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Research Article

Titanium Elastic Nailing System in Adult Forearm Fractures: An Original Study

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Abstract

Background: The present study aimed to evaluate the early functional and radiological outcomes of forearm fractures in adults treated using the titanium elastic nailing system (TENS).
Methods: This study was conducted between 2022 and 2025 in the department of orthopedics at a tertiary care medical college. A total of 30 adult patients with radiologically confirmed forearm fractures (radius, ulna, or both) treated with TENS nail were included. Exclusion criteria comprised pathological or open fractures, prior forearm surgeries, and systemic conditions affecting bone health. Follow-ups were scheduled at one week for aseptic dressing and follow-up check X-ray, two weeks for stitches and backslab removal, six weeks, and three months. Outcomes assessed included functional recovery using the Disabilities of the Arm, Shoulder, and Hand (DASH) and Grace-Eversmann scores, radiological union via the modified Radiographic Union Score for Tibia fractures (mRUST) scoring, and surgical complications.
Results: The mean age of patients was 47 years, with a predominance of ulna-only fractures (56.67%). Most patients were discharged within three days post-surgery. Functional recovery improved significantly over time, with 73.33% achieving "excellent" Grace-Eversmann scores and 66.66% having DASH scores < 20 by 12 weeks (P = 0.002). Radiological healing progressed steadily, with all patients achieving mRUST scores ≥ 11 at 12 weeks. The mean time t0 union was 11.6 weeks. Complications were minor and managed conservatively.
Conclusion: TENS in adult forearm fractures demonstrated excellent functional outcomes, fast radiological union, minimal surgical morbidity, and early return to activity. Given its minimally invasive nature and low complication rate, TENS represents a safe and effective treatment modality for adult forearm fractures.

Keywords: TENS; Titanium; Fracture Fixation; Forearm; Radius; Ulna

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Background

Diaphyseal forearm fractures are often classified as intra-articular fractures. Management of forearm fractures in adults focuses on achieving fracture union, maintaining proper alignment, and restoring function to pre-injury levels while minimizing complications. Non-operative treatment, typically involving immobilization with casts or splints, is suitable for non-displaced or minimally displaced fractures. Conversely, surgical intervention is required for displaced, unstable fractures or those involving joints or polytrauma cases, with open reduction and internal fixation (ORIF) being the predominant technique used. This approach allows for stable fixation, facilitating early mobilization and rehabilitation (1). However, it carries risks due to significant surgical exposure and periosteal stripping. These factors can increase the likelihood of complications such as neurovascular injuries, soft tissue damage, intraoperative fractures, muscular edema, and postoperative compartment syndrome.

For certain forearm fractures, particularly those involving the radius and ulna shaft, intramedullary (IM) nailing may be an effective alternative. The titanium elastic nailing system (TENS), though widely established in pediatric populations, is being increasingly explored for adult use due to its minimally invasive nature and enhanced biological healing environment (2). This technique allows for relative stability and promotes secondary bone healing. By using TENS, surgeons can achieve internal fixation of adult forearm fractures with minimal soft tissue disruption, reducing the risk of neurovascular injury and yielding favorable cosmetic results (3).

While the use of TENS in adults remains relatively less defined, emerging literature suggests its potential merits, warranting comprehensive evaluation in adult cohorts. Evaluating the real-world implications of this treatment on patients' return to daily activities offers a patient-centered approach to understanding efficacy. Additionally, surgical modalities that ensure early mobilization and minimal complications can yield significant socioeconomic advantages, both for patients and healthcare systems.

Methods

This single-center, hospital-based study was conducted over three years (2022-2025) in the department of orthopedics at a tertiary care medical college and hospital, following ethical approval from the Institutional Ethics Committee [MMMCH/IEC/22/582]. A total of 30 adult patients with forearm fractures were recruited using a non-probability convenience sampling method. These patients, who presented to the department of orthopedics and were treated using the TENS, were included after providing informed consent.

Inclusion Criteria:

- Adults aged between 18 and 60 years
- Radiologically confirmed fractures involving either single or both bones of the forearm (radius and ulna)
- Patients treated with TENS for the current fracture.
Exclusion Criteria:
- Pathological fractures
- History of prior forearm surgeries
- Systemic conditions affecting bone health (e.g., osteoporosis, metabolic bone disease)
- Patients unfit for surgery due to significant comorbidities
- Fractures with intra-articular extensions
- Compound (open) fractures.

