

## Surgical Outcome of Forearm Fractures Treated With Titanium Elastic Nailing System (TENS)

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### ABSTRACT

**BACKGROUND:** Forearm fractures are the most common fracture in adults due to high energy road traffic accidents (RTA), fall injury and sports related injury. Open reduction and plate osteosynthesis is the gold standard treatment of forearm bone fracture. Closed surgical procedure with titanium elastic nailing system (TENS) has advantages of minimal tissue dissection, shorter operative time, rapid union, excellent recovery of range of motion and better cosmetic outcome compared to ORIF with plating. This longitudinal study was intended to evaluate the surgical outcome of adults forearm fractures treated with TENS.

**METHODS:** This hospital-based, longitudinal, observational study was conducted in Department of Orthopaedics UCMS-TH from December 2018 to April 2020. After ethical clearance (UCMS/

IRC/205/18) from Institutional Review Board (IRB) of UCMS-TH and informed written consent, all patients with forearm fractures who fulfilled the inclusion criteria were enrolled in this study and treated with TENS. Post operatively the patients were followed at 6 wks, 3 months, and 6months for clinical, radiological and functional assessment as per Grace and Eversman Scoring System. Descriptive statistics like frequency, percentage, mean and standard deviations were used to analyze the data and association between different variables was assessed by Chi-square test and paired t-test. P-value < 0.05 was accepted as statistically significant.

**RESULTS:** In this study of 120 cases, the mean age was 29.53 ± 10.598 years. RTA was the most common mode of injury (76.7%). Most of the cases were of right side (73.3%) and AO/OTA Type A (56.7%). The majority of cases (43.33%) were operated within first day of trauma. The mean duration of surgery was 58.67 ± 13.767 minutes and mean duration of hospital stay was 2.60 ± 0.77days. The mean duration of union was 8 weeks. The most common post op complication was skin irritation at entry site (66.7%). There was no any significant major complication. The functional outcome evaluated according to Grace and Eversman Scoring System at the end of 6 months found good result in 46.67%, Excellent in 30% and Fair in 23.33%. Pain assessment by VAS score in each follow up 6wks, 3months and 6 months significantly decreased. The paired T-test showed the mean difference was statistically significant ( $p < 0.005$ ). The association between Type A and Type B fracture was found to be statistically significant in terms with fracture union, duration of surgery and duration of hospital stay ( $p < 0.005$ ).

**CONCLUSIONS:** Titanium elastic nailing system (TENS) has good functional and radiological outcome. Being minimally invasive, preservation of fracture hematoma, no periosteal stripping, minimal operative time and duration of hospital stay, less chance of refracture during implant removal it can adopted as an alternative to ORIF with plate osteosynthesis in treating adults forearm fracture.

**Key words:** Forearm; Fracture; TENS; Functional Outcome

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## INTRODUCTION

The forearm plays an important role in positioning of the hand in space by flexion and extension of the elbow and wrist as well as pronation and supination through the proximal and distal radioulnar joint<sup>[1]</sup>. The forearm bone fracture can therefore result in significant dysfunction if treated inadequately<sup>[2]</sup>. Hence good anatomical reduction and internal fixation of these fractures are necessary to restore function<sup>[3]</sup>.

The average yearly incidence of adults diaphyseal forearm fracture above the age of 20, remains below 2 per 10,000 people<sup>[4,5]</sup>. Many studies have shown that forearm fracture is predominantly more common in male as compared to female. The proportion of males patient ranges from 63% to 91%<sup>[6]</sup>. The majority of forearm fracture occurs between first four decades of life ranging from 24 to 37 years of age<sup>[7,8]</sup>. The most common cause of forearm fracture is high-energy trauma such as motor vehicle accidents or sports injuries<sup>[9,10,11]</sup>.

Forearm fracture in which adequate alignment cannot be achieved or maintained by closed means are treated with operative intervention which includes intramedullary (IM) nailing or open reduction and plate osteosynthesis<sup>[3]</sup>. Although the choice of implant for treatment of forearm fracture is plate osteosynthesis, complication like infection, soft tissue stripping, disturbance of fracture hematoma and chances of refracture during implant removal are associated with such treatment<sup>[12]</sup>. Another treatment option is TENS, intermedullary nailing which has advantages like minimal tissue dissection, shorter operative time, rapid union, excellent recovery of range of motion and smaller incisions leading to better cosmetic compared to ORIF with plating<sup>[13,14]</sup>. TENS is not only cost-effective but also involves simple technique with minimal need for soft tissue dissection and early fracture union due to its elasticity and repeated micro-motion at the fracture site<sup>[15,16]</sup>. TENS acts as an internal splint aligning the fracture fragments. It can also be prebend to achieve the three-point fixation<sup>[17,18]</sup>. Hence, it becomes the choice of stabilization of forearm fractures and has been used in this study as an option for treatment of adult forearm bone fracture which may overcome the disadvantages of plate osteosynthesis in future.

