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Original Research Article

A STUDY OF OUTCOME OF LONG BONE FRACTURES IN PAEDIATRIC PATIENTS MANAGED WITH TITANIUM ELASTIC NAILING SYSTEM IN TERTIARY CARE HOSPITAL

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ABSTRACT

Background: Titanium Elastic Nailing System (TENS) has become a preferred minimally invasive method for stabilizing paediatric diaphyseal long bone fractures, offering balanced flexible fixation that preserves periosteal blood supply and allows early mobilization. This study assessed short-term functional and radiological outcomes, pain trajectory, malalignment, limb length discrepancy (LLD), and complications following TENS fixation in a tertiary care setting.

Materials and Methods: A prospective cohort study was conducted over 12 months in the department of orthopaedics of a tertiary care hospital. Institutional ethics committee approved the study and informed and written consent was obtained from guardians of the cases. Children with simple, minimally displaced diaphyseal long bone fractures treated with TENS were included in this study on the basis of a predefined inclusion and exclusion criteria. Convenience sampling yielded 25 patients (sample size based on pilot proportion). Baseline demographics, injury mechanism, fracture pattern and final diagnosis were documented. Follow-up evaluations were performed postoperatively, at 1 month, and at 3 months. Functional outcomes were graded using Flynn et al TENS scoring system. Radiographs were assessed for alignment and union. Complications, pain, malalignment grades, and LLD were documented. SSPS 29.0 was used for statistical analysis and p value less than 0.05 was considered as statistically significant.

Results: Mean age was 8.96±2.91 years; 68% were 5–10 years and 60% were male. Self-fall was the commonest mechanism (80%). Transverse fractures predominated (80%); femoral shaft fractures formed the largest diagnostic group. Malalignment <5° was maintained in 76% postoperatively and 80% at 3 months, with no significant change over follow-up ($p=0.725$). Pain decreased significantly to 0% at 3 months ($p<0.0001$). Minor complications occurred in 20% at 1 and 3 months ($p=0.0139$). Radiologically, 96% achieved union by 3 months. Malunion was reported in 1 (4%) patient. Mean LLD remained small (0.61–0.65 cm across intervals). Excellent functional outcomes were seen in 80% at 3 months.

Conclusion: In selected paediatric diaphyseal long bone fractures, TENS provided reliable alignment control, rapid pain resolution, high union rates, minimal LLD, and predominantly excellent short-term functional outcomes with low minor complication rates.

Keywords: Pediatrics long bone Fractures; Femur Fractures; Intramedullary Nailing; Treatment Outcome.

INTRODUCTION

The management of paediatric long bone fractures has evolved significantly over the years. Historically, conservative treatment with plaster casts and traction was the standard of care.[1] However, advancements in Orthopaedic surgery, particularly in fracture fixation techniques, have led to the widespread adoption of intramedullary nailing methods such as the Titanium Elastic Nailing System (TENS) for paediatric diaphyseal fractures.[2]

Paediatric fractures differ from adult fractures due to the unique biomechanical and biological characteristics of growing bones. Children's bones have a greater capacity for remodelling, which influences treatment decisions. Additionally, the presence of open growth plates (physes) makes paediatric fractures distinct from adult fractures often requiring specialized treatment to prevent growth disturbances.[3] Intramedullary fixation, particularly using TENS, has gained prominence because it provides stable fixation while preserving the biological properties of the bone. The traditional approach to managing paediatric fractures involved traction and casting, with surgical intervention reserved for severe cases. However, concerns over prolonged immobilization, joint stiffness, and malunion led to a paradigm shift in favour of internal fixation techniques. The concept of TENS was first introduced in the early 1980s in France, demonstrating favourable outcomes for shaft of long diaphyseal fractures in children. Since then, TENS has become the preferred method for treating various diaphyseal fractures, including those of the femur, tibia, humerus, and radius-ulna.[4]

TENS operates on the principle of balanced flexible fixation, providing sufficient stability while allowing controlled micromotion at the fracture site which promotes callus formation and rapid healing. Compared to other fixation procedures such as external fixation or plating TENS is minimally invasive preserves periosteal blood supply and decreases soft tissue damage making it an ideal choice for paediatric long bone fractures.[5]

