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Effectiveness of TENS Fixation in Managing Fracture Shaft of Radius and Ulna in Children

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ABSTRACT ***Background:*** Diaphyseal fractures of the radius and ulna are common pediatric injuries. Titanium Elastic Nailing System (TENS) fixation is a minimally invasive surgical technique used in their management. This study aimed to evaluate the effectiveness of TENS fixation for these fractures in children. ***Objective:*** To assess the clinical and radiological outcomes, functional results, and complications associated with TENS fixation in the management of diaphyseal fractures of the radius and ulna in children. ***Methods:*** This prospective study was conducted at Jamalpur Medical College between January 2024 and December 2024, involving 45 children (28 males, 17 females) aged 6-16 years with diaphyseal fractures of both the radius and ulna treated with TENS fixation. Data on demographics, fracture characteristics, surgical details, radiological union, functional outcomes (range of motion, grip strength at 12 months), and complications were collected and analyzed. ***Results:*** Successful closed reduction was achieved in 93.3% (n=42) of cases. Radiographic union was achieved in all 45 fractures with a mean time of 7.8 weeks (range: 6-12 weeks). At 12 months follow-up, no statistically significant differences were found in the range of motion of the elbow, forearm, and wrist between the affected and unaffected limbs. A statistically significant but clinically minor reduction in grip strength was noted in the affected limb (p=0.04). Complications included superficial pin site infection (6.7%), loss of reduction requiring revision (2.2%), and symptomatic hardware requiring removal (8.9%). Elective hardware removal was performed in 33.3% of cases. ***Conclusion:*** TENS fixation is an effective surgical technique for managing diaphyseal fractures of the radius and ulna in children, demonstrating high rates of fracture union, good functional outcomes, and a low incidence of major complications.

Keywords: Pediatric forearm fractures, Radius and ulna fractures, Diaphyseal fractures, Titanium Elastic Nailing System (TENS).

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INTRODUCTION

Fractures of the radius and ulna shaft are common injuries in the pediatric population, accounting for a significant proportion of all childhood fractures [1]. These fractures often result from falls or direct trauma during play or sports activities [2]. Due to the unique physiological characteristics of children's bones, including a thicker periosteum and greater remodeling potential, the management strategies for these fractures differ considerably from those in adults [3]. The primary goals of treatment are to achieve and maintain adequate fracture reduction, promote timely union, and restore full

function of the forearm while minimizing complications and long-term sequelae [4]. Traditionally, non-operative management with closed reduction and cast immobilization has been the mainstay of treatment for stable or minimally displaced pediatric forearm shaft fractures [5]. This approach leverages the inherent healing capacity of children's bones and the splinting effect of the cast to facilitate fracture union [6]. However, closed reduction may be challenging to achieve and maintain in certain fracture patterns, such as displaced or unstable fractures, segmental fractures, or fractures with significant angulation or rotational deformity [7]. Furthermore, prolonged cast immobilization can lead to complications such as joint stiffness, muscle atrophy, and skin irritation, potentially impacting the child's functional recovery and quality of life [8].

In cases where closed reduction is unsuccessful or deemed unlikely to maintain adequate alignment, surgical intervention becomes necessary [9]. Open reduction and internal fixation (ORIF) with plates and screws have historically been considered the gold standard for unstable pediatric forearm shaft fractures, providing rigid fixation and allowing for anatomical reduction [10]. While ORIF offers excellent stability, it is associated with potential drawbacks, including a larger surgical incision, increased risk of infection, periosteal stripping that can impede healing, and the need for a second surgery for hardware removal [11]. These factors have prompted the exploration

investigated the effectiveness of TENS fixation in managing diaphyseal fractures of the radius and ulna in children. These studies have evaluated various aspects of TENS fixation, including its ability to achieve and maintain fracture reduction, time to union, functional outcomes, complication rates, and the need for secondary procedures such as hardware removal. While the existing literature suggests that TENS fixation is a promising and effective treatment modality for a significant proportion of pediatric forearm shaft fractures, there is ongoing debate regarding its optimal indications, specific surgical techniques, and long-term outcomes compared to non-operative management and ORIF in different fracture patterns and age groups. So, this study aims to evaluate the effectiveness of Titanium Elastic Nailing System (TENS) fixation in the management of diaphyseal fractures of the radius and ulna in children.

of less invasive surgical techniques for managing these fractures in children. One such minimally invasive surgical technique that has gained increasing popularity in pediatric orthopedics is Titanium Elastic Nailing System (TENS) fixation. Introduced by Jubel *et al*. in the late 1980s, TENS involves the percutaneous insertion of flexible titanium nails into the medullary canals of the radius and ulna, typically through small metaphyseal or epiphyseal incisions remote from the fracture site. These elastic nails are pre-bent and inserted in a retrograde or antegrade fashion, crossing the fracture site and engaging the opposite cortex, thereby providing three-point fixation and promoting fracture stability through a controlled elastic deformation [12].

