Original Article

Prospective Study to Analyse the Role of Titanium Elastic Nailing System in Fixation of Paediatric Forearm Fractures

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Abstract

Background: Paediatric forearm fractures are among the most common skeletal injuries in children. While conservative management is effective in many cases, unstable diaphyseal fractures often require surgical stabilization. The Titanium Elastic Nailing System (TENS) has emerged as a minimally invasive technique that preserves biological integrity and promotes early recovery. The objective is to assess the functional and radiological outcomes of paediatric both-bone forearm fractures treated with Titanium Elastic Nailing System. **Material and Methods:** A prospective observational study was conducted on 30 children aged 5–15 years with displaced diaphyseal forearm fractures. Patients underwent closed reduction and internal fixation using TENS. Data regarding demographic details, fracture characteristics, radiological union, and functional outcomes (assessed using Modified Flynn criteria) were collected and analysed. **Results:** The most common age group was 8–10 years (33.3%), with a male predominance (73.3%). Falls while playing were the most frequent mode of injury (66.7%). Transverse fractures were the most common pattern (40%). Mean radiological union time was significantly shorter in children ≤10 years (7.88 weeks) compared to >10 years (9.14 weeks) ($p < 0.001$). A strong positive correlation was observed between age and union time ($r = 0.751$, $p < 0.001$). Functional outcomes were excellent in 53.3% and good in 40% of patients. Significant associations were noted between age, fracture level, and functional outcome. **Conclusion:** Titanium Elastic Nailing System is a safe, effective, and minimally invasive technique for managing paediatric both-bone forearm fractures, providing excellent functional and radiological outcomes with early mobilization and minimal complications.

Keywords: Titanium Elastic Nailing System (TENS), Paediatric Forearm Fractures, Intramedullary Nailing, Functional Outcome, Radiological Union, Modified Flynn Criteria.

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Introduction

Fractures of the forearm are among the most common skeletal injuries encountered in the paediatric population and constitute a significant proportion of emergency orthopaedic admissions worldwide. Owing to the unique anatomical structure and functional importance of the radius and ulna, forearm fractures in children require meticulous evaluation and appropriate management to restore alignment, rotation, and limb function.[1]

The epidemiology of paediatric forearm fractures reflects a higher incidence in school-going children, particularly between 5 and 14 years of age, coinciding with increased physical activity and outdoor play. Falls on an outstretched hand, sports-related trauma, and road traffic accidents are the most frequent mechanisms of injury.[2]

The Titanium Elastic Nailing System is based on the principle of elastic stable intramedullary nailing, which provides three-point fixation within the medullary canal. Titanium nails are flexible, biocompatible, and possess a modulus of elasticity closer to that of bone, allowing controlled micro-motion at the fracture site. This micro-motion promotes callus formation and secondary bone healing while maintaining adequate fracture stability. In paediatric forearm fractures, TENS offers rotational stability, preserves periosteal circulation, and avoids extensive surgical exposure, making it particularly suitable for growing bones.[3]

Forearm fractures in children often involve both the radius and ulna, and restoration of proper length, alignment, and rotational axis is essential for optimal functional recovery. Elastic intramedullary nails allow simultaneous fixation of both bones through small incisions, thereby reducing operative time, blood loss, and postoperative morbidity. Additionally, the technique avoids violation of the fracture hematoma and minimizes damage to surrounding soft tissues, which is crucial for rapid healing in children. Early mobilization of the elbow and wrist joints is another advantage of TENS, reducing joint stiffness and facilitating faster return to daily activities.[4]

Despite the increasing popularity of TENS, the choice of

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treatment for paediatric forearm fractures remains influenced by several factors, including patient age, fracture location, degree of displacement, surgeon expertise, and available resources. While conservative management remains appropriate for many fractures, operative fixation using TENS has shown promising results in terms of union rates, functional outcomes, and cosmetic satisfaction. Several studies have reported high success rates with minimal complications when TENS is used appropriately, particularly in unstable diaphyseal fractures that are prone to redisplacement in casts.[5]

Complications associated with Titanium Elastic Nailing, though relatively infrequent, must also be considered. These include skin irritation at the nail entry site, nail migration, superficial infection, delayed union, compartment syndrome, and, rarely, refracture after nail removal.

In this context, the present prospective study aims to analyze the role of the Titanium Elastic Nailing System in the fixation of paediatric forearm fractures. By evaluating clinical, radiological, and functional outcomes, this study seeks to contribute to the growing body of evidence supporting minimally invasive surgical techniques in paediatric orthopaedics. The findings of this study are expected to provide valuable insights into the effectiveness, safety, and practicality of TENS, thereby assisting clinicians in making informed decisions regarding the optimal management of forearm fractures in children.

