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COMPARISON OF OUTCOME OF PEDIATRIC TIBIAL DIAPHYSEAL FRACTURES TREATED WITH TITANIUM ELASTIC NAILING SYSTEM (TENS) VERSUS CONSERVATIVE MANAGEMENT

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Abstract

Background:
Pediatric tibial diaphyseal fractures are common long bone injuries, often managed either conservatively with casting or operatively with Titanium Elastic Nailing System (TENS). This study aimed to compare the clinical and radiological outcomes of TENS versus conservative management in children.

Methods:
This prospective observational study was conducted in the Department of Orthopaedic Surgery, Jinnah Postgraduate Medical Centre (JPMC), Karachi from August 2024 to February 2025. A total of 82 children aged 5–11 years with tibial diaphyseal fractures were enrolled, with 41 managed by the TENS and 41 by conservative casting. Patients were followed at scheduled intervals until radiological union was confirmed. Time to partial and full weight bearing along with duration of hospital stay and complication rates were noted.

Results:
Excellent and acceptable functional outcomes were significantly more frequent with TENS (53.7% vs. 24.4%, p = 0.022; and 97.6% vs. 75.6%, p = 0.004, respectively). The TENS group demonstrated earlier mobilization, with shorter mean time to partial (2.85 ±0.76 vs. 5.94 ±1.13 weeks, p <0.001) and full weight bearing (8.05 ±1.35 vs. 11.88 ±1.93 weeks, p <0.001). Hospital stay was longer in the TENS group (4.07 ±0.96 vs. 2.07 ±0.91 days, p <0.001). Delayed union occurred more frequently in the conservative group (p =0.007), while rates of malunion, infection, limb-length discrepancy, and re-fracture were comparable between groups.

Conclusion:
TENS demonstrated superior outcomes in terms of earlier mobilization and reduced incidence of delayed union compared to conservative management, though at the cost of a slightly longer hospital stay.

Introduction

Pediatric fractures remain a significant public health issue globally.[1] According to recent estimates in the Global Burden of Disease (GBD) study, over 33 million new cases of fractures in children and adolescents were reported

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worldwide in 2019, with South Asia alone accounting for approximately 8.3 millions of those cases.[2] The global age-standardized incidence rate of fractures among children and adolescents was about 1,716.9 per 100,000 population in 2019.[3] Long bone fractures especially of the tibia are among the more common injuries in the pediatric population due to both falls and high-energy trauma.[4,5] These injuries can lead to significant morbidity including malunion, infection, prolonged immobilization, and delayed return to function.

In children, management of diaphyseal fractures historically has been conservative with closed reduction and casting.[6] However, operative fixation methods such as the Titanium Elastic Nailing System (TENS) have gained popularity in unstable or displaced fractures because they may allow earlier weight bearing, decreased time to union, and potentially fewer complications.[7] Several studies have reported favorable outcomes with TENS in pediatric tibial fractures showing reduced hospital stay and earlier mobilization compared to conservative methods.[8-10] However, many of these studies are retrospective, single-center, or from settings different from high-volume public hospitals in low-middle income countries.

This study aims to compare outcomes of TENS vs conservative management specifically for pediatric tibial diaphyseal fractures in Karachi, Pakistan, conducted at a large public sector hospital. Given the lack of locally relevant high-quality data, especially from metropolitan public hospitals in Pakistan, this study will help to elucidate treatment effectiveness, hospital stay, functional recovery, and complication rates in this context. Furthermore, this study will provide evidence to guide clinician decision-making in similar resource-limited settings and may inform national guidelines on optimal management of these fractures.

Subjects and Methods

This prospective observational study was conducted at the Department of Orthopaedic Surgery, Jinnah Postgraduate Medical Centre (JPMC), Karachi, Pakistan from August 2024 to February 2025 after synopsis approval from CPSP. Written informed consent was taken from parents or guardians of all participants.

Children aged 5 to 11 years of either gender presenting with diaphyseal fractures of the tibia were eligible for inclusion. Closed fractures and Gustilo–Anderson type I and II open fractures with a duration of injury not exceeding seven days were included through consecutive sampling. Patients with Gustilo–Anderson type III open fractures, pathological fractures, polytrauma, ipsilateral femur fractures, metabolic bone disease, or those medically unfit for anesthesia were excluded.