TENS is primarily indicated for simple minimally displaced diaphyseal fractures in children aged 5 to 16 years. It is particularly effective for femoral shaft fractures which have historically posed a challenge due to difficulties in maintaining alignment with nonoperative treatment. Other indications include fractures of the tibia, humerus, radius, and ulna, provided that the fracture pattern is amenable to flexible intramedullary fixation.[6]

The advantages of TENS include a shorter hospital stay, early mobilization, reduced risk of malunion and a lower rate of complications compared to external fixation and rigid intramedullary nailing. Additionally, since TENS is a minimally invasive procedure it results in smaller surgical scars reduced postoperative pain and improved patient compliance.[7] The ability to remove implants with relative ease also contributes to its widespread acceptance among Orthopaedic surgeons. Despite its advantages, TENS is associated with certain complications, which need careful consideration. The most commonly reported complications include irritation at the nail entry site, hardware prominence and occasional loss of reduction in unstable fractures. Studies have also reported cases of limb length discrepancy, malalignment, and infection although these are relatively rare. One of the critical aspects of using TENS is patient selection.[8] While it is highly effective for stable diaphyseal fractures it may not be suitable for complex fractures, comminuted fractures or fractures with significant soft tissue injury. In such cases, alternative fixation methods, such as rigid intramedullary nails, plates or external fixators may be preferred.[9]

Assessing the outcome of TENS fixation requires a combination of functional and radiological evaluations. Flynn et al Developed a scoring system specifically for assessing the functional outcome of paediatric fractures treated with flexible intramedullary nailing. This scoring system considers parameters such as LLD, malalignment, pain, and complications, categorizing results as excellent, satisfactory, or poor. In cases of femoral fractures, rigid intramedullary nailing is typically reserved for older adolescents due to concerns over growth plate damage.[10] TENS, on the other hand, is well-suited for younger children, offering a balance between stability and flexibility that facilitates bone healing without compromising growth. Despite the extensive literature on TENS, there remains a need for region-specific data, particularly in the context of tertiary care hospitals. This study was conducted to assess the outcomes of long bone fractures in paediatric patients treated with TENS in a tertiary care setting, focusing on functional recovery, complication rates, and patient satisfaction. Given the increasing use of TENS worldwide, understanding its efficacy in different patient populations is crucial for optimizing treatment protocols.

MATERIALS AND METHODS

This prospective cohort study was conducted in a tertiary care hospital with the objective of evaluating functional outcomes following Titanium Elastic Nailing System (TENS) fixation in paediatric patients presenting with diaphyseal fractures of long bones. Institutional ethics committee approved the study and informed and written consent was obtained from legal guardians of the children. The study was carried out over a total period of twelve months. Patient enrolment and clinical data collection were completed within the first nine months, during which eligible children were assessed, operated and followed up at predefined postoperative intervals. The remaining three months were reserved for compilation of records, verification of variables, and statistical analysis of clinical and radiological

outcomes. Convenience sampling was employed for case selection during the study period. Sample size was estimated using pilot observation data where the expected proportion (p) was calculated as 20/63 (p = 0.32). With a 95% confidence level (Z = 1.96) and absolute precision (d = 0.2), the minimum required sample size was computed using the formula $n = Z^2p(1-p)/d^2$, yielding approximately 21, and was rounded up to 25 to improve adequacy and account for possible losses to follow-up.

The study population comprised paediatric-age patients with shaft fractures of long bones who fulfilled eligibility criteria and underwent operative fixation with TENS during the study period. Potential patients were identified from orthopaedic emergency and inpatient department. Eligibility was confirmed through clinical assessment as well as on the basis of radiographic evaluation. Baseline variables including demographic characteristics, mode of injury, side involved and pattern of fractures were recorded on a structured proforma. Preoperative assessment included documentation of soft-tissue status, neurovascular examination and radiological characterization of the fracture to ensure appropriateness for elastic stable intramedullary nailing.