Operative Principle and Technique

In this technique, the emphasis is laid upon the closed, indirect, and acceptable reduction, biological fixation, and relative stability with flexible titanium nails that have the Young's modulus close to that of the cortical bone and almost half of the same for stainless steel. Comparatively, precise open anatomical reduction, rigid mechanical fixation, and absolute stability are required in internal fixation with plating. In contrast to the long, wide bones of the lower limb that require at least two curved titanium nails for three-point fixation, in the forearm bones, usually a single curved titanium nail is sufficient because of the small diameter of the medullary canal and the surrounding musculature. The TENS nail just acts as a pure internal splint without compression and allows the fracture to heal naturally in the setting of no damage to the surrounding soft tissues. Rarely, a second nail may be needed to aid in better reduction and supplement the fixation.

In a fracture of both bones of forearm, we preferred nailing the ulna first to restore the length that facilitates the subsequent reduction of the radius fracture. The diameter of the nail was tentatively selected based on the size of the medullary canal on X-ray. However, we relied more upon the intra-operative 'feeling' and 'fit' of the size that was subsequently increased or decreased until satisfactory reduction and stability were achieved. The nails were pre-bent as per the shape of the normal bone on the opposite side. All the surgeries were performed by a single surgeon having more than ten years of experience in trauma surgeries.

In the present study, in the radius fractures, the TENS nailing was always done retrogradely, with the preferred entry point being just radial to the Lister's tubercle. In the ulna fractures, majority of nailing procedures were done antegradely, with the entry point being at the lateral side of the ulnar proximal metaphyseal region. This prevents any injury to the ulnar nerve and any interference with the function of the triceps or the irritation of the bursa. The exception was those cases where the ulna fracture was located too proximally. In those situations, the entry was made distally from the dorso-lateral metaphyseal region of the ulna, and the nail was inserted in a retrograde manner. The supination and pronation range of motion (ROM) of the forearm, distal radioulnar joint (DRUJ) stability, and the fracture reduction stability were checked on the operating table.

Follow-Up and Outcome Measures

Postoperative care included immobilization of the operated upper limb for each patient with a long-arm splint/cast for two weeks. All participants were followed up at one week for aseptic dressing (ASD) and follow-up check X-ray, two weeks for stitches and backslab removal, six weeks, and three months postoperatively. Evaluations were performed at the follow-up visits through clinical assessments, functional scoring, and radiographic imaging.

Primary Outcomes

Functional Recovery: Functional recovery was evaluated using the Disabilities of the Arm, Shoulder, and Hand (DASH) score and the Grace-Eversmann criteria. These tools assessed patients' upper limb functionality, ROM, and ability to perform daily activities.

Radiographic Union: Radiographic union was determined using the modified Radiographic Union Score for Tibial fractures (mRUST) criteria, applied to radiographs. Union was defined as the obliteration of the fracture line and evidence of callus bridging on multiple cortices. The reliability of mRUST criteria in upper limb fractures has already been validated in the available literature (4, 5).

Secondary Outcomes

Surgical Complications: Postoperative complications such as infection, hardware migration, and re-fracture were monitored at each follow-up and comprehensively recorded.

Data Analysis

All patient data were systematically recorded in pre-designed case report forms during clinical interactions and follow-ups. The data were transcribed into Microsoft Excel and analyzed using Stata statistical software (version 17.0, Stata Corporation, College Station, TX, USA). Descriptive statistics [mean, median, standard deviation (SD), frequencies, and percentages] were used to summarize demographic details and baseline clinical profiles. Paired t-tests were applied for comparison of pre- and post-treatment outcomes, depending on the distribution of the data. Statistical significance was assessed through P-values and 95% confidence intervals (CIs) to determine the reliability and strength of observed effects.

Results

The present study comprised 14 women and 16 men, i.e., a total of 30 participants with forearm fractures, with a mean age of 47 years, ranging from 24 years to 60 years. The predominance of left-sided forearm fractures in the study sample of 20 participants (66.67%) was seen. Out of the total 30 patients enrolled in the present study, the fracture involved both radius and ulna in four participants (13.33%), radius alone in nine participants (30.00%), and ulna alone in 17 participants (56.67%), indicating that fractures of the ulna alone were the most common. The intraoperative findings from the 30 participants undergoing surgery for forearm fractures are summarized in table 1 concerning the duration of surgery and the amount of blood loss.

Table 1. Duration of surgery and intraoperative blood loss

Age	Both bones	Radius	Ulna	Total
Mean duration of surgery (minute)	53.3	42.0	26.3	34.6
Mean amount of blood loss (ml)	14.3	12.7	11.1	12.8

The majority of patients, approximately 93.34%, were discharged within three days of their operation (Table 2), indicating a generally quick postoperative recovery period for most individuals involved in the study. The longer stays of four and five days were exceptions, affecting only a small fraction of the participants.

