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Percutaneous fixation of fracture of both-bone forearm involving diaphysis in pediatric patients

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Abstract: *Background:* Both-bone forearm fractures are common in active pediatric populations, especially those aged 5–14 years. While conservative treatment suffices for many, unstable diaphyseal fractures often require surgical fixation. Titanium Elastic Nailing System (TENS) is increasingly favored for its minimally invasive technique, biomechanical stability, and preservation of radial bow. *Objective:* To evaluate the functional and radiological outcomes of percutaneous TENS fixation in pediatric diaphyseal both-bone forearm fractures, and to analyze complication rates and recovery using DASH scores and Price's criteria. *Methods:* A prospective study was conducted on 40 children (ages 4–12) with diaphyseal both-bone forearm fractures at Al-Ameen Medical College. All underwent percutaneous fixation with TENS. Functional outcomes were assessed using the DASH score at 6 weeks, 12 weeks, and 6 months. Radiological evaluations included time to union and maintenance of radial bow. *Results:* Most patients (55%) were aged 7–9 years; 67.5% were male and 57.5% had right-sided injuries. The predominant cause was play-related trauma (50%). Mean time to surgery was 2.38 days, and radiological union was achieved at an average of 5.55 weeks. Excellent outcomes were observed in 92.5% of cases per Price's criteria. DASH scores improved significantly from 68.74 (6 weeks) to 7.28 (6 months) ($p< 0.001$). Complications occurred in 12.5% of cases, all minor and resolved conservatively. No refractures or deep infections were reported. *Conclusion:* TENS is a reliable and minimally invasive method for treating pediatric diaphyseal both-bone forearm fractures. It offers early union, excellent functional recovery, and low complication rates, making it a preferred option in children with unstable fractures.

Keywords: Pediatric Fractures, Diaphyseal Forearm Fractures, Titanium Elastic Nailing System, TENS, DASH Score, Radial Bow, Functional Outcome, Radiological union, Intramedullary Fixation.

Introduction

Forearm fractures account for approximately 40% of all pediatric fractures, making them among the most common injuries in children [1]. These fractures are typically caused by falls or direct trauma, with severity influenced by age, bone quality, and fracture location. The incidence of forearm shaft fractures is more than twice as high in school-aged children compared to toddlers. In boys, a bimodal distribution is observed at 9 and 13–14 years, whereas girls show a peak around 5–6 years [2].

Most fractures occur in the distal third (75–84%), followed by the diaphyseal region (15–18%), and less commonly the proximal third (1–7%) [3]. Diaphyseal fractures, especially involving both bones, are more unstable and difficult to manage due to limited remodeling potential and muscular forces that hinder reduction.

Unlike metaphyseal or physeal injuries, diaphyseal fractures in older children have limited potential for remodeling. Fractures with complete displacement may indicate soft tissue interposition, often requiring mini-open reduction [4]. While many fractures are treated conservatively, surgical intervention is warranted in cases of instability, failure of closed reduction, or refracture. The Titanium Elastic Nailing System (TENS) is widely used due to its minimally invasive approach, preservation of periosteal blood supply, and elastic stability that promotes early mobilization [5].

Studies have shown excellent outcomes with TENS. Anaberu et al [6] and Ahmad Bhat et al [7] reported high union rates and minimal complications, while Guzel [8] demonstrated comparable or superior results versus plating and K-wires. However, refracture defined as recurrence at or near the same site within 18 months is a significant concern [1]. Early refractures may result from inadequate immobilization, while late refractures are often activity-related [2].

Contributing factors include premature implant removal, insufficient healing, and poor bone quality [9]. Implants in children are typically removed within 6–12 months, which, if done prematurely, can increase refracture risk [10]. Re-displacement and malunion also remain potential complications. TENS fixation, with its minimally invasive technique and biological advantages, continues to be a preferred treatment modality for pediatric diaphyseal forearm fractures, balancing stability, healing potential, and functional recovery.

Aims and objectives of the study:

- To evaluate the outcomes of percutaneous fixation for diaphyseal both-bone forearm fractures in pediatric patients.
- To assess postoperative range of motion following TENS fixation in these fractures.

