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Original Article

Functional Outcome of Titanium Elastic Nail Fixation in Diaphyseal Fractures of Forearm in Adolescents

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ABSTRACT

Introduction: This study aims to assess the functional outcomes of Titanium Elastic Nailing System (TENS) fixation for managing diaphyseal forearm fractures in adolescents.

Method: The study was a prospective clinical study conducted at B.P. Koirala Institute of Health Sciences Between December 1, 2020, and November 30, 2021. Ethical clearance was obtained from the Institutional Review Committee (Registration Number 305/077/078-IRC). A total of 27 patients who underwent TENS fixation for forearm diaphyseal fractures were included. Patients were followed at 2 weeks, 6 weeks, 12 weeks, and 24 weeks. Radiological and functional outcome evaluations were assessed, including the range of motion, deformity, and time taken for union and active recovery. Collected data were entered in Microsoft Excel and converted to SPSS (Statistical Package for Social Sciences) version 28 for statistical analysis.

Results: Among 27 included patients, 66.7% were males, 81.5% were within the age group of 10-13 years, 70.4% fell on outstretched hands, and 66.7% had fractures at the middle third of the forearm. Union was seen in 6 weeks among 29.6%, 12 weeks among 66.6%, and 24 weeks among 3.8%—7.4% developed complications.

Conclusion: TENS is an effective fixation method for diaphyseal forearm fractures in adolescents and provides satisfactory functional outcomes.

Keywords: Adolescents; Forearm bone fractures; Functional outcome; TENS

INTRODUCTION

Forearm diaphyseal fractures account for 13-40% of all pediatric fractures.[1] Adolescents aged 12 to 16 years are at a higher risk and pose more significant challenges in the treatment.[2] Although closed reduction and cast or splint application remain the first line of treatment in young children, treatment in adolescents remains controversial.[2-4] There is a higher risk of malunion and poor functional outcomes with only conservative methods.[5,6] Open reduction and plate fixation have drawbacks of extensive surgical dissection, unwanted scars, potential neurovascular injury, muscle fibrosis leading to limited motion, subsequent major surgery for implant removal, refracture after plate removal, and peri-implant fractures if the plate is not removed.[3,7] In contrast, the Titanium Elastic Nailing System (TENS) has gained popularity and created a paradigm shift in managing such fractures in adolescents because of its minimal invasiveness.[8]

TENS can provide adequate stability, allowing early mobilization and return to normal activities.[9] However, the functional outcomes following TENS fixation are poorly investigated, especially in our context. So, this study aims to assess TENS fixation's clinical and functional outcomes for managing diaphyseal forearm fractures in adolescents.

METHODS

The prospective clinical study was conducted in the Department of Orthopaedics, B.P. Koirala Institute of Health Sciences, Nepal, between December 1, 2020, and November 30, 2021. Ethical clearance was obtained from the Institutional Review Committee (IRC) of B.P. Koirala Institute of Health Sciences (Registration Number 305/077/078-IRC). The study group includes patients between 10 and 16 years old with diaphyseal forearm fractures (proximal, middle, and distal third). Written informed consent was taken from parents or legal guardians. Patients presenting with open fractures, non-displaced fractures, neurovascular compromise and disorders, pathological fractures, previous

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surgery, comminuted fractures, segmental fractures, refractures, and open reduction cases were excluded from the study.

A Convenient sampling method was used. The sample size was calculated based on Goyal et al. (2019), who observed that 80% of the patients undergoing TENS fixation achieved excellent functional outcomes. [10]

Considering

P (proportion) =80%

Q (complement of P) =100-p=20%

L (Permissible error) =20% of P=16

By Formula:

Sample size (n) = Z^2PQ/L^2, where Z (95% confidence level) =1.96

= 24.01 = 24

The calculated minimal sample size was 24.

Initially, 32 patients were assessed for eligibility. Of 32 patients, 5 did not meet the inclusion criteria (2 had refracture, 2 had open fracture, and 1 had pathological fracture). So, 27 patients were included and underwent closed reduction and fixation with TENS.

