, Sri Venkateshwaraa Medical College Hospital and Research Centre, Ariyur, Puducherry, India,
[2]Department of Orthopaedics, Aarupadai Veedu Medical College and Hospital, Puducherry, India,
[3]Department of Orthopaedics, Sri Manakula Vinayagar Medical College and Hospital, Puducherry, India.

Address of Correspondence:
Dr. Raja Velayudham,
Department of Orthopaedics, Sri Venkateshwaraa Medical College Hospital and Research Centre, Ariyur, Puducherry, India.
E-mail: vmraja92@gmail.com

Submitted: 02/08/2026; Review: 26/09/2026; Accepted: October 2026; Published: November 2026

DOI: https://doi.org/10.13107/jocr.2026.v16.i11.8502

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displaced diaphyseal tibia fractures, conservative management is enough to achieve the union. Considering the physical and psychosocial burden on the child, various treatment modalities are now being utilized. These recent advances have reduced the family burden of care during the recovery period as well as early disabilities. Among these treatment modalities, flexible intramedullary nails have advantages over others because the chances of pin tract infection, refracture, physeal injuries, and excessive periosteal stripping are less common.

Aim

The objective of this study was to evaluate the functional outcome of titanium elastic nailing (TENS) system in pediatric lower-limb fractures.

Materials and Methods

This is a hospital-based prospective analytical study conducted in the tertiary care center after ethical committee approval (No: outward/SMVMCH-ECO/AL/348/2019). Fifteen children of age group between 5 and 16 years with closed lower-limb fractures presenting to the hospital from November 2019 to April 2021 were recruited for elastic nailing. Patients were aged up to 16 years with displaced diaphyseal fractures of the femur and tibia and type 1 and type 2 compound diaphyseal fractures of the femur and tibia. Failed conservative treatments were included in the present study. Patients weighing more than 50 kg, fractures linked to neurovascular injuries, and type 3 compound diaphyseal fractures of the tibia and femur were eliminated. The Flynn et al. formula (diameter of nail = width of the narrowest point of medullary canal on anteroposterior and lateral views ×0.4 mm) was used to estimate nail diameter before surgery [5]. Of the fifteen youngsters, seven had tibial diaphyseal fractures and eight had femur shaft fractures. Seven patients with tibial diaphyseal fractures had antegrade nailing, while all eight patients with femur fractures received retrograde nailing. High groin slabs were used for external immobilization if reduction proved insufficient. After that, the patient was confined in a cast and not allowed to bear any weight for a month.

Exercises for knee range of motion and quadriceps were initiated early for tibial fractures. An X-ray was obtained after a month, and partial weight bearing was initiated once the callus was confirmed on the radiograph. Patients were evaluated clinically and radiologically at intervals of 2 weeks, 6 weeks, 3 months, and 6 months. They were also monitored for complications, range of motion, and union. The Flynn et al. grading method was used to analyze the results.

All patients were made to weight bear after 2 months of surgery with four cortices united on X-ray. Nails were removed after bone remodeling occurred between 9 months and 12 months. The independent and dependent variables were compared using Chi-square test for categorical variables and either Mann–Whitney U test or Kruskal–Wallis test for numerical