Table 2. Duration of postoperative stay

Duration of postoperative stay (day)	n (%)
2	11 (36.67)
3	17 (56.67)
4	1 (3.33)
5	1 (3.33)

In the present study, the progression of scores of the Grace-Eversmann criteria over the follow-up indicates a significant improvement in functional outcomes (Table 3).

Table 3. Grace-Eversmann scores at 6th and 12th weeks of follow-up

Grace-Eversmann score	6 week [n (%)]	12 week [n (%)]
Excellent	15 (50.00)	22 (73.33)
Good	10 (33.33)	7 (23.33)
Acceptable	5 (16.67)	1 (3.33)
Unacceptable	0 (0)	0 (0)

The percentage of patients rated as "excellent" increased consistently from 50% at six weeks to 73.33% at 12 weeks. Concurrently, there were no participants rated as "unacceptable" by the six-week follow-up. This trend demonstrates effective recovery and rehabilitation processes post-surgery (Figures 1-5).

Figure 1. X-rays of Galeazzi fracture in a 66-year-old man showing signs of union at 12 weeks and satisfactory range of motion (ROM)

The distribution of scores among participants at one week, six weeks, and 12 weeks was statistically significant (P = 0.002).

Figure 2. X-ray of fracture radius showing complete disappearance of fracture line

Figure 3. X-rays of a comminuted ulna fracture requiring two titanium elastic nailing system (TENS) nails

The progression of the DASH score over the follow-up period shows a substantial improvement in the DASH scores, reflecting better functional outcomes and decreased disability. By 12 weeks, the majority of participants (66.66%) scored below 20 (Table 4), indicating significant functional recovery.

Table 4. Disabilities of the Arm, Shoulder, and Hand (DASH) scores at 6th and 12th weeks of follow-up

DASH score	6 week [n (%)]	12 week [n (%)]
0-10	0 (0)	4 (13.33)
11-20	5 (16.67)	16 (53.33)
21-30	10 (33.33)	7 (23.33)
31-40	15 (50.00)	3 (10.00)
41-50	0 (0)	0 (0)
Mean	30	17

DASH: Disabilities of the Arm, Shoulder, and Hand

The mean DASH score decreased consistently, illustrating the overall reduction in disability and enhancement in limb function over time. The difference between the mean DASH score at one week, six weeks, and 12 weeks was statistically significant (P < 0.0001).

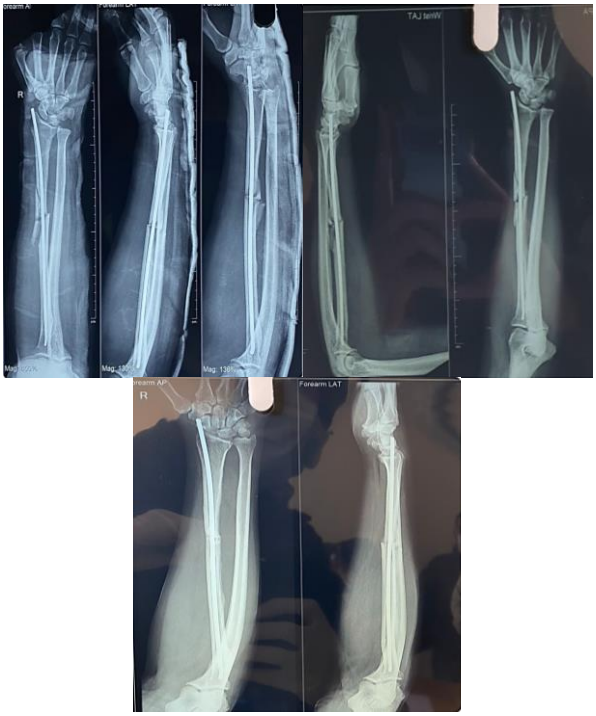

Figure 4. X-ray showing comminuted radius fracture in various stages of healing

Figure 5. X-ray of comminuted ulna fracture in a 35-year-old man showing early signs of union at 6 weeks with a single titanium elastic nailing system (TENS) nail in situ; but even at this stage, the functional outcome is satisfactory

The data of the mRUST score, adapted for assessing the healing of forearm fractures, indicate a statistically significant progression in bone healing over the 12 weeks ($P < 0.001$). By six weeks, all participants scored between eight and ten, indicating substantial progress. By 12 weeks, all scores were 11 or higher (Table 5), suggesting near-complete to complete bone healing in all participants.

