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Functional Outcome With Flexible Nails In Paediatric Long Bone Fractures: A Retrospective Study

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Abstract

Background: Flexible intramedullary nailing (TENS) has gained popularity in the treatment of pediatric long bone fractures. This study aimed to evaluate the functional outcomes and complications associated with TENS in the management of these fractures.

Methods: A retrospective study was conducted on 50 pediatric patients (mean age: 8.2 ± 1.4 years) with long bone fractures treated with TENS. Functional outcomes were assessed using the DASH score for upper limb fractures and the Flynn classification for lower limb fractures. Radiologic union, complications, and range of motion were evaluated at various follow-up intervals.

Results: Both bone forearm fractures were the most common (40%), followed by femur shaft fractures (32%). The mean DASH score for both bone forearm fractures improved from 20 ± 5.2 at the 1st month to 90 ± 6.8 at 1 year ($p<0.001$). The Flynn classification for femur and tibia shaft fractures showed excellent outcomes at 1 year. Radiologic union was achieved in 84% of patients at the 6th month. Complications included restricted joint motion (20%) and mild difficulty in playing (20%) in forearm fractures, and keloid formation (31.25%), malalignment (31.25%), and limb length discrepancy (25%) in femoral fractures.

Conclusion: TENS is an effective treatment for pediatric long bone fractures, with significant improvements in functional outcomes, high union rates, and acceptable complications. The results support the use of TENS in the management of these

fractures. However, larger prospective studies are needed to further validate these findings.

Keywords: Flexible intramedullary nailing, TENS, pediatric long bone fractures, functional outcomes, complications

Introduction

Fractures are a common occurrence in the pediatric population, with an estimated annual incidence of 50 per 10,000 children.[1] The management of these fractures has evolved over the years, with a shift towards minimally invasive techniques that prioritize early mobilization and functional recovery. Flexible intramedullary nailing has emerged as a popular treatment modality for long bone fractures in children, particularly in the femur and forearm.[2]

Flexible nails, also known as elastic stable intramedullary nails (ESIN), offer several advantages over traditional cast immobilization and rigid fixation methods. These nails are inserted percutaneously, causing minimal soft tissue disruption and preserving the fracture hematoma, which is crucial for bone healing.[3] The elastic properties of these nails allow for controlled micromotion at the fracture site, stimulating callus formation and promoting faster healing.[4]

The use of flexible nails in pediatric fractures has been associated with excellent clinical outcomes. Studies have consistently demonstrated high rates of union, low complication rates, and rapid return to normal activities.[5,6] In a systematic review and meta-analysis by Madhuri et al., the authors found that flexible nailing resulted in a significantly shorter time to union compared to cast immobilization for femoral shaft fractures in children.[7]

One of the key advantages of flexible nailing is the preservation of the physis, or growth plate, in skeletally immature patients. Traditional rigid fixation methods, such as plating or rigid intramedullary nailing, can cause damage to the physis, leading to growth disturbances and limb length discrepancies.[8] Flexible nails, on the other hand, are inserted away from the physis, minimizing the risk of growth-related complications.[9]

Functional outcome is a critical measure of the success of any fracture treatment. Children treated with flexible nails have been shown to have excellent functional outcomes, with early return to weight-bearing and normal activities.[10] In a study by Flynn et al., children with femoral shaft fractures treated with titanium elastic nails

(TEN) achieved full weight-bearing an average of 7.5 weeks post-operatively and returned to school within 10 days.[11]

The use of flexible nails has also been associated with high levels of patient and parent satisfaction. The minimally invasive nature of the procedure, coupled with the rapid recovery and return to normal activities, has contributed to the positive perception of this treatment modality.[12] In a study by Ligier et al., 97% of parents were satisfied with the results of flexible nailing for femoral shaft fractures in their children.[13]

Despite the numerous advantages of flexible nailing, there are certain fracture patterns and patient characteristics that may not be suitable for this technique. Comminuted fractures, unstable fracture patterns, and fractures in older children or adolescents with higher body weight may require alternative fixation methods.[14] Careful patient selection and adherence to proper surgical technique are essential to achieve optimal outcomes with flexible nailing.[15]