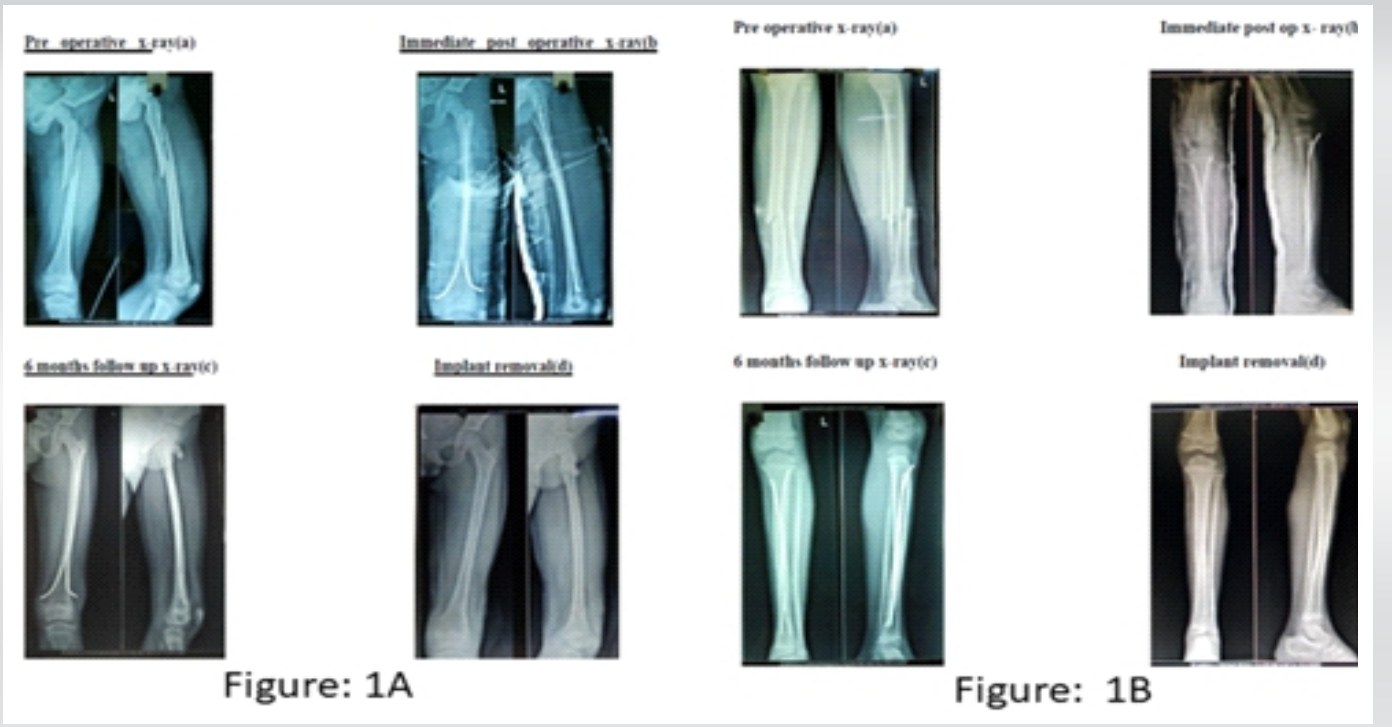


Figure 1a&b: Complete union of femur fracture.

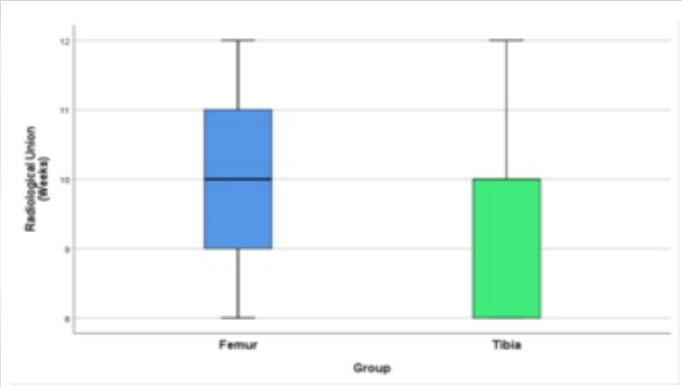


Figure 2: Time for radiological union (weeks) among the fracture groups (n = 15).

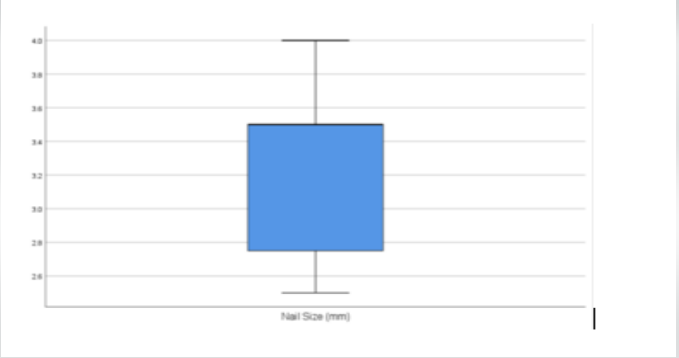


Figure 3: Distribution of nail size among the patients (n = 15).

variables. The correlation between two numerical variables was compared using Pearson's correlation coefficient. For all the statistical tests, a $P < 0.05$ was considered significant.