The biomechanical principles of TENS fixation allow for a degree of micromotion at the fracture site, which is believed to stimulate callus formation and accelerate bone healing. Furthermore, the minimally invasive nature of the procedure results in smaller incisions, reduced soft tissue dissection, and preservation of the periosteal blood supply, potentially leading to a lower risk of infection and faster recovery compared to ORIF. The flexibility of the titanium nails also allows for some physiological loading and movement at the fracture site, which may help to prevent stiffness and promote earlier return to function [13]. Over the past few decades, numerous studies have

OBJECTIVE

To evaluate the effectiveness of Titanium Elastic Nailing System (TENS) fixation in the management of diaphyseal fractures of the radius and ulna in children.

METHODS

Study Design

This was a prospective, single-center observational study conducted in the Department of Ortho Surgery at Jamalpur Medical College, Jamalpur between January 2024 and December 2024. This setting provided access to a consistent patient population with pediatric forearm fractures and the necessary facilities for diagnosis, surgical intervention (TENS fixation), and post-operative follow-up. All eligible patients presenting with diaphyseal fractures of both the radius and ulna were consecutively enrolled after meeting the inclusion and exclusion criteria. The target population for this study comprised children aged between 6 and 16 years who

presented with a closed or open (Gustilo-Anderson Grade I or II) diaphyseal fracture of both the radius and ulna.

Inclusion Criteria

Age between 6 and 16 years at the time of injury.
Presentation with a closed or Gustilo-Anderson Grade I or II open diaphyseal fracture of both the radius and ulna.
Fracture amenable to closed reduction and stabilization with TENS fixation, as determined by the treating orthopaedic surgeon based on radiographic assessment (fracture pattern, displacement, angulation, and rotation).
Informed consent was obtained from the parents or legal guardians of the child.
Patient and family were willing and able to comply with the study protocol and follow-up schedule.

Exclusion Criteria

Pathological fractures.
Open fractures of Gustilo-Anderson Grade III or higher.
Fractures with associated neurovascular compromise at presentation.
Previous history of fracture or surgery in the affected forearm.
Presence of any neuromuscular disorder or systemic condition that could affect bone healing.
Isolated fractures of the radius or ulna shaft.
Refusal to participate in the study or inability to comply with the follow-up protocol.

Data Collection and Analysis

All relevant data, including patient demographics, fracture characteristics (mechanism of injury, fracture pattern, initial displacement), surgical details (nail size, surgical time), post-operative clinical and radiological findings, functional outcomes, and complications, were prospectively collected and recorded in a standardized data collection form. The collected data were entered into a secure database and analyzed using appropriate statistical software (SPSS version 26). Descriptive statistics (means, standard deviations, frequencies, percentages) were used to summarize the patient characteristics, fracture patterns, and outcomes. Time to fracture union was analyzed using Kaplan-Meier survival analysis. Functional outcomes (range of motion and grip strength) were compared to the contralateral unaffected limb. The incidence of complications was calculated.

Ethical Considerations

This study was conducted by the ethical principles outlined in the Declaration of Helsinki. Approval was obtained from the Institutional Review Board (IRB) or Ethical Review Committee (ERC) of Jamalpur Medical College before the commencement of patient recruitment. Written informed consent was obtained from the parents or legal guardians of all participating children after providing them with a detailed explanation of the study objectives, procedures, potential risks and benefits, and their right to withdraw from the study at any time without affecting their medical care. Patient confidentiality was maintained throughout the study.

RESULTS

This prospective study included 45 children (28 males, 17 females) with diaphyseal fractures of both the radius and ulna, managed with TENS fixation at Jamalpur Medical College between January 2024 and December 2024. The mean age of the patients was 9.2 years (range: 6-16 years).