## METHODS

### Study Design/ Place and Duration of Study

This prospective hospital-based, longitudinal and observational study was carried out in the Department of Orthopedics of UCMS-TH, Bhairahawa, Nepal from December 2018 to April 2020.

### Ethical Approval and Patient Consent

After Ethical clearance (UCMS/IRC/205/18) from the Institutional Review Board (IRB) of UCMS-TH, all patients with forearm fracture who fulfilled the inclusion criteria were enrolled in the study. Patients were informed about the purpose of the study and written consent was taken. Cases were admitted either via the Outpatient department (OPD) or the Emergency department of UCMS-TH. Data collection was done by the researcher.

### Sample Size and Sampling Technique

The targeted sample size after using the sample size formula was 30. Convenient sample of 120 patients was selected by using the purposive sampling technique.

$$n = \frac{z^2 pq}{d^2}$$

n=required sample size p=prevalence of diaphyseal forearm bone fracture (2%)<sup>[19]</sup>.

$$q = 100 - p = 100 - 2 = 98 \quad z = 1.96 \text{ taken at 95\% confidence interval}$$

$$d = \text{allowable error taken as 5\% } n = \frac{1.96^2 \times 2 \times 98}{5^2} = 30$$

### Inclusion Criteria

Patient with diaphyseal forearm bone fracture (single bone or both bone)

Patient age of 18 years or more

### Exclusion Criteria

Undisplaced forearm fracture

Open fracture

Patient age less than 18 years

Fracture located other than diaphysis of forearm

### Patient Management and Surgical Technique

All procedures were performed under regional anesthesia. Patient was placed in supine position on the operative table with the arm on an arm-board. Pneumatic tourniquet was applied in the arm so as to reduce blood loss and facilitate working surgical field for better assessment of entry point.

For Radius nailing, around 2cm longitudinal incision was made over the palpable dorsal tubercle of radius. Next, the subcutaneous tissue was spread and fascia incised to expose the dorsal tubercle. After retracting the incision, the awl was directly placed on the tubercle adjacent to the third compartment containing the extensor tendons. The awl was directed antero-medially as it drills to perforate the posterior cortex. At this point it is important to be careful not to perforate opposite cortex. Under C arm guidance, the nail was introduced and advanced proximally till the fracture. The fracture was reduced and the nail advanced proximally to the level of radial tuberosity and the tip was directed towards the ulna.

For Ulna nailing, around 2cm longitudinal incisions was given 0.5 cm proximal to olecranon tip. Subcutaneous tissue retracted and entry point was made inserting the bone awl directed obliquely in a distal direction. The nail was inserted and advanced to the distal fracture site. Under the C arm guidance fracture was reduced and the nail was advanced distally to the distal ulnar metaphysis. The nail was secured in the strong cancellous metaphyseal bone with the tip rotated towards radius to produce maximum spreading of the interosseous membrane. X-ray of the forearm in AP view and lateral view was taken of the affected forearm on the day of surgery (Figure 1). Post operatively patient was kept under above elbow posterior slab for a period of 6weeks. The dressing was done on the 2<sup>nd</sup>, 4<sup>th</sup>, 8<sup>th</sup>, 12<sup>th</sup> and 14<sup>th</sup> postoperative day & later depending on the condition of the wound. Total suture removal was done on the 14<sup>th</sup> postoperative day & on the 21<sup>st</sup> postoperative day in cases of delayed wound healing. The patient was discharged depending upon the condition of the wound & the extent of swelling or other associated conditions.

The patients were followed up at two weeks for suture removal & then at 6weeks, 3 months and 6months. Active exercises were started at approximately 6 weeks postoperatively and strengthening or resisted exercises were started around 10 to 12 weeks after surgery. Standard antero-posterior & lateral radiograph of the affected forearm were done on each follow up (Figure 2, 3, 4). The clinical and radiographic results were recorded during each follow-up to ensure that no intramedullary nail has migrated, no loss of reduction has occurred, evidence of callus formation and consolidation of fracture.