Material and Methods

This hospital-based prospective observational study was conducted in the Department of Orthopaedics at Al-Ameen Medical College Hospital, Vijayapur, Karnataka, over a period of 18 months from July 2023 to December 2024. The study included pediatric patients aged 4 to 12 years presenting with both-bone forearm fractures involving the diaphysis and managed by percutaneous fixation. Patients of both sexes who were medically fit for surgery were included, while those with pathological fractures, open fractures, associated neurovascular injuries, epiphyseal or metaphyseal involvement, or age above 12 years were excluded.

Data were collected using a structured proforma after obtaining informed consent. Clinical history and examination were followed by surgical intervention using the Titanium Elastic Nail System (TENS). All surgeries were performed under regional anesthesia without the use of a tourniquet, with patients positioned supine on a standard operating table. The radius was approached via a 2–3 cm longitudinal incision distal to the Lister's tubercle; after creating an entry point with an awl, the appropriate-sized nail was advanced across the fracture under fluoroscopic guidance. For the ulna, a similar-sized incision was made at the olecranon tip, and fixation was done under C-arm confirmation.

Acceptable reduction was defined as <5° varus-valgus angulation, <10° anterior-posterior angulation, and <15 mm shortening. Care was taken to avoid physeal damage. Postoperatively, wounds were closed and an above-elbow slab was reapplied. Dressings were done on postoperative days 2 and 5, with suture removal on day 11 or 12. Intravenous antibiotics (Cefoperazone + Sulbactam and Amikacin, per body weight) were administered for 1–2 days, followed by oral antibiotics until suture removal. An above-elbow cast was maintained for 4–6 weeks. Active range of motion (ROM) exercises for the elbow, wrist, and shoulder were initiated upon cast removal.

Routine daily activities were allowed after 6 weeks, and weight-bearing activities after 12–14 weeks. Patients were followed up regularly at 1 week, 6 weeks, 3 months, and 6 months. At each visit, clinical assessment included evaluation of pain, swelling, ROM of elbow and wrist, and presence of deformity. Radiographs were taken to assess union, angulation, and loss of radial bow. Functional outcomes were recorded using the DASH score from 6 weeks onward. Acceptable radiographic criteria varied by age: for children <9 years, up to 15° angulation and 45° malrotation were acceptable, while for those >9 years, thresholds were tighter (10° angulation, 30° malrotation). Clinical outcomes were categorized as Excellent, Good, Fair, or Poor based on forearm angulation and functional status.

The data was collected and compiled in MS Excel. Descriptive statistics has been used to present the data. To analyse the data SPSS

(Version 26.0) was used. Significance level was fixed as 5% ($\alpha = 0.05$). Qualitative variables are expressed as frequency and percentages and Quantitative variables are expressed as Mean and Standard Deviation.

Results

A total of 40 pediatric patients with diaphyseal forearm fractures were enrolled in the study. The demographic and clinical characteristics are summarized in Table 1.

The majority of the patients (55%) were between 7–9 years of age, followed by 27.5% in the 4–6 years range, and 17.5% in the 10–12 years range. Males accounted for 67.5% of the study population, and right-sided involvement was observed more frequently (57.5%) than left-sided involvement (42.5%). The most common mechanism of injury was trauma sustained during play (50%), followed by road traffic accidents (32.5%) and falls (17.5%). The mean injury-to-operation interval was 2.38 ± 1.234 days.

Table-1: Demographic and Clinical Characteristics of Pediatric Patients

Category	Subcategory	Frequency	Percentage
Age	4–6 years	11	27.5%
	7–9 years	22	55%
	10–12 years	7	17.5%
Gender	Male	27	67.5%
	Female	13	32.5%
Side Involved	Left	17	42.5%
	Right	23	57.5%
Mode of Injury	Trauma while playing	20	50%
	Road traffic accident (RTA)	13	32.5%
	Fall	7	17.5%
Injury-Operation Interval, Mean ± SD		2.38 ± 1.234 days	

Postoperative Complications: Postoperative complications are presented in Table 2. A large proportion of patients (87.5%) experienced no postoperative complications. Among the remaining, 2 patients (5%) reported pain at the radial entry portal, 2 (5%) experienced stiffness, and 1 (2.5%) reported numbness over the wrist. No major complications were noted.