All enrolled patients underwent fixation with titanium elastic nails. Standard principles of elastic stable intramedullary nailing were followed in all cases. Postoperatively, patients were monitored for early as well as late complications. These complications included wound-related issues, infections, implant-related signs and symptoms, malalignment, pain and limb length discrepancy where applicable. Follow-up assessments were done at 1 month and 3 months postoperatively. Outcomes were evaluated using predefined study variables that included range of motion of the relevant joints, postoperative infection and complications. Functional outcome assessment was done by using the Flynn et al. TENS scoring system. At each follow-up, a standardized clinical examination was performed, radiographs were reviewed where indicated, and Flynn scoring was applied to categorize the result. All findings were documented in a proforma to analyse variability in recovery and complication profiles across patients.

Statistical analysis was performed using SPSS version 29 for inferential analysis. Categorical variables such as age group, sex, mode of injury, side, fracture pattern, diagnosis, complications, and outcome categories were summarized as frequency and percentages. Fisher's exact test was applied to assess significant differences in malalignment, pain, complications, and overall outcome between the immediate postoperative period and the 3-month follow-up interval. A p value of <0.05 was considered statistically significant for all comparisons.

Inclusion criteria

- Parent/guardian who have given written assent for treatment as per institutional protocol.
- Patients undergoing TENS in paediatric age group.
- Patients with simple and minimally displaced diaphyseal long bone fractures.

Exclusion criteria

- Parents' refusal to give informed and written consent to be part of study.
- Patients with compound diaphyseal long bone fractures.

RESULTS

The analysis of the distribution of demographic variables, side of injury and type of fractures in the study participants showed that the majority of children belonged to the 5–10 years age group accounting for 17 cases (68%), while 8 patients (32%) were in the 11–15 years age group. With respect to sex distribution, males were more commonly affected with 15 cases (60%) compared to females with 10 cases (40%). Regarding the mode of injury, self-fall was the predominant cause seen in 20 patients (80%), whereas road traffic accidents (RTA) accounted for 5 cases (20%). The side of injury was almost equally distributed, with right-sided fractures slightly more common in 13 cases (52%) compared to left-sided fractures in 12 cases (48%). In terms of fracture pattern, transverse fractures were the most frequent type observed in 20 patients (80%), followed by oblique fractures in 4 patients (16%) and spiral fractures in 1 patient (4%) [Table 1].

Table 1: Distribution of Demographic Variables, side of injury and type of fractures in Study Participants (n = 25)

Variable	Category	Frequency (n)	Percent (%)
Age group (years)	5–10	17	68
	11–15	8	32
	Total	25	100
Sex	Female	10	40
	Male	15	60
	Total	25	100
Mode of injury	RTA	5	20
	Self-fall	20	80
	Total	25	100
Side of injury	Left	12	48
	Right	13	52
	Total	25	100
Type of Fracture	Oblique	4	16
	Spiral	1	4

	Transverse	20	80
	Total	25	100

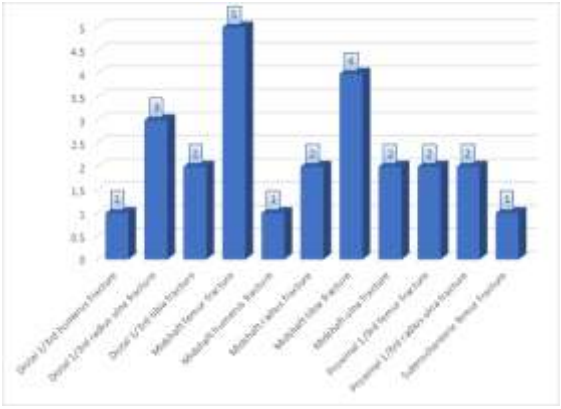

Figure 1: Diagnosis Distribution of Paediatric Patients with Long Bone Fractures

The analysis of the diagnosis distribution of paediatric patients with long bone fractures showed that midshaft femur fractures were the most common diagnosis, observed in 5 cases (20%), followed by midshaft tibia fractures in 4 cases (16%). Distal one-third radius-ulna fractures accounted for 3 cases (12%). Distal one-third tibia fractures, midshaft radius fractures, midshaft ulna fractures, proximal one-third femur fractures, and proximal one-third radius-ulna fractures were each noted in 2 cases (8%) respectively. The least common fractures were distal one-third humerus fractures, midshaft humerus fractures, and subtrochanteric femur fractures, each seen in 1 case (4%). Overall, femoral shaft fractures constituted the largest proportion of cases in the present study [Figure 1].