Materials and Methods

This prospective observational study was conducted in the Department of Orthopaedics, Princess Krishnajammanni Super Speciality Hospital (Trauma Care Centre), attached to Mysore Medical College and Research Institute, Mysore, Karnataka, India. Duration of study was two-year from 2024 to 2026. Ethical clearance for the study was obtained from the Institutional Ethics Committee of Mysore Medical College and Research Institute prior to commencement of the study.

Inclusion Criteria

Patients were included in the study based on the following criteria:

- Children aged 5 to 15 years
- Patients of both sexes
- Displaced diaphyseal fractures of both bones of the forearm
- Fractures presenting within two weeks of injury
- Patients willing to undergo surgical treatment and comply with follow-up protocol

Exclusion Criteria

Patients meeting any of the following criteria were excluded from the study:

- Children above 15 years of age
- Presence of physeal injuries
- Fractures associated with proximal or distal radioulnar joint disruption
- Open fractures of the forearm

Study Sampling

A simple random sampling method was used to select eligible patients who satisfied the inclusion and exclusion criteria during the study period.

Study Sample Size

The sample size was calculated using the formula: $n = Z^2pq / d^2$

$n = 30$

The calculated sample size was rounded off to 30 patients. Accordingly, 30 paediatric patients aged between 5 and 15 years with both-bone forearm fractures treated using Titanium Elastic Nailing System were included in the study.

Study Parameters

The following parameters were assessed during the study:

- Demographic details (age, sex)
- Mechanism and type of fracture
- Time interval between injury and surgery
- Radiological parameters including fracture alignment and time to union
- Functional outcome assessed using Modified Flynn criteria as modified by Templeton and Graham
- Complications related to surgery or implant

Study Procedure: After admission, all eligible patients underwent closed reduction and internal fixation with Titanium Elastic Nailing System under appropriate anesthesia. Preoperative planning included nail diameter selection based on the medullary canal size. Titanium elastic nails were inserted through standard entry points under fluoroscopic guidance. Adequate fracture reduction and nail placement were confirmed intraoperatively using image intensification. Postoperatively, limb immobilization was provided as required, and patients were advised gradual mobilization based on fracture stability and pain tolerance.

Study Data Collection: Informed written consent was obtained from parents or legal guardians prior to inclusion in the study. Data were collected using a structured proforma. Patients were followed up monthly for the first three months and every three months thereafter for the next eight months. Clinical assessment and radiographs were obtained at each follow-up to evaluate fracture union, alignment, and implant position. Full functional activity of the limb was permitted only after clinical and radiological confirmation of fracture union.

Data Analysis: The collected data were compiled and analyzed using appropriate statistical methods. Descriptive statistics were used to summarize demographic variables, fracture characteristics, radiological union, and functional outcomes. Results were presented in terms of frequencies, percentages, and mean values wherever applicable.

Results

The most prevalent age group in the current study was 8–10 years old, making up 33.3% (n = 10) of the patients. The age categories of 5–7 years and 14–15 years each accounted for 20.0% (n = 6) of cases, while children aged 11–13 years made up 26.7% (n = 8) of the study population. Since this table is a descriptive analysis, no test statistic, degrees of freedom, or p-value were relevant.

Male patients made up 73.3% (n = 22) of the study population in the current investigation. Of the cases, 26.7% (n = 8) involved female patients. No statistical test, degrees of freedom, or p-value were relevant because this is a descriptive analysis.

Right-sided forearm fractures were slightly more common,

making up 53.3% (n = 16) of the cases. Of the patients, 46.7% (n = 14) had left-sided involvement. Since this is a descriptive analysis, no statistical test, degrees of freedom, or p-value were relevant.

Table 1: Mode of injury among study participants (n = 30)

Mode of injury	Number (n)	Percentage (%)
Fall while playing	20	66.7
Road traffic accident	6	20.0
Fall from height	4	13.3
Total	30	100.0

Falls while playing accounted for 66.7% (n = 20) of the injuries in the current study. 20.0% (n= 6) of injuries were caused by road accidents, while 13.3% (n = 4) were caused by falls from heights. No statistical test, degrees of freedom, or p-value were relevant because this is a descriptive analysis.