Results

The results of the study are presented in the form of Tables 1, 2, 3, 4, 5 and Figs. 1, 2, 3, 4, and master chart. Among the fifteen children, 10 were males and 5 were females; the mean age of study participants was 8.5 years. The distribution of gender, side of fracture, type of fracture (open/closed), mode of injury, and pattern of fracture were not significant as tested by the test of proportions. Majority of the patients (53%) were operated on within the 2nd day of injury with an average duration of 3 days.

The average time for radiological union was 10.1 (±1.5) weeks for femur fractures and 9.4 (±1.5) weeks for tibial fractures. There was no significant difference ($P > 0.05$) in the time for radiological union among the fracture groups as calculated by Mann–Whitney U test.

Only one patient out of fifteen showed a limb length discrepancy (shortening of 1 cm). Due to nail irritation, one patient experienced knee stiffness with a range of motion of 0–20°. Nine of the fifteen patients began complete weight-bearing walking after 12 weeks. Two patients had valgus angulation, one patient had greater anterior femur angulation, and about 87% of patients achieved fracture union without angulation. Thirteen percent of the patients had adequate results, and over 80% had exceptional results. Just one patient (7%) experienced a bad outcome.

There was no significant association ($P > 0.05$) between age and the time for radiological union among the patients as tested by Chi-square test. There was no significant association ($P > 0.05$) between the age and the outcome among the patients. The average canal diameter and nail size were 9.1 (1.5) and 3.2 (0.5) mm. The mean and percentage of nail occupancy were 73.9 (8.5%).

The mean percentage of nail occupancy among patients with excellent, poor, and satisfactory outcomes was 75.4 (8.6), 70.0, and 66.3 (5.3%). There was no statistically significant difference ($P > 0.05$) in the distribution of nail as calculated by Kruskal–Wallis test [6]. All patients' nail removal was done between 9 months and 1 year.

Table 1: Flynn *et al.* scoring system

Parameter	Excellent	Satisfactory	Poor
Limb length inequality	<1 cm	<2 cm	>2 cm
Malalignment	Up to 5°	5–10°	>10°
Pain	None	None	Present
Complications	None	Minor	Major complications and or lasting morbidity

Discussion

Pediatric shaft fractures of the femur and tibia are treated by various methods such as traction, traction followed by spica cast, immediate spica cast, long leg cast, internal fixation with submuscular plate osteosynthesis, external fixator application, and flexible intramedullary nailing. For the past 20 years, there has been an increased trend toward operative treatment because

Table 2: Complications among the patients post-procedure (*n* =15)

Complications	Number	Percentage
Nil	12	80
Knee stiffness and angulation	1	6.7
Nail irritation	1	6.7
Malunion	1	6.7

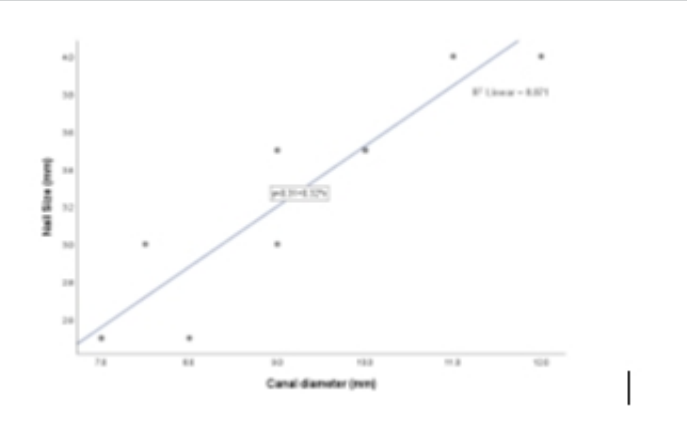


Figure 4: Scatter plot of canal diameter and nail size among the patients (n = 15).