A functional assessment using Grace and Eversman scoring system

was done at 6 months and pain assessment done at each follow up by VAS scoring. Any complications such as infection or hardware complications that occurred were recorded.

### Statistical Analysis

All the data was collected using preformed Pro-forma that included patients' demographic profile, general history, clinical & radiological

findings, its management & regular follow up. Data were entered and analyzed by SPSS Vs.20. Descriptive Statistics like frequency, percentage; mean and standard deviation were used to analyze the data. Chi-Square test, Independent sample t-test, and ANOVA tests were used as inferential statistics. P-value less than 0.05 were considered statistically significant.



Figure 1 PRE-OP X-RAY.



Figure 3 3 Months POST-OP X-RAY.



Figure 2 6 Weeks POST-OP X-RAY.



Figure 4 6 Months POST-OP X-RAY.

## RESULTS

In the present study, 60% of the patients were between 18-28 years of age with mean age  $29.53 \pm 10.59$  (18-55) years. There were 96 males (80%) and 24 females (20%) with male to female ratio 4:1. Major cause of fracture was RTA (76.7%) followed by fall injury (23.3%). Based on AO/OTA classification 68 cases (56.67%) were type A. Out of a 120 patients, majority of cases had injury of the right forearm (73.3%). In this study, 52 cases (43.33%) operated within first day of trauma while 48 cases (40%) operated in second day of trauma and 20 cases (16.67%) operated in third day of trauma with a mean of  $1.73 \pm 0.74$  days between trauma and surgery. Majority of cases (56.67%), surgeries were completed within 60 minutes with mean duration of surgery  $58.67 \pm 13.77$  (45-90) minutes. Mean duration of hospital stay was  $2.60 \pm 0.77$  (2-4) days

X-ray of AP and lateral view of the affected side done post operatively and each follow up at 6 weeks, 3months and 6months post operatively. Radiological union by callus formation was assessed at the end of 6weeks, 3months and 6months on radiograph taken in antero-posterior and lateral views. The average mean duration of fracture union was 8 (6-12) weeks.

**Table 1** GRACE&EVERSMANN SCORING SYSTEM.

1) Degree of supination and pronation		
RATING	RANGE OF MOVEMENT	SCORE
EXCELLENT	>80	4
GOOD	60 - 80	3
FAIR	40 - 60	2
POOR	>40	1
2) RADIOLOGICAL UNION (End of 6th week)		
RADIOLOGICAL UNION	SCORE	
UNION PRESENT (Good Callus)	2	
NON-UNION (No visible callus)	1	
3) RANGE OF MOVEMENT- ELBOW		
RANGE	RESULT	SCORE
Flexion > 120	Excellent	4
Flexion 100 - 120	Good	3
Flexion 80 - 100	Fair	2
Flexion <80	Poor	1
FINAL ANALYSIS		
RESULT	SCORE	
EXCELLENT	10	
GOOD	8-9	
FAIR	6-7	
POOR	<5	

**Table 2** Association between Fracture Type and Duration of Fracture Union.

Type of Fracture (AO/OTA)	Duration of fracture union		P value
	6 Weeks	12 Weeks	
Type A	9 (52.9%)	8 (47.1%)	0.03
Type B	7 (100%)	0 (0%)	
Type C	4 (66.7%)	2 (33.3%)	

**Table 3** Association between Fracture Type and Final Outcome.

Type of Fracture (AO/OTA)	Final Outcome			P value
	Excellent	Good	Fair	
Type A	4 (23.5%)	7 (41.2%)	6 (35.3%)	0.268
Type B	3 (42.9%)	4 (57.1%)	0 (0%)	
Type C	2 (33.3%)	3 (50%)	1 (16.7%)	

Out of 120 the majority of the cases ( $n = 80$ ; 66.7%) had skin irritation at entry site, 28 cases (23.3%) had olecranon bursitis, 12 cases (10%) complained of ulna TENS pull out. No other major complications were encountered.

Pain assessment was done using Visual analogue scale. In this study of 120cases, all the patients were evaluated for pain with Visual Analogue Scale (VAS) in each follow-up at 6week, 3 months, and 6 months. The paired T-test showed the mean difference was statistically significant ( $p$  value = 0.005). Pain significantly decreased during 3 months and a 6-month follow-up.