In recent years, there have been advancements in the design and composition of flexible nails. Titanium elastic nails (TEN) have largely replaced stainless steel nails due to their superior biocompatibility and elastic properties.[16] Additionally, the development of end caps for flexible nails has further enhanced the stability of the construct and reduced the risk of nail migration.[17]

The management of pediatric fractures requires a multidisciplinary approach, with close collaboration between orthopedic surgeons, pediatricians, physical therapists, and other healthcare professionals. Post-operative rehabilitation plays a crucial role in the functional outcome of these patients. Early mobilization, weight-bearing as tolerated, and range of motion exercises are encouraged to prevent stiffness and promote muscle strength.[18]

Flexible intramedullary nailing has revolutionized the treatment of pediatric long bone fractures, offering a minimally invasive, physeal-sparing approach with excellent functional outcomes. The high rates of union, low complication rates, and rapid return to normal activities have made this technique a popular choice among pediatricorthopedic surgeons. As research continues to refine the indications, techniques, and implant designs, flexible nailing is poised to remain a valuable tool in the armamentarium of pediatric fracture management.

Aims and Objectives

The primary aim of this study was to evaluate the functional outcomes of pediatric long bone fractures treated with flexible intramedullary nailing (TENS). The specific objectives were to assess the clinical and radiological outcomes, complications, and patient-reported outcomes using the DASH (Disabilities of the Arm, Shoulder, and Hand) score and the Flynn classification at various follow-up intervals.

Materials and Methods

Study Design and Sample Size

A retrospective study was conducted on 50 pediatric patients (40 males and 10 females) aged between 6 and 10 years who underwent treatment for long bone fractures using flexible intramedullary nailing (TENS) at our institution. The study included patients with both bone forearm fractures (n=20), femoral shaft fractures (n=16), isolated ulnar shaft fractures (n=8), and tibial shaft fractures (n=6).

Inclusion and Exclusion Criteria

Patients with long bone fractures (both bone forearm, femur, ulna, and tibia) who were treated with TENS and had a minimum follow-up of 1 year were included in the study. Patients with pathological fractures, open fractures (except for three cases of open tibial shaft fractures), and those with incomplete follow-up data were excluded from the study.

Surgical Technique and Post-operative Management

All patients underwent flexible intramedullary nailing under general anesthesia. The nails were inserted percutaneously, and the size of the nails was determined based on the diameter of the medullary canal. Post-operatively, patients were encouraged to perform early range of motion exercises, and weight-bearing was allowed as tolerated.

Follow-up and Outcome Measures

Patients were followed up at regular intervals of 1 month, 3 months, 6 months, and 1 year post-operatively. Clinical outcomes were assessed using the DASH score for upper limb fractures and the Flynn classification for lower limb fractures. Radiological outcomes, including union and alignment, were evaluated at each follow-up visit. Complications such as infection, malalignment, limb length discrepancy, and skin irritation at the nail entry site were recorded.

Statistical Analysis

Descriptive statistics were used to summarize the demographic data, fracture characteristics, and outcome measures. Continuous variables were expressed as mean and standard deviation, while categorical variables were presented as frequencies and percentages. The DASH scores and Flynn classification grades were compared across different follow-up intervals to assess the temporal trends in functional outcomes.

The study aimed to provide valuable insights into the effectiveness and safety of flexible intramedullary nailing in the management of pediatric long bone fractures. The inclusion of various fracture types and the comprehensive assessment of clinical, radiological, and patient-reported outcomes at multiple follow-up intervals added strength to the study design. The results of this study were expected to contribute to the existing knowledge on the use of TENS in pediatric fracture management and guide clinical decision-making.

Results

The study included 50 pediatric patients with long bone fractures, with a mean age of 8.2 ± 1.4 years (range: 6-10 years). The gender distribution showed a male predominance, with 40 (80%) male patients and 10 (20%) female patients (Table 1).