Table 3: Outcome among the patients following the procedure (*n* =15)

Outcome post-procedure	Number	Percentage
Excellent	12	80
Satisfactory	2	13.3
Poor	1	6.7

Table 4: Comparison of the results

Outcome	Flynn et al.	Ligier et al.	Goodwin et al.	Our study
No. of cases	48	128	19	15
Knee stiffness	–	13	–	1
Limb length discrepancy	–	7	–	1
Angulation	–	–	2 (>10°)	–
Malunion	2	14	–	–

of early mobilization and rehabilitation. Many studies and literature support the surgical treatment using titanium elastic nails as the best and safest method in treating pediatric lower-limb fractures.

Caglar et al. examined the average time to union for plating and flexible nail groups in femur shaft fractures in a randomized controlled trial [7]. Plate groups took 7.7 months to unite, while flexible nail groups took 4 months. The average union time for a femur fracture is 10 weeks, while the average union time for a tibia fracture is 8 weeks, according to the results of our study (P = 0.478). This demonstrated a flexible nailing technique for fracture treatment that minimized soft tissue dissection, prevented periosteal stripping, and conserved the fracture hematoma.

Two incidences of knee stiffness caused by nail irritation at the entrance site were described by Flynn et al. in their prospective study of 234 patients treated with titanium elastic nails for femur shaft fractures [5]. The most frequent side effect of titanium nails for femur fractures is nail irritation at the entry site, which accounts for 7–40% of cases [7]. Similarly, out of eight femur shaft fractures treated with titanium elastic nails, we found one incidence of knee stiffness as a result of nail irritation of the soft tissue. Occurrences of discomfort at the nail insertion site were reported in a retrospective study by Narayanan et al. on 79 patients with femur shaft fractures, with an overall acceptable result [8]. Six of the eight femur fractures in the present study had great outcomes, one was satisfactory, and one was unsatisfactory. Knee stiffness developed as a result of nail irritation of soft tissue, which might have been avoided with proper titanium nail clipping. An earlier study by Khazzam et al. documented 14 problems, including two delayed unions, three refractures, three occurrences of malalignment, five irritated nail tips, and one nail migration [9]. In a similar way, three patients in our study experienced angulation, nail tip discomfort, and malunion.

Table 5: Master chart of the study

S. No.	Age	Sex	Mechanism of injury	Type of fracture	Associated injuries	Trauma to surgery (days)	Closed/ Open reduction	Side	Canal diameter (mm)	Nail size (mm)	LLD	Range of motion (knee/hip)	Angulation (AP view)	Bowing (lateral view)	Radiological union (weeks)	Full weight bearing (weeks)	Complications	Nail removed	Timing of nail removal (months)	Score	Group
1	13	M	Accidental fall	Short oblique	-	3	CR	RIGHT	11	4	-	FULL	-	-	12	12	-	YES	12	EXCELLENT	Femur
2	7	M	Accidental fall	Long oblique	-	2	CR	LEFT	9	3.5	-	FULL	-	-	8	12	-	YES	12	EXCELLENT	Femur
3	11	M	RTA	Transverse	-	2	CR	RIGHT	10	3.5	-	0–20°	-	-	12	12	Knee stiffness, nail irritation	NO	-	SATISFACTORY	Femur
4	10	F	Accidental fall	Short oblique	-	2	CR	LEFT	10	3.5	-	FULL	-	-	10	12	-	NO	-	EXCELLENT	Femur
5	13	M	Accidental fall	Transverse	0	2	CR	RIGHT	10	3.5	-	FULL	-	-	10	12	-	NO	-	EXCELLENT	Femur
6	9	F	RTA	Transverse	-	1	CR	RIGHT	10	3.5	-	FULL	-	-	10	12	-	YES	12	EXCELLENT	Femur
7	12	F	RTA	Short oblique	-	2	CR	RIGHT	10	3.5	Shortening 1 cm	FULL	-	20°	10	12	Angulation	YES	12	POOR	Femur
8	5	F	Accidental fall	Short oblique	-	2	CR	LEFT	9	2.5 / 3.0	-	FULL	-	-	8	12	-	YES	-	EXCELLENT	Femur
9	5	M	RTA	Transverse	Fracture BB leg	1	CR	RIGHT	7	2.5	-	FULL	-	-	8	10	-	YES	8	EXCELLENT	Tibia
10	5	F	RTA	Short oblique	Fracture BB leg	2	CR	RIGHT	7	2.5	-	FULL	-	-	8	10	-	YES	18	EXCELLENT	Tibia
11	12	M	Accidental fall	Short oblique	Fracture BB leg	5	CR	LEFT	12	4	-	FULL	-	-	12	12	-	YES	10	EXCELLENT	Tibia
12	8	M	RTA	Short oblique	Fracture BB leg	1	CR	RIGHT	8	2.5	-	FULL	6° valgus	-	10	10	-	YES	12	SATISFACTORY	Tibia
13	5	M	RTA	Short oblique	Fracture BB leg	2	CR	LEFT	7.5	3	-	FULL	3° valgus	-	10	10	-	YES	10	EXCELLENT	Tibia
14	8	M	RTA	Short oblique	Fracture BB leg	3	CR	RIGHT	9	3.5	-	FULL	-	-	10	10	-	YES	12	EXCELLENT	Tibia
15	5	M	Accidental fall	Short oblique	Fracture BB leg	8	CR	LEFT	7	2.5	-	FULL	-	-	8	10	-	YES	10	EXCELLENT	Tibia