The analysis of the distribution of malalignment grades at post-operative period and during follow-up showed that the majority of patients had malalignment of less than 5° at all time intervals. 19 cases (76%) in the immediate post-operative period, 19 cases (76%) at 1 month, and 20 cases (80%) at 3 months follow-up. Malalignment between 5–10° was observed in 6 patients (24%) post-operatively, which decreased to 5 patients (20%) at 1 month and further to 4 patients (16%) at 3 months. Malalignment greater than 10° was not seen in the immediate post-operative period (0%), but was noted in 1 patient (4%) at 1 month and persisted in 1 patient (4%) at 3 months. The difference in malalignment distribution across the follow-up periods was statistically not significant ($p > 0.05$) [Table 2].

Table 2: Distribution of Malalignment Grades at Post-Operative, 1 Month, and 3 Months Follow-Up (n = 25)

Malalignment (°)	Post-Operative		1 month follow up		3 Months follow up		P value
	Frequency	%	Frequency	%	Frequency	%	
<5	19	76	19	76	20	80	0.725 Not Significant
5–10	6	24	5	20	4	16	
>10	0	0	1	4	1	4	
Total	25	100	25	100	25	100	
Test used: Fisher's exact test							

The analysis of the distribution of pain in post-operative period, 1 month, and 3 months follow-up showed that immediately after surgery, all 25 patients (100%) experienced pain. At 1 month follow-up, pain was absent in the majority of patients (96%), while only 1 patient (4%) reported persistent pain. By 3 months follow-up, pain was completely absent in all 25 patients (100%). The reduction in pain over the follow-up period was statistically highly significant ($p < 0.0001$) [Table 3].

Table 3: Distribution of Pain Status at Post-Operative, 1 Month, and 3 Months Follow-Up (n = 25)

Pain	Post-Operative		1 month follow up		3 Months follow up		P value
	Frequency	%	Frequency	%	Frequency	%	
Absent	0	0	24	96	25	100	<0.0001 Significant
Present	25	100	1	4	0	0	
Total	25	100	25	100	25	100	
Test used: Fisher's exact test							

The analysis of the distribution of post-operative complications at post-operative, 1 month, and 3 months follow-up showed that immediately after surgery, all patients had no complications (100%). At 1 month follow-up, 20 patients (80%) had no complications whereas 5 patients (20%) reported minor complications. A similar distribution was observed at 3 months follow-up where 80% patient didn't report any complication. The difference in complication rates across the follow-up periods was statistically significant ($p < 0.05$) [Table 4].

Table 4: Distribution of Post-Operative Complications at Post-Operative, 1 Month, and 3 Months Follow-Up (n = 25)

Complication	Post-Operative		1 month follow up		3 Months follow up		P value
	Frequency	%	Frequency	%	Frequency	%	
None	25	100	20	80	20	80	0.0139 Significant
Minor	0	0	5	20	5	20	
Total	25	100	25	100	25	100	
Test used: Fisher's exact test							

The analysis of the distribution of functional outcome results at post-operative, 1 month, and 3 months follow-up showed that the majority of patients had excellent results at all time intervals, with 19 cases (76%) in the immediate post-operative period, 19 cases (76%) at 1 month, and 20 cases (80%) at 3 months follow-up. Satisfactory outcomes were observed in 6 patients (24%) post-operatively, which decreased to 5 patients (20%) at 1 month and further to 4 patients (16%) at 3 months. Poor results were not seen in the immediate post-operative period (0%), but were noted in 1 patient (4%) at 1 month and persisted in 1 patient (4%) at 3 months. Fisher's exact test revealed a p value of 0.725, indicating that the difference in functional outcomes across the follow-up periods was statistically not significant ($p > 0.05$) [Table 5].