Table 5. Modified Radiographic Union Score for Tibial fractures (mRUST) scores at 6th and 12th weeks of follow-up

mRUST score	6 week [n (%)]	12 week [n (%)]
4	0 (0)	0 (0)
5	0 (0)	0 (0)
6	0 (0)	0 (0)
7	0 (0)	0 (0)
8	10 (33.33)	0 (0)
9	14 (46.67)	0 (0)
10	6 (20.00)	0 (0)
11	0 (0)	11 (36.67)
12	0 (0)	8 (26.67)
13	0 (0)	5 (16.67)
14	0 (0)	6 (20.00)

mRUST: Modified Radiographic Union Score for Tibial fractures

In the present study, the time for radiological union of fractured bone ranged from a minimum of eight weeks to a maximum of 16 weeks (15 weeks ± a few days). The mean time for union was 11.6 weeks. Among the 30 participants enrolled in the present study, a total of six participants (20.0%) developed minor complications during the follow-up (Table 6).

Table 6. Complications

Complications	n (%)
No	24 (80.00)
Yes	6 (20.00)
Type of complications	
Skin irritation at the radius entry point	1 (3.33)
Ulnar bursitis	2 (6.67)
Elbow stiffness	3 (10.00)

Table 7 shows the outcome of the study by the type of bone fractured. These results suggest that fractures involving only the ulna tend to heal with a higher mRUST score, indicating better radiographic union, and a lower DASH score, indicating better functional recovery. Fractures of both bones took longer to achieve union compared to fractures involving a single bone.

Table 7. Type of bone fracture and outcome

	Both bones	Radius	Ulna	Total
mRUST score at 12 weeks	11.5	11.9	12.5	12.2
DASH score at 12 weeks	18.4	16.1	14.4	17.2
Time to union of bone (week)	12.1	11.0	11.1	11.6

mRUST: Modified Radiographic Union Score for Tibial fractures; DASH: Disabilities of the Arm, Shoulder, and Hand

Discussion

The concept of biological internal fixation utilizing flexible TENS allows for internal splintage without compression, thereby reducing the necessity for anatomically precise reductions and minimizing surgical trauma. This approach fosters an optimal environment for callus formation and bone healing by avoiding extensive dissection and periosteal stripping often associated with conventional compression plate osteosynthesis, which can lead to complications such as infection, bone necrosis, and delayed union or non-union. The stiffness of the implant is influenced by its geometric dimensions and the Young's modulus of the material used. Initial efforts using 316L stainless steel nails for forearm fracture fixation exhibited varying degrees of delayed union or non-union due to the implant's rigidity, which impedes load-dependent displacement of the fracture site, thus adversely impacting healing in accordance with Perren's Interfragmentary Strain Theory (6). TENS becomes constrained by the medullary canal of the radius and ulna through three-point pressure on the bone, that makes it different from other varieties of rigid and locked IM nails.

Saka et al. demonstrated excellent clinical results in isolated diaphyseal radius, isolated diaphyseal ulna, and both-bone forearm fractures using a specially designed IM nail, which allowed for static locking by placing a screw inside an oblique hole at one end of the nail (7-9). These findings underline the adaptability of IM nails for adult diaphyseal forearm fractures when designed appropriately. A comparative study by Köse et al. evaluating IM nailing versus ORIF in adult forearm diaphyseal fractures (radius and/or ulna) showed significantly better outcomes in the IM group in terms of union time, operative time, and intraoperative bleeding, without compromising functional outcomes (10). This study utilized specially designed nails with locking capabilities as well, further validating the practicality of such implants in adults. In a separate cohort study by Huang et al., involving five patients with proximal radial shaft fractures, the titanium elastic nail was found to be a viable alternative to conventional methods, demonstrating acceptable union rates and satisfactory functional recovery (11). Despite the small sample size, these results further support the exploration of TENS in adult cases.

In our study, the average surgical duration was 34.6 minutes, with slightly higher times for both-bone fractures (53.3 minutes) compared to the isolated radius (42 minutes) and ulna (26.3 minutes) fractures. Similarly, blood loss remained minimal across all groups, averaging 12.8 ml. These results align with the findings of Sharma et al., who emphasized the benefit of reduced operative time and minimal blood loss when using TENS in elderly patients (12). Additionally, Richter et al. reported that IM nailing offered substantial soft tissue preservation, especially valuable in osteoporotic bone (13). The insertion of an IM interlocking nail typically requires reaming the medullary canal, a process that can lead to increased blood loss due to the more invasive nature of the procedure. In contrast, titanium elastic nail insertion is generally less invasive, utilizing smooth oscillating movements, which tend to result in less blood loss. Postoperative recovery was also favorable, with 93.34% of patients discharged within three days. This swift recovery underscores the minimally invasive nature of the procedure and its contribution to early mobilization.