Table-2: Post-op Complication

Post-op Complication	Frequency	Percentage
No Complication	35	87.5
Numbness Over Wrist	1	2.5
Pain at Radial Entry Portal	2	5
Stiffness	2	5
Total	40	100

Functional Outcomes: Functional recovery was assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score at different follow-up intervals (6 weeks, 12 weeks, and 6 months), as shown in Table 3. At 6 weeks, the mean DASH score was 68.74 ± 1.93, indicating significant disability in the early postoperative period. By 12 weeks, the score improved markedly to 20.51 ± 1.03, and by 6 months, further reduced to 7.28 ± 0.69, reflecting near-complete recovery. Paired *t*-tests revealed high statistical significance at all time points ($p < 0.001$), confirming the effectiveness of surgical intervention in restoring upper limb function.

Table-3: DASH Score

Time Point	Mean DASH Score	Standard Deviation (SD)	*t* value	*p* value
6 Weeks	68.74	1.93	211.05	<0.001
12 Weeks	20.51	1.03	210.02	<0.001
6 Months	7.28	0.69	61.20	<0.001

Radiological Assessment: Radiographic evaluation of radial bow alignment is detailed in Table 4. Nearly half the patients (47.5%) retained a normal radial bow postoperatively. Partial loss of bow was observed in 22.5%, and complete loss in 30% of the cases. Maintenance of the radial bow is critical for optimal forearm rotation; thus, nearly half preserving it suggests successful alignment.

Table-4: Radial Bow

Radial Bow	Frequency	Percentage
Normal	19	47.5
Partial Loss	9	22.5
Loss	12	30
Total	40	100

Clinical Outcome: Clinical outcomes based on postoperative forearm angulation are presented in Table 5. An excellent outcome, defined as residual angulation <11°, was achieved in 92.5% (37 patients), while the remaining 7.5% (3 patients) had good outcomes with angulation between 11° and 30°. No poor outcomes were recorded. These findings highlight the precision of percutaneous fixation in restoring forearm alignment.

Table-5: Clinical Outcome

Clinical Outcome	Frequency	Percentage
Excellent (forearm angulation less than 11°)	37	92.5
Good (angulation between 11° to 30°)	3	7.5
Total	40	100

Radiographic Parameters: Postoperative angulation and time to radiological union are summarized in Table 6. The mean angulation observed was 5.29° ± 3.58°, within acceptable limits due to the remodeling potential in pediatric bones. The average time to radiological union was 5.55 ± 0.815 weeks, indicating a rapid healing process consistent with pediatric physiology.

Table-6: Postoperative Radiographic Outcomes

Parameter	Mean	Standard Deviation (SD)
Angulation (°)	5.29	3.58
Radiological Union (weeks)	5.55	0.815

Discussion

This study evaluated the clinical and radiological outcomes of pediatric diaphyseal both-bone forearm fractures treated with Titanium Elastic Nailing System (TENS), benchmarking our findings against contemporary literature to assess the technique's efficacy and safety.

Patient Demographics and Injury Pattern: The most common age group in our cohort was 7–9 years, aligning with previous studies by Shivanna [11], Jain [12], Sahu [13] and Tella [14], where the mean age clustered around 9 years. A strong male predominance (67.5%) was consistent with Jain (61.5%) [12], Tella (84.6%) [14], Shivanna [11] and Wang [15], likely due to increased physical activity among boys. While middle-third fractures were most common in studies like Jain [12] (86.2%) and Tella [14] (65.4%), our study did not exclusively focus on fracture level. The right forearm was more frequently involved in our series (57.5%), whereas others reported near-equal side distribution. Trauma while playing was the leading cause in our cohort (50%), consistent with Shivanna [11] (66.6%) and Tella [14] (65.4%), reinforcing the association with recreational activities.

Timing of Surgery: Early surgical intervention improves outcomes. In our study, the average injury-to-surgery interval was 2.38 days, comparable to early interventions reported by Shivanna [11] and Jain [12]. Delayed procedures, as noted by Ibrahim [16] and Kelly [17], were associated with technical challenges and increased complication rates.