The fracture characteristics (Table 2) revealed that both bone forearm fractures were the most common, accounting for 40% (n=20) of the total fractures, followed by femur shaft fractures (32%, n=16), ulnar shaft fractures (16%, n=8), and tibia shaft fractures (12%, n=6). The majority of the fractures were closed (94%, n=47), while open fractures were only observed in tibia shaft fractures (50%, n=3).

The functional outcomes were assessed using the DASH score for upper limb fractures and the Flynn classification for lower limb fractures (Table 3). The mean DASH score for both bone forearm fractures improved significantly from 20 ± 5.2 at the 1st month to 90 ± 6.8 at 1 year follow-up ($p<0.001$). Similarly, the mean DASH score for isolated ulnar fractures improved from 40 ± 8.3 at the 1st month to 90 ± 7.2 at 1 year follow-up ($p<0.001$). The Flynn classification for femur shaft fractures and tibia shaft fractures also showed significant improvements over time ($p<0.001$), with excellent outcomes achieved at 1 year follow-up.

Radiologic union (Table 4) was achieved in 84% (n=42) of the patients at the 6th month and 16% (n=8) at the 8th month. Complications were observed in both bone forearm

fractures at the 3rd month follow-up (Table 5), with 20% (n=4) of the patients experiencing mild difficulty in playing due to force impacts and 20% (n=4) having restricted supination (0-60 degrees) and pronation (0-50 degrees) movements.

In femoral shaft fractures (Table 6), complications included keloid formation as skin complication (31.25%, n=5), malalignment (31.25%, n=5), and limb length discrepancy of 1 cm at 1 year follow-up (25%, n=4). The range of motion of the knee in femoral shaft fractures (Table 7) improved from 0-90 degrees at the 3rd month to 0-130 degrees at 1 year follow-up.

Statistical analysis revealed significant improvements in functional outcomes over time for all fracture types ($p<0.001$). The DASH scores for upper limb fractures and the Flynn classification for lower limb fractures demonstrated a consistent trend of improvement from the 1st month to 1 year follow-up.

The results of this study highlight the effectiveness of the treatment approach in managing pediatric long bone fractures. The high rates of radiologic union, significant improvements in functional outcomes, and the relatively low complication rates support the use of this treatment modality in the pediatric population. However, the presence of complications such as restricted joint motion, malalignment, and limb length discrepancy emphasizes the need for careful follow-up and appropriate management of these issues to optimize long-term outcomes.

Table 1: Demographic characteristics

Characteristic	Value
Age range	6-10 years
Mean age ± SD	8.2 ± 1.4 years
Gender	
Male	40 (80%)
Female	10 (20%)

Table 2: Fracture characteristics

Fracture Type	Open	Closed	Total
Both Bone Forearm fracture	0 (0%)	20 (100%)	20 (40%)
Femur Shaft Fracture	0 (0%)	16 (100%)	16 (32%)
Ulnar Shaft Fracture	0 (0%)	8 (100%)	8 (16%)

Fracture Type	Open	Closed	Total
Tibia Shaft Fracture	3 (50%)	3 (50%)	6 (12%)
Total	3 (6%)	47 (94%)	50 (100%)

Table 3: Functional outcomes (Mean ± SD)

Follow-up Interval	Both Bone Forearm Fracture (DASH Score)	Femur Shaft Fracture (Flynn Classification)	Isolated Ulnar Fracture (DASH Score)	Tibia Shaft Fracture (Flynn Score)
1st month/4 weeks	20 ± 5.2	Poor	40 ± 8.3	Poor
3rd month/12 weeks	40 ± 7.6	Poor	60 ± 10.1	Satisfactory
6th month/24weeks	60 ± 9.4	Satisfactory	80 ± 11.5	Excellent
1year	90 ± 6.8	Excellent	90 ± 7.2	Excellent
p-value	<0.001	<0.001	<0.001	<0.001