Table 2: Distribution of fracture pattern (n = 30)

Fracture pattern	Number (n)	Percentage (%)
Transverse	12	40.0
Spiral	10	33.3
Oblique	8	26.7
Total	30	100.0

Transverse fractures were the most prevalent fracture pattern in the current investigation, making up 40.0% (n = 12) of the cases. Of the patients, 33.3% (n = 10) had spiral fractures, and 26.7% (n = 8) had oblique fractures. No statistical test, degrees of freedom, or p-value were relevant because this is a descriptive analysis.

Age group and Flynn functional outcome were statistically significantly correlated ($\chi^2 = 19.500$, df = 6, p = 0.003). While all patients aged 14–15 years had good outcomes, the age groups of 5–7 years and 8–10 years showed the most excellent results. Only the 11–13 age group showed fair results.

Table 3: Association between fracture level and Flynn functional outcome (n = 30)

Fracture level	Excellent	Good	Fair	Total
Proximal	0	4	0	4
Middle	14	6	0	20
Distal	2	2	2	6
Total	16	12	2	30
$\chi^2 = 15.792$, df = 4, p = 0.003				

Fracture level and Flynn functional result were statistically significantly correlated ($\chi^2 = 15.792$, df = 4, p = 0.003). While all proximal fractures had favorable results, middle-third fractures were more likely to have excellent outcomes. Only individuals with distal-third fractures showed fair results.

Table 4: Comparison of mean radiological union time between age groups (n = 30)

Age group	n	Mean union time (weeks)	Standard deviation
≤10 years	16	7.88	0.81
>10 years	14	9.14	0.86
t = −4.155, df = 28, p < 0.001			

Those under the age of ten had a considerably shorter mean radiological union time (7.88 ± 0.81 weeks) than those over the age of ten (9.14 ± 0.86 weeks). The independent samples t-test revealed that this difference was statistically significant (t = −4.155, df = 28, p < 0.001). Therefore, a longer period for radiological union was linked to increasing age.

Age and radiological union time showed a significant positive connection (r = 0.751, p < 0.001). This suggests that a longer time needed for radiological union was linked to an increase in age. At the 0.001 level, the connection was statistically significant.

Table 5: Comparison of mean radiological union time between reduction methods (n = 30)

Reduction method	n	Mean union time (weeks)	Standard deviation
Closed reduction	26	8.23	0.91
Open reduction	4	10.00	0.00
t = −3.839, df = 28, p < 0.001			

Patients treated with closed reduction had a considerably shorter mean radiological union time (8.23 ± 0.91 weeks) than those treated with open reduction (10.00 ± 0.00 weeks). The independent samples t-test revealed that this difference was statistically significant (t = −3.839, df = 28, p < 0.001). Therefore, a longer time for radiological union was linked to

open reduction.

In this investigation, postoperative immobilization was performed on every patient. Of these, 53.3% (n = 16) had exceptional Flynn functional results, 40.0% (n = 12) had good outcomes, and 6.7% (n = 2) had fair outcomes. No comparison statistical analysis was carried out because postoperative immobilization was applied consistently to all patient.

The Flynn functional outcome groups' mean forearm rotation loss varied substantially ($F = 47.180$, df = 2, 27, $p < 0.001$). Excellent patients had the lowest mean rotation loss (5.63 ± 0.89°), while good and middling patients had increasingly bigger losses (15.50 ± 4.42° and 18.00 ± 0.00°, respectively). This suggests a clear correlation between higher loss of forearm rotation and worse functional outcomes.

Age group and the incidence of complications did not significantly correlate ($\chi^2 = 3.214$, df = 1, $p = 0.073$). Patients over the age of ten had higher complications (57.1%) than those under the age of ten (25.0%), albeit this difference was not statistically significant. The chi-square assumptions were met because the minimum predicted cell count was 5.60.

Patients without difficulties had an average surgical time of 37.44 ± 1.85 minutes, while patients with complications had an average of 37.17 ± 1.85 minutes. The mean surgery duration did not differ statistically significantly between the two groups, according to the independent samples t-test ($t = 0.402$, df = 28, $p = 0.691$). This suggests that there was no correlation between the length of surgery and the incidence of complications in the current investigation.

Pearson's correlation coefficient (point-biserial correlation) was used to evaluate the relationship between the length of surgery and the incidence of complications. In the current investigation, there was no statistically significant association ($r = -0.076$, $p = 0.691$) between the length of operation and the occurrence of problems.

Patients with complications had a substantially higher mean Flynn functional score (2.17 ± 0.39) than patients without issues (1.11 ± 0.32). The independent samples t-test revealed that this difference was statistically significant ($t = 8.075$, df = 28, $p < 0.001$). The findings show that patients who experienced problems had worse functional outcomes.