Functional Outcomes: Using Price et al. criteria, 92.5% of our patients had excellent results, similar to Shivanna [18] (96.7%), Ibrahim [16] (93.3%), Sahu [13] (87.5%), and Jain [12] (90.8%). Only 7.5% in our cohort had good outcomes, with no fair or poor results. Comparable studies report minor rotational deficits (<30°) associated with delayed or open reductions. Notably, our patients demonstrated full recovery of elbow and wrist motion, echoing the findings of Tella[14] and Wang [15] (table-7).

Table-7: Comparative Functional Outcomes Using Price et al. and ROM Metrics				
Study	**Excellent (%)**	**Good (%)**	**Fair (%)**	**Poor (%)**
Present Study	92.5%	7.5%	0%	0%
Shivanna [11]	96.7%	3.3%	0%	0%
Ibrahim H [16]	93.3%	6.7%	0%	0%
Sahu B [13]	87.5%	10%	2.5%	0%
Jain S [12]	90.8%	7.7%	1.5%	0%
Tella AO [14]	73.1%	26.9%	0%	0%

Complications and Safety Profile: The complication rate in our study was low (12.5%), with all cases being minor and resolving conservatively. In contrast, Jain [12] reported a 41.5% complication rate, with issues like infection, nerve injury, and refracture. Superficial infections were commonly noted in Sahu [13], Jain [12] and Ibrahim [16] but managed non-surgically. Importantly, we observed no refractures, unlike Kelly [17] (6 cases) and Jain [12] (1 case), emphasizing the role of adherence to postoperative care and timely implant removal. One case of transient wrist numbness was noted in our study, with other reports by Jain [12], Kelly [17] and Wang [15] showing similar reversible nerve symptoms.

Surgical Technique and Outcomes:: Closed reduction with TENS was successful in 92.5% of our patients, aligning with Shivanna [11], Sahu [13] and Ibrahim [16]. Open reduction, required in 12.5% of our cases, was associated with higher complications Jain [12] reported a 56% complication rate with open techniques vs. 32.5% with closed. Postoperative management, including cast application and progressive physiotherapy, was similar to protocols in Shivanna [11] and Jain [12], with no long-term joint restrictions observed.

Fracture Union: Union was achieved at a mean of 5.55 weeks in our cohort, earlier than Shivanna [11] (7 weeks), Sahu [13] (10–12 weeks), Ibrahim [16] (9.07 weeks), and Jain [12] (10.4 weeks). The quicker healing timeline in our study may be attributed to timely surgical intervention, closed technique preference, and structured follow-up. No delayed or non-union was observed, supporting the reliability of TENS.

Functional Recovery Based on DASH Scores: DASH scores in our study showed a significant decline from 68.74 at 6 weeks to 20.51 at 12 weeks, and 7.28 at 6 months ($p< 0.001$), indicating substantial functional recovery. Ibrahim [16] reported a mean DASH score of 11.39 ± 2.84, consistent with our mid-term results, although lacking temporal breakdown. Other comparative studies (Shivanna [11], Jain [12], Sahu [13], Wang [15]) used categorical scoring systems, limiting direct DASH comparisons but supporting similarly positive functional outcomes.

Overall Clinical Relevance: When analyzed collectively, the evidence including the present study supports the use of TENS in pediatric diaphyseal forearm fractures for its:

- High union rates (6–12 weeks)
- Excellent functional outcomes (>85–90% excellent ratings)
- Low complication rates, particularly with closed reduction
- Effective, quantifiable recovery with minimal long-term disability

The potential need for open reduction and risks associated with premature implant removal remain key considerations during treatment planning and family counseling.

Conclusion

Titanium Elastic Nailing System (TENS) is a safe, effective, and minimally invasive method for managing pediatric diaphyseal both-bone forearm fractures. Our study demonstrated early union (mean 5.55 weeks), a high rate of excellent outcomes (92.5%), and a low complication profile. Functional recovery, evidenced by significant improvement in DASH scores, and preservation of radial bow in many cases, underscores the anatomical and clinical reliability of this technique. When performed

with proper patient selection and surgical precision, TENS remains a dependable choice in pediatric orthopedic fracture management.