The dual bone fixation technique involved first fixing the radius, which was more challenging, through an intramedullary approach using small nails. The entry site was confirmed under imaging, and the pin was manually advanced to the fracture site. After fixing the radius, the ulna usually reduces. Ulna was then set using antegrade nailing with fluoroscopic guidance. The protruding nail ends are trimmed and left slightly outside the bones for later removal. The technique aims to achieve stability and promote proper bone healing for fractures involving both the radius and ulna.

Patients were discharged on the second postoperative day after wound inspection, and most patients required no external immobilization. However, depending on fracture stability, in some patients above the elbow, Plaster of Paris (PoP) splints were applied for up to 3 weeks. Active motion commenced as soon as the patient was pain free and it was tolerated. They were followed-up in 2 weeks, 6 weeks, 12 weeks, and 24 weeks with an X-ray of the forearm that included wrist and elbow joint (AP and Lateral views) and looked for length, alignments, reduction, union, and callus formation.

The clinical and functional outcomes were assessed using the criteria of Anderson et al. [10,11] (Table 1)

Table 1 Classification of Functional Outcome

Result	Union	Flexion and Extension at the elbow	Pronation and Supination of the forearm
Excellent	Present	< 10° loss	< 25% loss
Satisfactory	Present	< 20° loss	< 50% loss
Unsatisfactory	Present	> 20° loss	> 50% loss
Poor	Non-union with or without loss of motion		

Collected data was entered in Microsoft Excel and converted to SPSS (Statistical Package for Social Sciences) version 28 for statistical analysis. For descriptive data, proportion, percentage, mean, and standard deviation were calculated.

RESULTS

Most patients were 10-13 years old, with a mean age of 11.45±1.74 years. Of the total, 66.7% of patients were male. It was noticed that injury to the right forearm was more common than to the left forearm, and the most common mode of injury was a fall on outstretched hands, while few were due to road traffic accidents, direct blows, and direct falls. It was noticed that the fracture site in 66.7% of cases was in the middle third, followed by distal third and proximal third of forearm bones. (Table 2)

Table 2 Demographics of the patients

Characteristics	Details	n (%)
Age (years)	10-13	22 (81.5)
	14-16	5 (18.5)
Gender	Male	18 (66.7)
	Female	9 (33.3)
Side Distribution	Right	17 (63)
	Left	10 (37)
Mode of Injury	Fall on outstretched hand	19 (70.4)
	RTA	6 (22.2)
	Others	2 (7.4)
Fracture Site	Proximal	3 (11.1)
	Middle	18 (66.7)
	Distal	6 (22.2)

Out of the total cases, most patients did not develop any complications, whereas only 1 (3.7%) developed a superficial infection and 1 (3.7%) bursitis. The fracture was united in 8 (29.6%) patients by 6 weeks, in 18 (66.6%) patients by 12 weeks, while it was observed by 24 weeks in one (3.8%) patient. No cases of non-union were observed. (Figure 1-5)

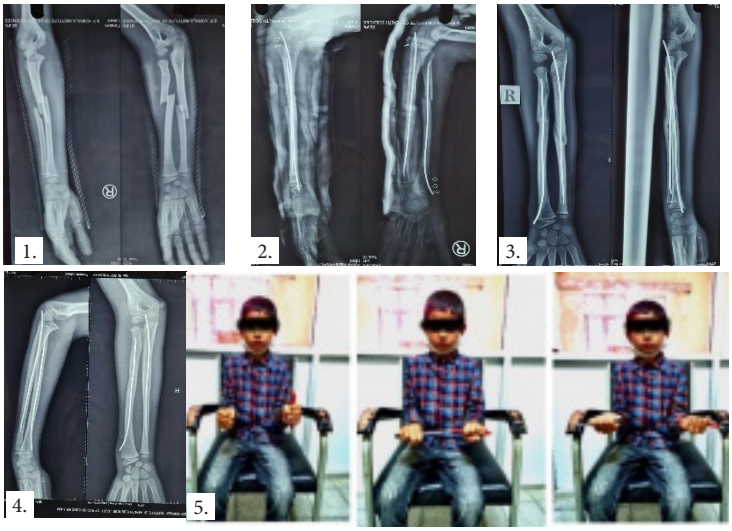

Figure 1-5: 1. Pre-operative radiographs (Lateral and AP) 2. Immediate post-operative radiographs (Lateral and AP) 3. Radiographs at six

weeks follow-up (AP and Lateral) 4. Radiographs at 24 weeks follow-up (Lateral and AP) 5. Range of motion of forearm at final follow-up