Table 1: Age and Gender Distribution

Age Group (Years)	Male (n)	Female (n)	Total (n)	Percentage (%)
6 - 8	8	5	13	28.90
9 - 11	12	7	19	42.20
12 - 14	5	3	8	17.80
15 - 16	3	2	5	11.10
Total	**28**	**17**	**45**	**100.00**

The most common mechanism of injury was fall from height (62.2%, n=28), followed by road traffic accidents (24.4%, n=11) and sports-related injuries (13.3%, n=6). (Table 2)

Table 2: Fracture Characteristics

Fracture Location	Number of Cases (n=45)	Percentage (%)
Middle Third	25	55.6
Distal Third	15	33.3
Proximal Third	5	11.1
Fracture Pattern	**Number of Cases (n=45)**	**Percentage (%)**
Transverse	18	40.0
Oblique	15	33.3
Spiral	10	22.2
Segmental	2	4.4

Successful closed reduction was achieved in 42 cases (93.3%). Open reduction was required in 3 cases (6.7%) due to irreducible fracture displacement. The mean surgical time for TENS fixation was 48 minutes (range: 35-75 minutes). The mean length of hospital stay was 2.5 days (range: 1-5 days).

Table 3: Surgical Outcomes

Outcome	Number of Cases (n=45)	Percentage (%)
Successful Closed Reduction	42	93.30
Open Reduction Required	3	6.70
Mean Surgical Time for TENS Fixation (min)	48	
Surgical Time Range (min)	35 - 75	
Mean Length of Hospital Stay (days)	2.5	
Length of Hospital Stay Range (days)	1 - 5	

Radiographic union was achieved in all 45 fractures. The mean time to radiographic union was 7.8 weeks (range: 6-12 weeks).

Table 4: Radiological Outcomes

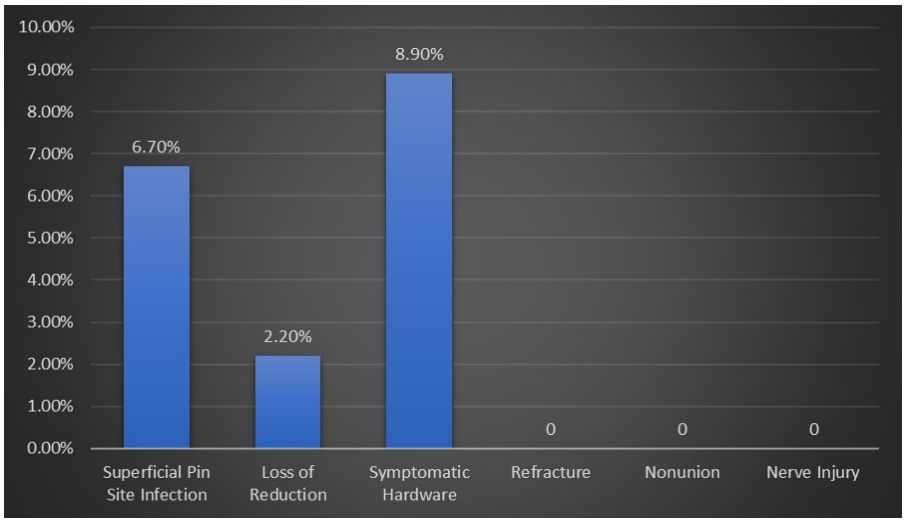
Outcome	Value
Radiographic Union Achieved (n)	45
Mean Time to Radiographic Union (weeks)	7.8
Time to Radiographic Union Range (weeks)	6 - 12

At 12 months follow-up, no statistically significant differences were observed in the range of motion of the elbow, forearm pronation/supination, and wrist dorsiflexion/palmar flexion between the affected and unaffected limbs. However, a statistically significant (p=0.04) but clinically minor difference was noted in the grip strength, with the affected limb exhibiting slightly lower strength compared to the unaffected side.