A difference of twenty percent between the rates of acceptable outcome is set to represent a clinically significant difference between the two treatment methods. Assuming an acceptable outcome of seventy-five percent in the cast group and ninety-five percent in the TENS group, with a type I error of 0.05 and a type II error of 0.2, thirty-nine patients will be required in each group. To account for a possible ten percent drop-out, the sample size will be increased. Therefore, a total of eighty-two patients with tibia diaphyseal fracture will be included in the study, with forty-one children allocated to each group.

Consecutive eligible patients were enrolled and followed prospectively. Treatment decisions were made by the attending orthopedic surgeon in consultation with the caregivers according to clinical judgment and routine practice. Accordingly, patients were managed either with operative fixation using the TENS or with conservative treatment involving closed reduction and immobilization in an above-knee plaster cast. Patients were subsequently grouped into the TENS cohort and the conservative cohort.

TENS was performed under general or spinal anesthesia. Two flexible titanium nails were inserted retrograde through medial and lateral entry points at the proximal tibia and advanced across the fracture site under fluoroscopic guidance. The nail ends were cut and secured at the entry point. Following fixation, the operated limb was immobilized in an above-knee plaster

cast for six weeks. Postoperatively, all patients received intravenous antibiotics and analgesics as per institutional protocol, and the limb was kept elevated to reduce swelling. Once pain subsided, patients were mobilized with a walker under strict non–weight-bearing instructions.

Conservative surgery was performed using closed reduction under anesthesia or sedation when required. The limb was immobilized in an above-knee plaster cast with the knee flexed 30–40° and the ankle in neutral position. Casts were inspected regularly for tightness and skin complications. Conversion to a below-knee cast was performed after four to six weeks if adequate healing was observed. Weight-bearing was restricted until radiological evidence of callus formation, after which patients gradually advanced from partial to full weight-bearing.

All patients were followed at three weeks, six weeks, and three months after treatment, and then monthly until union was achieved. At each visit, clinical assessment and standard anteroposterior and lateral radiographs of the tibia were performed to evaluate callus formation, fracture alignment, and implant position. At six weeks, radiographs were reviewed for signs of union. If callus formation was evident, the above-knee cast was removed and partial weight-bearing was initiated, progressing to full weight-bearing as healing advanced. At the three-month follow-up, limb length was measured and compared with the contralateral side to evaluate for limb-length discrepancy as part of the functional outcome assessment.

The primary outcome was radiological union, defined as bridging callus visible in at least three cortices on standard anteroposterior and lateral radiographs. Secondary outcomes included functional outcome, time to partial and full weight bearing, duration of hospital stay, and complication rates such as malunion, delayed union, infection, limb-length discrepancy, and re-fracture. Patients were followed till six weeks.

Data were collected on a predesigned proforma, including demographics, fracture characteristics, treatment details, and outcomes. Statistical analysis was performed using SPSS version 27. Continuous variables such as age, time to union, time to weight bearing, and hospital stay were expressed as mean ± standard deviation and compared using the independent-sample t-test. Categorical variables such as gender and complications were expressed as frequencies and percentages, and comparisons were made using Chi-square or Fisher's exact test where appropriate. A p-value ≤ 0.05 was considered statistically significant.

Results

A total of 82 patients were enrolled. The mean age of the patients was 8.29 ±1.34 years. There were 51 (62.2%) males and 31 (37.8%) females. Road traffic accident (RTA) as mechanism of injury was observed in 18 (22.0) patients, fall in 42 (51.2%), and assault in 22 (26.8%) patients. Type I fracture was observed in 11 (13.4%), type II in 49 (59.8%), and closed type of fracture in 22 (26.8%). No statistically significant difference of any baseline characteristics was observed in between group (p-value >0.05). (Table 1)

Table 1: Comparison of baseline characteristics of the patients with respect to group

Variables	Total (n=82)	TENS (n=41)	Conservative Management (n=41)	p-value
	n (%)	n (%)	n (%)	
Age, years	8.29 ±1.34	8.21 ±1.44	8.36 ±1.24	0.623[a]
≤8	43 (52.4)	22 (51.2)	21 (48.8)	0.825
>8	39 (47.6)	19 (48.7)	20 (51.3)	
Gender				
Male	51 (62.2)	24 (47.1)	27 (52.9)	0.494