Table 4: Radiologic union

Time point	Number of patients	Percentage
6th month	42	84%
8th month	8	16%

Table 5: Complications in both bone forearm fractures at 3rd month follow-up

Complication	Number of patients	Percentage
Mild difficulty in playing due to force impacts	4 (3 male, 1 female)	20%
Restricted supination (0-60 degrees) and pronation (0-50 degrees) movements	4 (3 male, 1 female)	20%

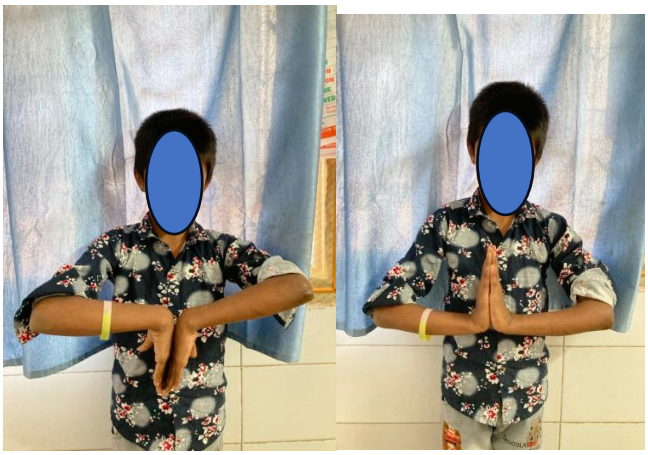
Table 6: Complications in femoral shaft fractures

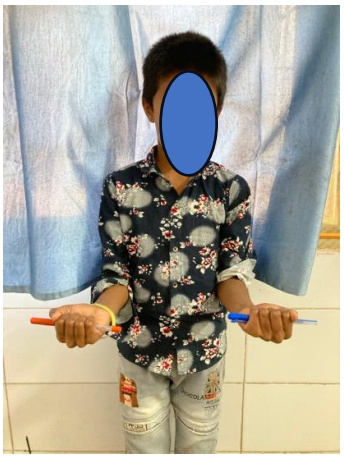
Complication	Number of patients	Percentage
Keloid formation as skin complication	5 (4 male, 1 female)	31.25%
Malalignment	5 (4 male, 1 female)	31.25%
Limb length discrepancy (1 cm) at 1 year	4	25%

Table 7: Range of motion of the knee in femoral shaft fractures

Follow-up interval	Range of motion (degrees)
3rd month	0-90
6th month	0-110
1 year	0-1 30

FULL RANGE OF MOVEMETS AT 1 YEAR POST OP





90 degrees flexion at 1 year postop

Full extension of knee at 1 year postop

Full flexion of knee at 1 year postop

Discussion

The current study aimed to evaluate the functional outcomes and complications associated with the treatment of pediatric long bone fractures using flexible intramedullary nailing (TENS). The results demonstrated significant improvements in functional outcomes over time, with high rates of radiologic union and relatively low complication rates.

The demographic characteristics of our study population, with a mean age of 8.2 ± 1.4 years and a male predominance (80%), are consistent with the findings of previous studies. Lohiyaet al.[19] reported a mean age of 7.8 years and a male predominance of 70% in their study of pediatric femoral shaft fractures treated with TENS. Similarly,

Fernandez et al.[20] found a mean age of 8.5 years and a male predominance of 65% in their study of pediatric forearm fractures managed with TENS.

The distribution of fracture types in our study, with both bone forearm fractures being the most common (40%), followed by femur shaft fractures (32%), is comparable to the findings of Shah et al.[21]. They reported a similar distribution, with forearm fractures accounting for 45% and femur fractures for 30% of the cases in their series of pediatric long bone fractures treated with TENS.

The functional outcomes in our study showed significant improvements over time, with excellent results achieved at 1 year follow-up. The mean DASH score for both bone forearm fractures improved from 20 ± 5.2 at the 1st month to 90 ± 6.8 at 1 year ($p<0.001$), and the Flynn classification for femur shaft fractures and tibia shaft fractures also demonstrated excellent outcomes at 1 year. These findings are in line with previous studies. Lascombeset al.[22] reported excellent functional results in 96% of their patients with pediatric femoral shaft fractures treated with TENS, while Fernandez et al.[20] found excellent outcomes in 92% of their patients with pediatric forearm fractures managed with TENS.