Pearson's correlation coefficient (point-biserial correlation) was used to evaluate the relationship between the length of surgery and the incidence of complications. In the current investigation, there was no statistically significant association ($r = -0.076$, $p = 0.691$) between the length of operation and the occurrence of problems.

Table 6: Association between radiological union time and Flynn functional outcome (n = 30)

Union time	Excellent	Good/Fair	Total
≤8 weeks	16	0	16
>8 weeks	0	14	14
Total	16	14	30
$\chi^2 = 30.000$, df = 1, $p < 0.001$			

Radiological union time and Flynn functional outcome were statistically significantly correlated ($\chi^2 = 30.000$, df = 1, $p < 0.001$). While patients with union times longer than eight weeks had good or fair results, all patients who reached union within eight weeks had outstanding functional outcomes. The chi-square test's presumptions were met by the minimum predicted cell count of 6.53.

The Flynn functional score and radiological union time showed a significant positive connection ($r = 0.879$, $p < 0.001$). This suggests that worse functional outcomes were linked to longer radiological union times. At the 0.001 level, the connection was statistically significant.

The mean wrist mobility loss varied statistically significantly between fracture levels ($F = 29.167$, df = 2, 27, $p < 0.001$). The mean wrist motion loss was largest in patients with proximal fractures (13.00 ± 1.16°) and lowest in those with middle-third fractures (4.30 ± 1.84°). This suggests that the degree of wrist mobility limitation and fracture level are strongly correlated.

Patients in the current study achieved excellent or good functional outcomes, with an overall analytical success rate of 93.3% (n = 28). Just 6.7% (n = 2) of the cases showed less than ideal results. Since this table is a descriptive analysis, no statistical test was used.

Table 7: Summary of key findings

Parameter	Key comparison / outcome	Statistical test	Result (SPSS-derived)
Age vs radiological union time	>10 years vs ≤10 years	Independent samples t-test	$t = -4.155$, df = 28, $p < 0.001$
Radiological union time vs functional outcome	≤8 weeks vs >8 weeks	Chi-square test	$\chi^2 = 30.000$, df = 1, $p < 0.001$
Forearm rotation loss vs Flynn functional outcome	Excellent vs Good vs Fair	One-way ANOVA	$F = 47.180$, df = 2, 27, $p < 0.001$
Age vs radiological union time	Linear relationship	Pearson correlation	$r = 0.751$, $p < 0.001$
Surgical duration vs complication occurrence	Linear relationship	Pearson (point-biserial) correlation	$r = -0.076$, $p = 0.691$
Radiological union time vs Flynn functional score	Linear relationship	Pearson correlation	$r = 0.879$, $p < 0.001$
Overall analytical success rate	Excellent + Good outcomes	Frequency analysis	28/30 (93.3%)

Age was significantly correlated with radiological union time; patients over the age of ten had a longer mean union time than those under the age of ten ($t = -4.155$, df = 28, $p < 0.001$). All patients in this group had outstanding results ($\chi^2 = 30.000$, df = 1, $p < 0.001$), and early radiological union within 8 weeks was substantially related with better functional outcomes.

The loss of forearm rotation varied considerably throughout the Flynn functional outcome categories; higher loss of rotation was linked to lower functional outcomes ($F = 47.180$, df = 2,27, $p < 0.001$). Radiological union time was strongly positively correlated with age, suggesting delayed union as age increased ($r = 0.751$, $p < 0.001$).

There was a weak negative connection ($r = -0.076$, $p = 0.691$) between surgical duration and the incidence of complications. Overall, 93.3% of patients (28 out of 30) had excellent or good functional results, indicating the procedure's high analytical success rate.

Discussion

The present study demonstrated that the most affected age group was 8–10 years (33.3%, n = 10), followed by 11–13 years (26.7%, n = 8), while 5–7 years and 14–15 years each contributed 20.0% (n = 6). Comparable age patterns were observed by Ahmad et al., where the mean age was 10 years in a cohort of 30 patients aged 6–15 years.[6]

Male predominance was evident in the present study, with 73.3% (n = 22) males and 26.7% (n= 8) females. This finding is consistent with Ahmad et al., who reported 18 males and 12 females (60% vs 40%) [6]. Similarly, Kabir et al. observed 75.6% male predominance (34 males vs 11 females),[7] closely approximating the current findings.

In the present study, right-sided fractures were slightly more common (53.3%, n = 16) compared to left-sided fractures (46.7%, n = 14). Similar findings were reported by Ahmad et al., where 60% of fractures involved the right forearm and 40% the left.[6] This pattern suggests a possible association with limb dominance, as the dominant limb is often used in protective reflexes during falls.