Range of motion of forearm (pronation and Supination): Most patients, i.e., 24(88.9%) cases, had a good range of motion (< 25 % loss), while 3 (11.1%) subjects had mild restriction (< 50 % loss), but no patients (0%) had severe condition (> 50% loss) during pronation and Supination of the forearm at final follow up in 6 months.

Range of motion at the elbow (Flexion and Extension): Most patients, i.e., 24 (88.9%) cases, had a good range of motion (< 10° loss), while 3(11.1%) subjects had mild restriction (< 20° loss), but no cases (0%) had severe condition (> 20° loss) during flexion and Extension at the elbow at final follow up in 6 months.

Functional outcome: Among the 27 patients analyzed at 3 and 6 months, the functional outcome evaluated by Anderson's Scoring system was excellent in 22 (81.5%) patients, satisfactory in 4 (14.8%) patients, and unsatisfactory result in 1 (3.7%) case with no poor outcome at 3 months. Whereas 24 (88.9%) subjects had excellent outcomes and 3 (11.1%) patients had satisfactory outcomes, none had unsatisfactory or poor results at 6 months. (Figure 6)

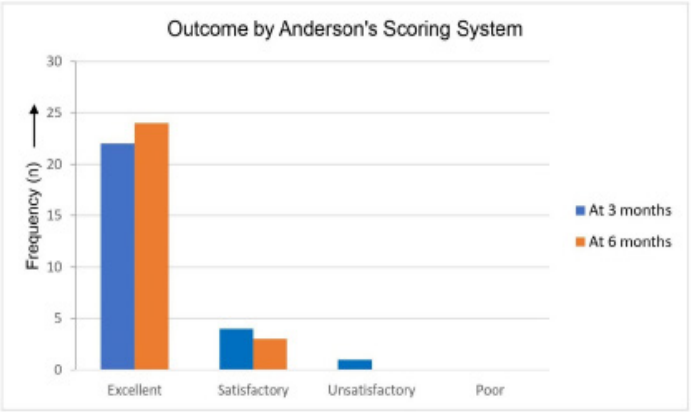

Figure 6: Bar diagram showing functional outcome by Anderson's scoring system

DISCUSSION

Although diaphyseal fractures of the forearm in adolescents are common in our hospital's emergency room, there is currently no strict protocol or guideline for their management, despite extensive research in this field. Standard reduction methods for most fractures in this age group are inconsistent, leading to indications for surgical intervention in many cases.[13] Numerous studies in the literature provide consistent results on various surgical options, which can assist clinicians in deciding the best treatment approach for forearm fractures. Younger children below ten tend to tolerate more significant deformities better due to better remodeling potential and are usually treated successfully with closed reduction and cast application.[10]

However, failures can still occur in older children managed with cast application despite good orthopedic intentions.[12] Adolescents beyond 16 years of age are often treated with plates and screws, which have few complications. The controversy lies in managing best forearm fractures in the age group of 10 to 16 years.[13] Intramedullary nailing with titanium elastic nails (TENS) has shown excellent results in both radiological union and functional outcomes compared to plate fixation, making it a recommended option for children between 10 and 16 years of age.[14]