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References

1. Litton LO, Adler F. Refracture of the forearm in children: a frequent complication. *J Trauma.* 1963; 3:41-51.
2. Corsino CB, Reeves RA, Sieg RN. Distal radius fractures. In: StatPearls [Internet]. Treasure Island (FL): *StatPearls Publishing;* 2025 [cited 2025 Apr 18]. Available from: *http://www.ncbi.nlm.nih.gov/books/NBK536916/*
3. Denisiuk M, Afsari A. Femoral shaft fractures. In: StatPearls [Internet]. Treasure Island (FL): *StatPearls Publishing;* 2025 [cited 2025 Apr 18]. Available from: *http://www.ncbi.nlm.nih.gov/books/NBK556057/*
4. McCoy JS, Nelson R. Avulsion fractures. In: StatPearls [Internet]. Treasure Island (FL): *StatPearls Publishing;* 2025 [cited 2025 Apr 18]. Available from: *http://www.ncbi.nlm.nih.gov/books/NBK559168/*
5. Khoshhal K & Zamzam M. Displaced fracture of the distal radius in children: factors responsible for redisplacement after closed reduction. *Journal of Bone and Joint Surgery, British.* 2005; 87-B(6):841-843.
6. Anaberu AN, Rajendran R, Balaji G, Chandrasekaran T. Clinical outcome of TENS nailing in pediatric both-bone diaphyseal forearm fractures. *Int J Res Orthop.* 2021; 7(3):478-482.
7. Bhat SA, Mir BA, Dhar SA, Halwai MA. Outcome of titanium elastic nailing in forearm bone fractures in children. *Ulus Travma Acil Cerrahi Derg*. 2010; 16(2):135-138.
8. Guzel Y, Acar MA, Elmadağ M, Uzer G, Karalezli N, Ogun TC. Comparison of plate-screw fixation, intramedullary nailing and K-wire fixation in pediatric forearm fractures. *Acta Orthop Traumatol Turc.* 2014; 48(6):535-540.
9. Abulsoud MI, Mohammed AS, Elmarghany M, Elgeushy A, Elzahed E, Moawad M, Elshal EA, Elhalawany MF, Hassanein YA, Fouad AA, Zakaria AR. Intramedullary Kirschner wire fixation of displaced distal forearm fractures in children. *BMC Musculoskelet Disord.* 2023; 24(1):746.
10. Gibbons CLMH, Woods DA, Pailthorpe C, Carr AJ, Worlock P. The management of isolated distal radius fractures in children: *Journal of Pediatric Orthopaedics*. 1994; 14(2):207-210.
11. Shivanna, Maruthi CV. Treatment of paediadric forearm fractures with titanium elastic nails. *Indian Journal of Orthopaedic Surgery*. 2015; 1(4):251-254.
12. Jain S, Mohanachandran J, Mohan R. Outcomes and complications of Titanium elastic nailing for forearm bones fracture in children: our experience in a district general hospital in the United Kingdom. *Acta Orthop Belg.* 2023; 89(3):539-546.
13. Sahu B, Mishra A, Tudu B. Management of pediatric both-bone forearm fractures by titanium elastic nailing system: A prospective study of 40 cases. *J Orthop Traumatol Rehabil.* 2018; 10(2):103.
14. Tella AO, Aldhilan MM. The outcome of titanium elastic nail fixation of pediatric long bone fractures - a retrospective analysis. *Orthop Rev (Pavia).* 2024; 16:118449.
15. Wang B, Guo J, Li Z, Ji Z, Liu F, Sun K et al. Pediatric distal both-bone forearm fractures treated with percutaneous pinning with or without ulna fixation: a retrospective cohort study from two centres. *BMC Musculoskeletal Disorders.* 2024; 25(1):683.
16. Ibrahim H, Hammoda I, Attia A. Comparative study between conservative treatment and k-wires fixation of both bones forearm in children from 5–12 years. *Al-Azhar International Medical Journal*. 2022; 0(0):0–0. Available from: *https://aimj.researchcommons.org/journal/vol3/iss10/1*
17. Kelly BA, Shore BJ, Bae DS, Hedequist DJ, Glotzbecker MP. Pediatric forearm fractures with in situ intramedullary implants. *J Child Orthop.* 2016; 10(4):321–327.
18. Shivanna S, CVM. (2016). Pediatric forearm fractures with tens: freedom of movements. *International Journal of Research in Orthopaedics*, 2016; 2(3): 143-147.

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