Table 5: Distribution of Functional Outcome Results at Post-Operative, 1 Month, and 3 Months Follow-Up (n = 25)

Result	Post-Operative		1 month follow up		3 Months follow up		P value
	Frequency	%	Frequency	%	Frequency	%	
Poor	0	0	1	4	1	4	0.725 Not Significant
Satisfactory	6	24	5	20	4	16	
Excellent	19	76	19	76	20	80	
Total	25	100	25	100	25	100	
Test used: Fisher's exact test							

The analysis of the radiological outcome distribution of paediatric long bone fractures post-operatively, at 1 month, and at 3 months follow-up showed that immediately post-operatively, alignment was maintained in all 25 patients (100%). At 1 month follow-up, the majority of cases were aligned and uniting, accounting for 24 patients (96%), while 1 patient (4%) was not aligned but showed signs of union. At 3 months follow-up, complete union was achieved in 24 patients (96%), whereas 1 patient (4%) had malunion. Overall, the radiological findings demonstrate progressive fracture healing with a high rate of satisfactory alignment and union over the follow-up period [Table 6].

Table 6: Radiological Outcome Distribution of Paediatric Long Bone Fractures Post-Operatively, 1 Month, and 3 Months Follow-Up.

Radiological Outcome	Post-Operative n (%)	1 Month n (%)	3 Months n (%)
Alignment maintained	25 (100)	–	–
Aligned, uniting	–	24 (96)	–
Not aligned, uniting	–	1 (4)	–
United	–	–	24 (96)
Malunited	–	–	1 (4)
Total	25 (100)	25 (100)	25 (100)

The analysis of limb length discrepancy (LLD) measurements post-operatively, at 1 month, and at 3 months follow-up showed that the mean LLD was 0.62 cm with a standard deviation of 0.47 cm in the immediate post-operative period. It slightly increased to a mean of 0.65 cm with a standard deviation of 0.57 cm at 1 month and then marginally decreased to a mean of 0.61 cm with a standard deviation of 0.49 cm at 3 months. The minimum LLD recorded was 0.1 cm at all time intervals, while the maximum LLD was 1.7 cm post-operatively, 2.4 cm at 1 month, and 2.1 cm at 3 months. The interquartile range remained relatively consistent across follow-ups. Q1 at 0.3 cm and median (Q2) at 0.5 cm throughout. Q3 was 0.8 cm post-operatively, 0.85 cm at 1 month, and 0.65 cm at 3 months [Table 7].

Table 7: Limb Length Discrepancy (LLD) Measurements Post-Operatively, at 1 Month, and 3 Months

LLD Measurement	Mean	Std. Deviation	Minimum	Maximum	Q1	Q2	Q3
Post-Op LLD	0.62	0.47	0.1	1.7	0.3	0.5	0.8
1M LLD	0.65	0.57	0.1	2.4	0.3	0.5	0.85
3M LLD	0.61	0.49	0.1	2.1	0.3	0.5	0.65

The analysis of the descriptive statistics for age and limb length discrepancy (LLD) showed that the mean age of the study participants was 8.96 years with a standard deviation of 2.91 years (ranging from a minimum of 5 years to a maximum of 15 years). The interquartile range for age revealed a first quartile (Q1) of 6.5 years, median (Q2) of 9 years, and third quartile (Q3) of 11 years. Regarding limb length discrepancy, the mean LLD was 0.616 cm post-operatively, 0.652 cm at 1 month, and 0.608 cm at 3 months. The minimum LLD recorded at all follow-ups was 0.1 cm. Maximum values were 1.7 cm post-operatively, 2.4 cm at 1 month, and 2.1 cm at 3 months. The quartile distribution for LLD remained fairly consistent [Table 8].

Table 8: Descriptive Statistics for Age and Limb Length Discrepancy (LLD)

Statistics	Age	Post-Op LLD	1M LLD	3M LLD
Mean	8.96	0.616	0.652	0.608
Std. Deviation	2.908	0.4749	0.5658	0.4932
Minimum	5	0.1	0.1	0.1
Maximum	15	1.7	2.4	2.1
Q1	6.5	0.3	0.3	0.3
Q2	9	0.5	0.5	0.5
Q3	11	0.8	0.85	0.65

Figure 2: Preoperative anteroposterior (AP) pelvis radiograph demonstrating a displaced right femoral shaft fracture (left), with postoperative AP and lateral femur radiographs showing stabilization using titanium elastic nailing system (TENS) with satisfactory alignment (right).

DISCUSSION

The present study evaluated Titanium Elastic Nailing System (TENS) fixation for paediatric diaphyseal long bone fractures and demonstrated consistently favourable short-term outcomes across clinical and radiological domains. Overall, the data suggest that TENS provides stable fracture control with rapid progression to union, substantial pain reduction over follow-up, minimal malalignment, negligible limb length discrepancy (LLD), and predominantly excellent functional outcomes by three months. These findings support TENS as an effective management modality in selected paediatric long bone fractures.