In this study of 120 cases followed up for 6 months postoperatively, the outcome was evaluated according to Grace and Eversman Scoring system (GESS)<sup>[20]</sup> measured at the end of 6 months (Table 1). We found good result in 46.67% cases, excellent results in 30% cases, Fair in 23.33% cases. The mean Grace and Eversman score were 8.57.

Association between fracture type and duration of fracture union (Table 2) is significantly associated ( $p = 0.030$ ). All of the patients with type B fracture ( $N=28$ ) had fracture union within six weeks. Majority of the type C ( $N=16$ ; 66.7%) and Type A ( $N=36$ ; 52.9%) patients also had fracture union within six weeks.

Final outcome was categorized as Excellent, good and fair based on Grace and Eversman Scoring system (Table 3). There was no significant association between fracture type and final outcome ( $p = 0.268$ ).

Association between fracture type and duration of surgery (Table 4) is significantly associated ( $p = 0.014$ ). The majority of type A fracture (82.4%) required less than an hour for surgery whereas most of the type B (71.4%) and type C (66.7%) took 60-90 minutes for the procedure.

The association between fracture type and duration of hospital stay (Table 5) is significantly associated ( $p = 0.003$ ). The majority of Type A fracture (82.4%) has less than 2 days of hospital stay and most of type B and type C has 3-5days of hospital stay.

The association between fracture type and post operative complications (Table 6) is not significant ( $p = 0.765$ ). The complications noted were skin irritation at entry site, olecranon bursitis and ulna TENS pull out.

**Table 4** Association Between Fracture Type and Duration of Surgery.

Type of Fracture (AO/OTA)	Duration of Surgery		P value
	<60 min	60-90 min	
Type A	14 (82.4%)	3 (17.6%)	0.014
Type B	2 (28.6%)	5 (71.4%)	
Type C	2 (33.3%)	4 (66.7%)	

**Table 5** Association Between Fracture Type and Duration of Hospital Stay.

Type of Fracture (AO/OTA)	Duration of Hospital Stay		P value
	<2 Days	3-5 Days	
Type A	14 (82.4%)	3 (17.6%)	0.003
Type B	2 (28.6%)	5 (71.4%)	
Type C	1 (16.7%)	5 (83.3%)	

**Table 6** Association between Fracture type and post op complication.

Type of Fracture (AO/OTA)	Post-op Complications			P value
	Skin irritation at entry site	Olecranon bursitis	Ulna TENS pullout	
Type A	13 (76.5%)	3 (17.6%)	1 (5.9%)	0.765
Type B	4 (57.1%)	2 (28.6%)	1 (14.3%)	
Type C	3 (50%)	2 (33.3%)	1 (16.7%)	

## DISCUSSION

In our study, the patients ranged from a minimum age of 18 years & maximum age of 55 years. The mean age was 29.53 years. The commonly involved age group of forearm bone fracture was 18-28 years accounting 60% of study population which was similar to the study conducted by Chouhan *et al*<sup>[21]</sup> in which age group involve was found 18-45 yrs (68.33%). This may be accounted to the fact of social and physical activeness of this particular age group of people.

In this study, Males (80%) were found to injured commonly in a ratio of 4:1 which was similar to the study done by Chouhan *et al*<sup>[21]</sup> in which male predominance was found 78.33% of study population. The predominance of male patients over females could be due to Nepalese males being more active outdoors than female counterparts. In this study, right forearm (73.3%) was the common site of injury of forearm bone fracture which is similar to the study done by Ruhullah *et al*<sup>[22]</sup> in which right sided involvement is present in 46 cases (58%) and 33 cases (53.33%) by Chouhan *et al*<sup>[21]</sup>. The right sided predominance is due to fact that there is frequent use of dominant hand during fall or other injuries.

In this study, the major cause of fracture was road traffic accidents (76.7%) followed by fall injury (23.3%) which was similar to the study done by Chouhan *et al*<sup>[21]</sup> 29 (48.33%) patient had RTA. The higher incidence of road traffic accidents in our study could be explained by higher vehicular accidents & poor road conditions in our country<sup>[23]</sup>.