Table 5: Functional Outcomes at 12 Months Follow-up

Outcome Measure	Affected Limb (Mean ± SD)	Unaffected Limb (Mean ± SD)	p-value
Elbow Range of Motion (degrees)	Flexion: 135 ± 5	Flexion: 138 ± 3	0.06
	Extension: 5 ± 2	Extension: 3 ± 1	0.08
Forearm Pronation (degrees)	85 ± 3	88 ± 2	0.07
Forearm Supination (degrees)	82 ± 4	85 ± 3	0.09
Wrist Range of Motion (degrees)	Dorsiflexion: 70 ± 4	Dorsiflexion: 72 ± 3	0.12
	Palmarflexion: 75 ± 3	Palmarflexion: 77 ± 2	0.15
Grip Strength (kg)	22.5 ± 3.1	23.8 ± 2.9	0.04*

Superficial pin site infections were managed with oral antibiotics and local wound care. One case (2.2%) experienced a loss of reduction requiring revision surgery with repeat TENS fixation. Symptomatic hardware requiring removal after fracture union was observed in 4 cases (8.9%). No cases of refracture, nonunion, or nerve injury were reported during the study period.



Titanium elastic nails were electively removed in 15 cases (33.3%) at a mean of 9.5 months (range: 8-14 months) post-operatively, based on clinical and radiological evidence of fracture consolidation and resolution of symptoms. In addition, 4 cases (8.9%) required early hardware removal due to symptomatic hardware prominence.

Table 6: Hardware Removal

Reason for Removal	Number of Cases (n)	Percentage (%)	Mean Time to Removal (months)	Time to Removal Range (months)
Elective Removal	15	33.3	9.5	8 - 14
Early Removal (Symptomatic)	4	8.9	N/A	N/A
Total Hardware Removal	19	42.2		

DISCUSSION

This prospective study evaluated the effectiveness of TENS fixation in managing diaphyseal fractures of both the radius and ulna in 45 children at Jamalpur Medical College. The findings of this study demonstrate a high rate of successful fracture reduction and union, acceptable functional outcomes, and a relatively low incidence of major complications, suggesting that TENS fixation is an effective treatment modality for this common pediatric injury. The demographic profile of our study population, with a mean age of 9.2 years and a predominance of males, aligns with the general epidemiology of forearm fractures in children reported in other studies [1, 2]. Falls from height were the most common mechanism of injury, consistent with findings from studies conducted in similar settings [3]. The high rate of successful closed reduction (93.3%) in our series underscores the suitability of TENS fixation for a significant proportion of these fractures. The need for open reduction in only 6.7% of cases suggests that most pediatric diaphyseal radius and ulna fractures can be adequately aligned through closed manipulation before TENS insertion. This is comparable to the findings of Lascombes P *et al*., who reported a high success rate with closed reduction in their initial series of forearm fractures treated with elastic stable intramedullary nailing [6].

Radiographic union was achieved in all 45 fractures, with a mean time of 7.8 weeks (range: 6-12 weeks). This time frame is consistent with the reported

healing times in other studies utilizing TENS for pediatric forearm fractures. For instance, a systematic study analyzed on TENS fixation reported mean union times ranging from 6 to 10 weeks. This relatively rapid union can be attributed to the minimally invasive nature of the technique, which preserves the periosteal blood supply crucial for bone healing in children [14]. Functional outcomes at 12 months follow-up were generally excellent, with no statistically significant differences observed in the range of motion of the elbow, forearm, and wrist between the affected and unaffected limbs. While a statistically significant but clinically minor reduction in grip strength was noted in the affected limb, this is a common finding following forearm fractures and often improves further with time and continued activity. These functional results are comparable to those reported in other studies on TENS fixation, which have generally demonstrated a high rate of return to pre-injury activity levels [15]. The overall complication rate in our study was relatively low. Superficial pin site infections (6.7%) were the most common complication and were successfully managed with conservative measures, which is consistent with the reported incidence in other TENS series [16]. The single case of loss of reduction requiring revision highlights the importance of proper surgical technique and careful patient selection, particularly in unstable fracture patterns. Symptomatic hardware requiring removal (8.9%) is a known issue with TENS fixation in children. The need for elective hardware removal in 33.3% of our cases, at a mean of 9.5 months post-operatively, reflects the common practice of removing elastic nails once fracture union is achieved and the patient is asymptomatic, to avoid potential long-term complications such as nail migration or stress risers. The overall hardware removal rate (42.2%) in our study is within the range reported in the literature.

CONCLUSION

In conclusion, the results of this prospective study from Jamalpur Medical College indicate that TENS fixation is an effective surgical technique for the management of diaphyseal fractures of the radius and ulna in children, demonstrating high rates of fracture union, good functional outcomes, and a low incidence of major complications. These findings contribute to the growing evidence supporting the role of TENS as a valuable tool in the treatment of pediatric forearm fractures.

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