The age distribution in our study showed a predominance of children aged 5–10 years. This was similar to the patterns described by Pulate et al who also noted that higher physical activity levels and risk-prone play behaviours may be the cause of increased fracture incidence in younger school-aged children.[11] Similarly, the observed male predominance is concordant with findings reported by Gupta MP et al where boys constituted the majority of paediatric long bone fracture cases.[12] Although behavioural and exposure differences are commonly invoked to explain this pattern, it is important to interpret sex-based differences cautiously because local sociocultural factors, supervision patterns, and differential participation in outdoor activities may influence injury mechanisms and healthcare-seeking behavior.

Regarding injury mechanism, self-fall constituted the major proportion of cases, with road traffic accidents representing a smaller subset. This distribution is consistent with Sreenivasulu et al who reported falls as a leading cause of paediatric diaphyseal fractures, particularly among younger children.[13] From a preventive perspective, these data reinforce the continued relevance of home and playground safety interventions and, for older children, structured road-safety education. The near-equal side distribution in our cohort further aligns with Sreenivasulu et al This also suggest absence of consistent laterality predisposition.[13] Injury risk in children is more likely driven by situational factors than limb dominance.

In this study there was a predominance of midshaft femur and tibia fractures. This parallels the distributions reported by Fortin K et al who documented high frequencies of femoral and tibial involvement in paediatric lower extremity fractures.[14] The predominance of transverse fractures may also be due to the biomechanical nature of common paediatric injuries that involves direct impact and bending forces from falls. In contrast spiral patterns reflecting torsional mechanisms were relatively uncommon. These baseline characteristics have practical implications for TENS performance. Stable intramedullary fixation is particularly effective when fracture morphology and canal size permit adequate three-point fixation and rotational control.

A key finding in the present study was the low magnitude of malalignment at all assessed time points, with most children maintaining less than 5° of angulation postoperatively and during follow-up. This is comparable to outcomes reported by Goodbody et al who observed minimal malalignment in paediatric tibial fractures treated with elastic nailing and reported good alignment control using TENS.[15] The ability to preserve alignment is important in children. In paediatric age group malunion may lead to persistent deformity if remodelling capacity is exceeded. In this study radiographic findings showed maintained alignment and early union. This further corroborate the effectiveness of TENS in providing stable fixation in paediatric long bone fractures.

Pain outcomes improved substantially over time. There was a steep decline in pain by one month and there was complete absence of pain in all cases by three months. These findings are consistent with the postoperative recovery patterns described by authors such as Harshwardhan et al who reported that early pain reduction accompanied functional restoration following elastic nailing.[16] While pain improvement is expected with fracture healing the rapid reduction observed may also be due to benefits of minimally invasive intramedullary fixation and early

mobilization.[17] These features are particularly relevant in paediatric patients, where early return to routine activities is one of the important considerations.

In this study complication rates were low and minor. These minor complications included skin irritation and transient joint stiffness. This complications profile was similar to the complications reported by Choudhari et al.[18] These studies reported complications such as implant related irritation, occasional nail migration and temporary stiffness in paediatric patients with long bone fractures treated by TENS.

Functionally, the majority of children achieved excellent outcomes, commonly assessed using Flynn's criteria, which integrates alignment, union, limb length discrepancy, pain, and functional limitations. Our distribution of excellent and satisfactory results is comparable to earlier reports by Velu et al,[19] and also aligns with more recent series by as well as Tella et al,[20] where most patients achieved excellent-to-good outcomes at approximately three months with minimal complications.

CONCLUSION

Titanium Elastic Nailing System (TENS) is an effective and minimally invasive option for selected paediatric diaphyseal long bone fractures in a tertiary care setting. In this study, TENS achieved high rates of radiological union with good alignment control, rapid pain resolution, minimal limb length discrepancy, and predominantly excellent functional outcomes by three months. Complications were minor and mainly consisted of implant-related irritation or transient stiffness. Careful patient selection remains important in improving outcome and minimizing incidence of malunion.

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