Female	31 (37.8)	17 (54.8)	14 (45.2)	
Mechanism of Injury				
RTA	18 (22.0)	10 (55.6)	8 (44.4)	0.817
Fall	42 (51.2)	21 (50.0)	21 (50.0)	
Assault	22 (26.8)	10 (45.5)	12 (54.5)	
Type of Fracture				
Type I	11 (13.4)	7 (63.6)	4 (36.4)	0.601
Type II	49 (59.8)	24 (49.0)	25 (51.0)	
Closed	22 (26.8)	10 (45.5)	12 (54.5)	

n: number, RTA: Road Traffic Accident, TENS: Titanium Elastic Nailing
[a]Independent t-test applied, [b]Chi-Square test/Fisher-Exact test applied

Radiological union was observed in 72 (87.8%) patients. Outcome of the treatment showed that 32 (39.0%) reported excellent, 46 (56.1%) reported satisfactory, and 4 (4.9%) reported poor treatment outcome. Acceptable outcome was observed in 71 (86.6%) patients.

Radiological union was significantly higher in TENS group as compared to conservative management group, i.e., 41 (100%) vs. 31 (75.6%) (p-value 0.001). Excellent outcome was significantly higher in TENS group as compared to conservative management group, i.e., 22 (53.7%) vs. 10 (24.4%) (p-value 0.022). Acceptable outcome was significantly higher in TENS group as compared to conservative management group, i.e., 40 (97.6%) vs. 31 (75.6%) (p-value 0.004). (Table 2)

Table 2: Comparison of outcome of treatment in between group

Variables	Total (n=82)	TENS (n=41)	Conservative Management (n=41)	p-value*
	n (%)	n (%)	n (%)	
Radiological Union				
Yes	72 (87.8)	41 (100)	31 (75.6)	0.001
No	10 (12.2)	0 (0)	10 (24.4)	
Outcome				
Excellent	32 (39.0)	22 (53.7)	10 (24.4)	0.022
Satisfactory	46 (56.1)	18 (43.9)	28 (68.3)	
Poor	4 (4.9)	1 (2.4)	3 (7.3)	
Acceptable Outcome				
Yes	71 (86.6)	40 (97.6)	31 (75.6)	0.004
No	11 (13.4)	1 (2.4)	10 (24.4)	

n: number, RTA: Road Traffic Accident, TENS: Titanium Elastic Nailing
*Chi-Square test/Fisher-Exact test applied

The mean time to partial weight bearing was 2.85 ± 0.76 weeks in the TENS group compared to 5.94 ± 1.13 weeks in the conservative group ($p < 0.001$). Similarly, the time to full weight bearing was significantly shorter in the TENS group (8.05 ± 1.35 weeks) than in the conservative group (11.88 ± 1.93 weeks, $p < 0.001$). Duration of hospital stay was also longer in the TENS group (4.07 ± 0.96 days vs. 2.07 ± 0.91 days, $p < 0.001$). Regarding complications, delayed union was significantly more frequent in the conservative group 11 (84.6%) compared to TENS 2 (15.4%) ($p = 0.007$). Other complications such as malunion,

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infection, limb-length discrepancy, and re-fracture showed no statistically significant differences between the two groups. (Table 3)

Table 3: Comparison of clinical outcomes and complications between TENS and conservative management groups in pediatric tibial diaphyseal fractures.

Variables	TENS (n=41)	Conservative Management (n=41)	p-value
	Mean ± SD	Mean ± SD	
Time to partial weight bearing (weeks)	2.85 ± 0.76	5.94 ± 1.13	<0.001
Time to full weight bearing (weeks)	8.05 ± 1.35	11.88 ± 1.93	<0.001
Number of hospital stays, days	4.07 ± 0.96	2.07 ± 0.91	<0.001
Complications	**n (%)**	**n (%)**	**p-value**
Malunion	1 (16.7)	5 (83.3)	0.090
Delayed union	2 (15.4)	11 (84.6)	0.007
Infection	9 (75.0)	3 (25.0)	0.061
Limb-length discrepancy	3 (75.0)	1 (25.0)	0.305
Refracture	2 (50.0)	2 (50.0)	0.05

Values are presented as mean ± standard deviation for continuous variables and as frequency (percentage) for categorical variables. p-values calculated using independent t-test for continuous variables and Chi-square/Fisher's exact test for categorical variables.