Flynn et al. reported no limb length discrepancy of not more than 1 cm in 49 patients with femur shaft fracture treated by titanium nails, but in our study, out of 8 patients with femur fracture, one patient had excessive femur anterior bowing and shortening of 1 cm [5]. Ideally, titanium nails should have three-point fixation in fracture reduction; this principle of fracture reduction failed in our patient which led to shortening and anterior bowing.

In 60% of instances, solitary tibial shaft fractures with an intact fibula result in varus angulation. Two of the 19 patients with tibial shaft fractures who had a mean follow-up of 13 months in the retrospective analysis by Goodwin et al. had angulation more than 10° [10]. The current study findings demonstrated that none of the seven tibial shaft fractures had more than 5° of valgus angulation since each of the seven tibial shaft fractures had corresponding fibula fractures.

In the earlier study by Sankar et al. reported of 19 patients with tibial shaft fractures, 11 found no limb length discrepancy and permitted full weight bearing after an average of 8.65 weeks; in our study, weight bearing was permitted after 3 months for femur shaft fractures and 10 weeks for tibial shaft fractures [11]. All of the patients in the present study were fixed with higher nail diameters that occupied more than 70% (interquartile range 70–77.8%) of the medullary canal, as described by Green et al. To preserve axial, rotational, flexural, and torsional stability, we thereby adhered to the symmetrical bracing principle [12].

Conclusion

A titanium elastic nail is the method of choice in pediatric lower-limb fractures due to its advantages over other methods. TEN system avoids excessive periosteal stripping with minimal soft tissue damage and preserves the fracture hematoma. Titanium nails provide micromotion at the fracture site, abundant callus formation, stability, and early mobilization. TENS is an easier and promising procedure with minimal complications, earlier post-operative rehabilitation, and better outcomes than any other procedure.

Clinical Message

Titanium elastic nails provide faster union with better psychosocial outcomes, which is a minimally invasive and functionally superior method for managing pediatric lower-limb fractures.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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Conflict of Interest: Nil
Source of Support: Nil

Consent: The authors confirm that informed consent was obtained from the patient for publication of this article

How to Cite this Article

Velayudham R, Manjini M, Kumarasamy M, Mohanen P. Functional Outcome of Titanium Elastic Nailing in Pediatric Lower-Limb Fractures: A Prospective Study. J Orthop Case Rep 2026 November;16(11):373-378. doi: 10.13107/jocr.2026.v16.i11.8502.