Ahmar et al. similarly noted that the use of TENS in adult long bone fractures supported early ambulation and shortened hospital stays (14). These short admissions not only benefit patients clinically but also offer economic advantages through reduced hospitalization costs.

The percentage of patients achieving "excellent" outcomes rose from 50% at six weeks to 73.33% at 12 weeks, with the number of "unacceptable" ratings dropping to zero by six weeks. These results highlight consistent functional gains, echoing the outcomes reported by Patel et al., who documented similar progressive recovery patterns in humeral fractures treated with TENS (15). The ability of TENS to support both fracture stability and early functional rehabilitation is especially valuable in maintaining limb use during healing. DASH scores further corroborate these functional improvements. The mean score decreased from 30 at six weeks to 17 by 12 weeks, with a majority of patients (66.66%) reporting scores under 20 at the final follow-up. This trend reflects a significant decline in disability over time. These findings mirror those of Huang et al., who reported favorable DASH outcomes in adults with proximal radial fractures managed with titanium elastic nails (11). Similarly, Ahmar et al. found consistent DASH score improvements in diaphyseal humerus fractures, reinforcing the broad applicability of TENS in upper limb diaphyseal fractures (14).

Radiographic union, as assessed by the mRUST score, demonstrated clear progression from early healing stages at six weeks (scores 8-10) to complete or near-complete union by 12 weeks (scores 11-14). This supports the biomechanical soundness of TENS in facilitating callus formation and cortical bridging. Jain et al. observed comparable radiographic trends in pediatric forearm fractures, with mRUST scores improving significantly over time (16). While their study involved children, the parallel in healing trajectories suggests that the biological fixation principle underlying TENS is effective across age groups. Fracture union was achieved between eight to fifteen weeks in all participants, with a mean time of 11.6 weeks. These findings closely align with those of Huang et al. (11) and Richter et al. (13). Factors such as minimal periosteal stripping, adequate canal filling, and implant elasticity likely contributed to an efficient union, as previously discussed by Behnke et al., who emphasized the importance of preserving biology during fixation (17).

Complication rates remained low. Only six out of 30 participants (20.0%) experienced minor complications, including elbow stiffness and soft tissue irritation. Importantly, all were managed conservatively. These rates are in line with those reported by Patel et al. in a systematic review comparing IM nailing and plating in pediatric forearm fractures (18). Furthermore, Furlan et al. confirmed that elastic nails generally resulted in fewer complications due to reduced hardware prominence and better tolerance (19).

Table 7 compares outcomes based on the bone involved. Isolated ulna fractures had the best results with the highest mean mRUST score (12.5) and the lowest DASH score (14.4). Both-bone fractures, predictably, had slightly longer union times (mean: 12.1 weeks). These findings support the conclusions of Sharma et al. (12) and Antabak et al. (20), who reported that single-bone fractures tended to have more predictable healing and better early functional outcomes due to reduced mechanical complexity and implant stress distribution.

TENS is particularly beneficial for patients with specific conditions beyond typical forearm fractures. These include patients with multiple trauma who require short operative times, patients with uremia with arteriovenous shunts who need to minimize soft tissue dissection and blood loss, and individuals with preoperative soft tissue swelling or extensive fractures requiring long plates. Additionally, TENS is advantageous for patients prioritizing cosmetic outcomes, especially women, as it involves limited soft tissue dissection. The rate of refracture after implant removal is also very low compared to plating. Overall, TENS offers a valuable treatment option for these unique patient populations.

This study had several limitations, including a small non-probability convenience sample of only 30 patients, a lack of a control group treated with ORIF and plate fixation, a short follow-up period, and an inability to accurately quantify radiation exposure. These limitations may impact the study's findings and generalizability, and highlight the need for a statistically stronger study with a large sample size, a control group, and longer follow-up.

Conclusion

Patients treated with the TENS showed rapid and significant improvements in functional outcomes (Grace-Eversmann, DASH) alongside faster radiological union (mRUST), with a mean union time of 11.6 weeks. The technique offered advantages such as shorter surgery duration, minimal blood loss, and early discharge. Its minimally invasive nature facilitates early mobilization and quicker return to daily activities. Given the low complication rates and high patient satisfaction, the TENS is a reliable and effective option for managing adult forearm fractures.

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgements

The study was approved by the Institutional Ethics Committee (MMMCH/IEC/22/582).

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