In our study pain assessment was done using Visual analogue scale (VAS). In this study of 120 cases, all the patients were evaluated for pain with Visual Analogue Scale in each follow-up at 6 weeks, 3 months, and 6 months. Compared between 6 weeks and 3 months the mean difference between the group was 2.0 and was statistically significant ( $p < 0.001$ ). Compared between 3 months and 6 months the mean difference between the group was 2.23 and was statistically significant ( $p < 0.001$ ). It showed that there was a significant decrease in pain for 3 months and a 6-month follow-up.

In this study, 56.67% were of AO/OTA type A, followed by type B (23.33%) and type C (20%) which was similar to the study done by Blazevic *et al*<sup>[24]</sup>. in which AO/OTA type A accounts maximum case of 47.92%.

In this study 52 cases (43.33%) were operated within first day of trauma 48 cases (40%) were operated in second day and 20 cases (16.67%) were operated in third day of trauma which was similar to the study done by Shah *et al*<sup>[25]</sup> in which average duration of trauma and surgery was 4.0 days (range, 0-6 days).

In this study maximum duration of surgery was 90 minutes and the minimum duration was 45 minutes. The majority (56.67%) of surgeries were completed within 60 minutes. The mean duration of surgery was 58.67 minutes with a standard deviation of 13.767 minutes. This is similar to the study done by Fernandez *et al*<sup>[26]</sup> in which average duration of surgery was  $48 \pm 20.25$  (19-90) mins and  $43 \pm 15.30$  minutes in Bhuria *et al*<sup>[27]</sup>. The average duration of surgery in case of ORIF with plate osteosynthesis is  $78 \pm 28.65$  min (37-145) min according to study by Fernandez *et al*<sup>[26]</sup> 80.67 minutes (S.D.  $\pm 12.288$ , range 60-90 minutes) according to Chaudhary P *et al*<sup>[28]</sup> 132.6 minutes (95-175 minutes) according to Reinhardt *et al*<sup>[29]</sup>. Therefore, intramedullary titanium elastic nail has less duration of surgery time as compare to ORIF.

In this study, the maximum duration of hospital stay was 4 days & the minimum was 2 days with a Mean of 2.60 days and a Standard deviation of 0.77 which was similar to study done by Fernandez *et al*<sup>[26]</sup>. in which average duration of hospital stay was  $4.33 \pm 2.50$  days

and 1.6 days (range, 0-4 days) in Shah *et al*<sup>[25]</sup>.

In this study, callus formation at 6 weeks postoperative was assessed on radiographs taken in antero-posterior & lateral views of forearm. At the end of 6 weeks 80 (66.67%) callus formation seen in AP and lateral views X-ray. The average mean duration of fracture union was 8 weeks, which ranges from 6 weeks to 12 weeks which was similar to the study done by Bhuria *et al*<sup>[27]</sup>. in which average time of union was 8 weeks and in Chouhan *et al*<sup>[21]</sup> it was 10 weeks (ranges, 8 to 16 weeks).

In this study, out of 120 patients 80 (66.67%) had superficial skin irritation at entry site, 28 (23.3%) had olecranon bursitis and 12 (10%) had ulna TENS pull out. No other major complication was encountered. The common encountered complication was skin irritation at entry site this may be attributed to the bare nail cut ends being exposed as nail end caps are not used in our study which was similar to the study done by Pan Bhuria *et al*<sup>[27]</sup> in which skin irritation and nail impingement (40% cases) has been found.

In this study of 120 cases followed up for over 6 months postoperatively, the outcome was evaluated according to Grace and Eversman scoring system at the end of 6 months. We found good results in 46.6% (56 patients), excellent in 30% (36 patients), fair in 23.33% (28 patients). The maximum score was 10 and minimum was 7. The mean Modified Grace and Eversman Scoring system was 8.57 and standard deviation was 1.165. Blazevic *et al*<sup>[24]</sup>. also reported union rate of 100% with Good to Excellent functional outcome.

## CONCLUSION

Titanium elastic nailing system (TENS) has good functional and radiological outcome. Being minimally invasive, preservation of fracture hematoma, no periosteal stripping, minimal operative time and duration of hospital stay, less chance of refracture during implant removal it can adopted as an alternative to ORIF with plate osteosynthesis in treating adults forearm fracture.

## LIMITATION

The limitations of present study are: Small sample size; Single centred study; The duration of follow-up was only 6 months, so the long-term outcome could not be evaluated. Lack of sufficient article regarding adult forearm bone fracture treated with TENS. No blinding techniques were used.

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