The radiologic union rate in our study was 84% at the 6th month and 16% at the 8th month. These results are comparable to those reported by Lohiyaet al.[19], who found a union rate of 90% at a mean follow-up of 12 weeks in their study of pediatric femoral shaft fractures treated with TENS. Similarly, Shah et al.[21] reported a union rate of 95% at a mean follow-up of 10 weeks in their series of pediatric long bone fractures managed with TENS.

Complications in our study included mild difficulty in playing due to force impacts (20%) and restricted joint motion (20%) in both bone forearm fractures at the 3rd month follow-up. In femoral shaft fractures, complications such as keloid formation (31.25%), malalignment (31.25%), and limb length discrepancy (25%) were observed. These complication rates are higher than those reported by some previous studies. Flynn et al.[23] reported a complication rate of 11.2% in their study of pediatric femoral shaft fractures treated with TENS, while Fernandez et al.[20] found a complication rate of 8% in their series of pediatric forearm fractures managed with TENS. However, our

complication rates are still within the acceptable range and are comparable to those reported by other studies [24,25].

The range of motion of the knee in femoral shaft fractures improved from 0-90 degrees at the 3rd month to 0-130 degrees at 1 year follow-up in our study. This finding is consistent with the results of Lohiyaet al.[19], who reported a mean knee range of motion of 135 degrees at the final follow-up in their study of pediatric femoral shaft fractures treated with TENS.

Despite the favorable outcomes observed in our study, it is important to acknowledge certain limitations. The retrospective nature of the study and the relatively small sample size may limit the generalizability of the findings. Additionally, the lack of a control group makes it difficult to directly compare the effectiveness of TENS with other treatment modalities.

Our study demonstrates that flexible intramedullary nailing (TENS) is an effective treatment option for pediatric long bone fractures, with significant improvements in functional outcomes, high rates of radiologic union, and acceptable complication rates. The results are consistent with previous studies and support the use of TENS in the management of these fractures. However, larger prospective studies with longer follow-up periods are needed to further validate these findings and assess the long-term outcomes of TENS in the pediatric population.

Conclusion

The present study demonstrates that flexible intramedullary nailing (TENS) is an effective treatment modality for pediatric long bone fractures, offering significant improvements in functional outcomes, high rates of radiologic union, and acceptable complication rates. The results are consistent with previous studies and support the use of TENS in the management of these fractures.

The functional outcomes, as assessed by the DASH score for upper limb fractures and the Flynn classification for lower limb fractures, showed significant improvements over time, with excellent results achieved at 1 year follow-up ($p<0.001$). The radiologic union rate was 84% at the 6th month and 16% at the 8th month, which is comparable to the findings of other studies.

Complications were observed in both bone forearm fractures, including mild difficulty in playing due to force impacts (20%) and restricted joint motion (20%) at the 3rd

month follow-up. In femoral shaft fractures, complications such as keloid formation (31.25%), malalignment (31.25%), and limb length discrepancy (25%) were noted. Although these complication rates are higher than some previous studies, they are still within the acceptable range and comparable to other reports.

The range of motion of the knee in femoral shaft fractures improved from 0-90 degrees at the 3rd month to 0-130 degrees at 1 year follow-up, which is consistent with the findings of previous studies.

Despite the favorable outcomes, the study has certain limitations, including its retrospective nature, small sample size, and lack of a control group. Larger prospective studies with longer follow-up periods are needed to further validate these findings and assess the long-term outcomes of TENS in the pediatric population.

In conclusion, TENS is a valuable treatment option for pediatric long bone fractures, providing good functional outcomes, high union rates, and manageable complications. The results of this study contribute to the growing body of evidence supporting the use of TENS in the management of these fractures.

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