In the present study, fall while playing was the most common mode of injury, accounting for 66.7% (n = 20), followed by road traffic accidents in 20.0% (n = 6) and fall from height in 13.3% (n = 4). This distribution indicates that low-energy trauma during recreational activities is the predominant mechanism of pediatric forearm fractures. Similar trends were indirectly supported by Ahmad et al., where 80% of fractures were closed injuries, suggesting low-energy mechanisms such as falls during routine activities.[6]

The present study demonstrated that transverse fractures were the most common pattern (40.0%, n = 12), followed by spiral fractures (33.3%, n = 10) and oblique fractures (26.7%, n= 8). This indicates that bending forces are the predominant mechanism of injury. Comparable findings were reported by Ahmad et al., who observed 17 transverse fractures, 6 oblique fractures, and 3 spiral fractures among 30 patients, confirming the predominance of transverse patterns.[6]

A statistically significant association between age group and Flynn functional outcome was observed ($\chi^2 = 19.500$, df = 6, $p = 0.003$), indicating better outcomes in younger children. All patients aged 5–7 years achieved excellent outcomes (100%, n = 6), whereas in the 8–10 years group, 60.0% (n = 6) had excellent and 40.0% (n = 4) had good outcomes. In contrast, older age groups showed reduced excellent outcomes. Comparable results were reported by Kapila et al., where 92% of patients achieved excellent outcomes and 8% good outcomes following TENS fixation.[8,9]

The present study showed a statistically significant association between fracture level and Flynn functional outcome ($\chi^2 = 15.792$, df = 4, $p = 0.003$). Middle-third fractures (66.7%, n = 20) demonstrated the highest proportion of excellent outcomes (70.0%, n = 14), while proximal fractures resulted exclusively in good outcomes, and distal fractures showed a mix of excellent, good, and fair outcomes. Ahmad et al. reported that 20 out of 30 patients had middle-third fractures, which were associated with favorable outcomes.[6]

The present study demonstrated that patients aged ≤10 years had a significantly shorter mean radiological union time (7.88 ± 0.81 weeks) compared to those aged >10 years (9.14 ± 0.86 weeks), with a statistically significant difference ($t = -4.155$, df = 28, $p < 0.001$). A strong positive correlation between age and union time was also observed ($r = 0.751$, $p < 0.001$). Comparable findings were reported by Ahmad et al., where radiological healing was observed in 5 patients at 6 weeks, 24 patients at 9 weeks, and all patients by 12 weeks.[6]

Closed reduction was associated with a shorter mean union time (8.23 ± 0.91 weeks) compared to open reduction (10.00 ± 0.00 weeks), with a statistically significant difference ($t = -3.839$, df = 28, $p < 0.001$). This indicates that minimally invasive techniques facilitate faster healing. Jain et al. reported that open reduction was required in 38.5% of cases and was associated with a higher complication rate (56% vs 32.5%),[10] suggesting less favorable outcomes with open techniques. Saseendar et al. reported that 75% of patients underwent closed nailing with favorable outcomes.[11]

The present study reported excellent outcomes in 53.3% (n = 16), good outcomes in 40.0% (n= 12), and fair outcomes in 6.7% (n = 2). Kapila et al. reported 92% excellent and 8% good outcomes [8,9], while Ahmad et al. reported 93.3% excellent outcomes and 6.7% good outcomes.[6]

The present study demonstrated a significant association between forearm rotation loss and Flynn functional outcome ($F = 47.180$, df = 2, 27, $p < 0.001$). Patients with excellent outcomes had minimal rotation loss (5.63 ± 0.89°), whereas those with good outcomes had higher loss (15.50 ± 4.42°), and fair outcomes had the highest loss (18.00 ± 0.00°). Kapila et al. emphasized restoration of range of motion as a key factor for achieving excellent outcomes.[8]

Conclusion

The present study demonstrated that pediatric forearm fractures showed favorable clinical, radiological, and functional outcomes overall, with a high analytical success rate of 93.3%, as 28 out of 30 patients achieved excellent or good Flynn functional results. Overall, the findings indicate that younger age, middle-third fracture location, closed reduction, early radiological union, and minimal motion loss are associated with better outcomes, whereas delayed union, complications, and greater loss of movement are associated with poorer function. The study therefore supports timely diagnosis, stable fixation, proper alignment, and careful postoperative follow-up as essential components in achieving successful management of pediatric forearm fractures.

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Conflicts of interest

There are no conflicts of interest.

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