Discussion

The present study demonstrated that radiological union was achieved in 87.8% of patients overall, with significantly higher rates in the TENS group compared to conservative management. These findings underscore the effectiveness of TENS in ensuring reliable bone healing, particularly in pediatric tibial diaphyseal fractures where early consolidation is crucial to restore mobility and minimize complications. Comparable results have been reported previously. Gupta et al., 2024 observed that the majority of their patients treated with TENS achieved radiological union within 8–12 weeks, reflecting the capacity of elastic intramedullary fixation to provide adequate stability while preserving periosteal blood supply.[11] Similarly, Küçük et al.[12] in 2022 documented bony union in all children managed with intramedullary fixation, lending further support to the findings of the current study that TENS provides predictable healing outcomes and can be considered a reliable modality for such fractures.

Functional outcomes in the present study also favored the use of TENS, with excellent and acceptable results being significantly higher compared to conservative management. More than half of the patients in the TENS group achieved excellent outcomes. This observation aligns with the work of Choudhury et al.[13], who reported excellent results in over 80% of cases assessed using Flynn's criteria. Similarly, Rahman et al.[10] documented excellent or satisfactory results in all their patients treated with TENS for pediatric long bone fractures. These consistent findings reinforce the idea that operative fixation with TENS not only ensures radiological union but also translates into improved functional outcomes. Conversely, Niazi et al.[14] did not observe significant differences between TENS and conservative casting. The discrepancy with the current study may be attributable to methodological differences, as their trial involved a smaller sample size and relatively shorter follow-up duration, potentially underestimating long-

term functional benefits of early mobilization afforded by TENS.

Another important observation in the current study is that TENS facilitated earlier mobilization, with significantly shorter times to partial and full weight bearing compared to conservative management. Early mobilization is a well-recognized advantage of elastic stable intramedullary nailing. Uludağ et al.[9] highlighted that children with unstable tibial fractures treated with TENS achieved early weight bearing alongside satisfactory clinical outcomes. Likewise, Nayak et al.[15] emphasized that elastic nails promote callus formation by maintaining micromotion at the fracture site, thereby accelerating recovery and reducing the period of immobility. This advantage is of particular relevance in children, as prolonged immobilization can predispose joint stiffness, muscle atrophy, and psychosocial stress. Thus, the findings of the present study support the broader consensus that early mobilization is a key clinical benefit of TENS compared with conservative methods.

In terms of complications, delayed union was significantly more frequent in the conservative management group. This is consistent with reports by Baig et al.[16], who noted that although conservative treatment typically results in eventual union, it carries a higher risk of delayed healing, malunion, and plaster-related problems. The higher frequency of delayed union in cast-treated patients may be explained by less stable fracture immobilization and the absence of controlled micro-movement that stimulates callus formation in intramedullary fixation. In contrast, the present study found no significant differences between groups in terms of malunion, infection, limb-length discrepancy, or re-fracture. These findings mirror existing literature which demonstrates that while TENS may be associated with certain implant-related complications such as nail migration or irritation, overall complication rates remain low and are generally manageable.[17-20]

The strength of this study lies in its prospective design, adequate sample size, and execution within a large public-sector tertiary care hospital in Karachi. These factors enhance the generalizability of the results to real-world practice in Pakistan, particularly in high-volume metropolitan hospitals where both operative and conservative methods are routinely employed. Importantly, the study provides locally relevant data, addressing a gap in the regional literature where most existing studies originate from different healthcare settings.

Nonetheless, several limitations should be acknowledged. The single-center design may limit external validity across varied institutional practices. The absence of randomization introduces the possibility of selection bias, although efforts were made to adjust baseline differences between groups. Furthermore, the follow-up period was relatively short, which may not capture late complications such as growth disturbances, angular deformities, or limb length discrepancies that can emerge over time in skeletally immature patients.

Future research should aim to build on these findings by conducting multicenter randomized controlled trials with larger sample sizes and extended follow-up durations. Such studies would help to validate the superiority of TENS in diverse clinical settings and provide more robust evidence for its widespread adoption. In addition, cost-effectiveness analyses are warranted, particularly in low- and middle-income countries where healthcare resources are constrained. Evaluating the balance between the higher upfront costs of surgery and the potential long-term benefits of reduced complications and earlier functional recovery will be critical for policymaking. Finally, patient-reported outcomes, including quality of life and return to school or daily activities, should be incorporated into future studies to provide a more holistic assessment of treatment success.

Conclusion

TENS provides superior outcomes compared to conservative management for pediatric tibial diaphyseal fractures. TENS achieved significantly higher rates of radiological union and excellent

functional results, facilitated earlier partial and full weight bearing, and reduced the incidence of delayed union. Although hospital stay was slightly longer, complication rates were comparable between groups.

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