Our study had a male predominance, with 18 (66.7%) cases being male patients. Similar male predominance was observed in other studies, such as the one by Goyal et al.,[10] which had 21 male and 9 female cases, as well as in the studies by Naorem et al. and Kumar et al., which reported 22 (73.33%) and 41 6(8.66%) male cases, respectively.[12,14] Most of the patients in our study were in the 10-12 age group, with a mean age of 11.45 years (S.D. 1.74 years). Other studies, such as the one by Vishwanath et al.,[15,] reported a mean age of 11.25 years in a study of 50 patients treated with closed reduction and internal fixation (CRIF) using TENS. Additionally, the studies by Myers et al. and Kruppa et al. reported mean ages of 10.75 and 9.7 years, respectively.[16,17] Most of the patients presented with an injury to the right forearm, the dominant side. The right side was injured in 17 (63%) patients, and the left in the remaining 10 (37%). In the study by Vishwanath et al.,[15] on the right side were injured in 56% of the cases, 40% of subjects had an injury on the left side, and 4% had a bilateral injury. Similarly, 19 out of 30 patients had right-sided injuries in the study conducted by Naorem et al., and Kumar et al. also observed right dominance in their research as 36 (60%) cases had right-sided injuries among the total 60 points.[12,14]

The most common mode of injury in our study was a fall on an outstretched hand, accounting for 70.4% of cases, followed by 22.2% due to road traffic accidents and 7.4% due to other modes of injury, such as a direct blow to the forearm or a natural fall from height. Similar findings were reported in the study by Vopat et al.,[1] where a fall on an outstretched hand was the most common mode of injury in 83% of cases, and in the study by Kruppa et al.,[17] where a fall on the hand accounted for 98% of cases.

Our study's most common fracture site was the middle third of the forearm in 66.7% of cases, followed by the distal third in 22.2%, and only 11.1% of cases involved the proximal third of the forearm. Similar patterns were observed in the study by Kumar et al.,[12] where fractures were in the distal third in 21.66% of cases, the middle third in 66.66% of cases, and the proximal third in 11.66% of cases. The middle third of the forearm was affected in 20 patients (66.66%), followed by a distal third in 6 patients (20%), and the remaining 4 cases (13.33%) had a fracture in the proximal third in a study carried out by Goyal et al.[10]

Most of the patients in our study (88.9%) had a good range of motion of the forearm and elbow at the final follow-up of 6 months, while only 11.1% had mild restriction of movement. Similar outcomes were reported in the study by Goyal et al.,[10] where 80% had a good range of motion, and 13.33%

had mild restriction of movement. Full range of motion of forearm, i.e., Supination and pronation, were seen in 83% of cases while the action was limited in 17% of patients in the study by Shah et al.[18] Similarly, there was a full range of motion of the forearm as well as elbow with the excellent outcome at the final follow-up, in a study by Purushothaman et al.[19] Twenty-six (86.67%) patients regained full range of motion, 3 (10%) patients had mild restriction of movements and 1 (3%) patient had moderate limitation of activities in a study conducted by Naorem et al.[14]

In our study, complications were rare, with only 3.7% of patients experiencing superficial infection and bursitis each, which were subsequently managed. We did not encounter difficulties such as compartment syndrome, implant breakage, implant migration, neurovascular injury, tendon injury, or refracture after implant removal. Similarly, the study by Goyal et al. reported one patient with a superficial infection and another with a non-union. In contrast, Vishwanath et al. said 10% of cases had a superficial infection at pin sites and 4% had refracture following implant removal.[10,15]

In our study, the outcome was excellent in 88.9% of patients, with the remaining 11.1% having a satisfactory outcome. None of the cases had an unsatisfactory or poor outcome. Similar results were found in other studies, such as the one by Goyal et al.,[10] where 80% had excellent results, and 13% had satisfactory outcomes.

This study has several limitations. As our research was carried out with a small sample size within a single institution, this precludes generalization of results. Also, there were no comparison groups in the form of conservative or plate fixation methods. We excluded open and comminuted fracture and open reduction cases from our study, which could make a difference in results. Moreover, the follow-up was done for a shorter period, during which complications like malalignment and associated wrist stiffness could not be appropriately assessed.

CONCLUSION

We conclude that TENS in both bone forearm fractures in the adolescent age group regarding union and range of motion is a minimally invasive and effective fixation method without a significant complication rate.

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