

Original research article**Study on management of pediatric long bone diaphyseal fractures using titanium elastic intramedullary nailing system****¹Dr. Konatham Bhaskar, ²Dr. V Divya, ³Dr. Kadeveti Sritej, ⁴Dr. Varakuti Santhi Swaroop**^{1,2} Assistant professor, Department of Orthopedics, ACSR Govt. medical college, Nellore, Andhra Pradesh, India³Senior resident, Department of Orthopedics ACSR Govt. medical college, Nellore, Andhra Pradesh, India⁴Assistant Professor, Department of Orthopedics, GMC Anantapur, Andhra Pradesh, India**Corresponding Author:**

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Abstract

Diaphyseal fractures of long bones are the most commonly encountered fractures in children. Although the majority of them are managed conservatively using traction, operative treatment is preferred, especially in adolescents. Various operative modalities are available of which titanium elastic intramedullary nailing (TENS) offers better outcomes.

Materials and methods: 30 children with diaphyseal fractures were admitted to the Department of Orthopedics, Andhra Medical College, Visakhapatnam, over 2 years. All of the patients were operated via TENS procedure and outcomes were assessed.

Results: The majority of the patients were between 6-10 years of age. Males were commonly involved. Road traffic accidents were the most common mode of trauma. Most of the fractures were transverse type. The median period from trauma to surgery was 3.96 days. The operating time was an average of 59.9 minutes. 9.26 days on average were spent in the hospital. All of the patients in the current study exhibited full ranges of motion. No patients had rotational malalignment, anteroposterior angulation, or varus or valgus angulation.

Conclusion: The TENS procedure offers minimal surgery time, minimal tissue dissection, and excellent treatment outcomes

Keywords: Diaphysis, fractures, children, TENS

Introduction

Fractures of the diaphysis of long bones are the most common fractures encountered in the pediatric age group. Trauma is the most common cause. The skeletal system in children is relatively immature, due to which it has a high remodeling potential for fractures in children ^[1]. Hence, fractures in children are usually managed conservatively.

For fractures in children below 6 years, conservative treatment like plaster casting, is the mainstay. However, managing long bone fractures for ages between 6-16 years is controversial. Conservative treatment remains the mainstay for long bone fractures in children below the age group of six years as the remodeling ability of the immature bone in children is excellent ^[2]. However, the ideal course of management of long bone fractures for ages between six years and 16 years is still disputed ^[3].

Children aged 6 years and above with displaced long bone fractures; require operative management to prevent complications like limb length discrepancy, non-union, mal-alignment, and growth disturbances ^[4,5]. Operative management is also preferred for early ambulation and shorter hospital stays to prevent psychological and social effects which are often associated with prolonged non-operative treatment methods. There are various operative treatment and fracture fixation methods available which can be customized according to patient age group, fracture pattern, associated injuries, and socio-economic factors ^[5].

Metazziau suggested managing diaphyseal long bone fractures in adolescents using intramedullary nailing. It is preferable over casting, as older children have a low tolerance for immobilization and casting. Moreover, there is less scope for mal-alignment correction in adolescents ^[6]. Many intramedullary nails, are available such as Rush nails and Ender's nails, for the treatment of long bone fractures in children, but they lack rotational stability. Titanium elastic intramedullary nailing (TENS) has a few advantages over other methods such as less intraoperative blood loss, shorter operative time, comparatively less pain, and shorter hospital stay ^[4].

The purpose of our study was to evaluate the functional and radiological outcomes of pediatric diaphyseal fracture of long bones treated with titanium elastic intramedullary nailing (TENS) and to assess the complications encountered in the procedure of TENS.

Patients and Methods

30 children and adolescents aged between 6-15 years, with fractures of diaphysis of the humerus, femur or tibia, or both forearm bones, who were admitted to the Department of Orthopedics, Andhra Medical College between August 2021 and August 2023, were included in the study after taking consent from their guardians. Patients with compound fractures, who are unfit for surgery, or patients whose guardians were not willing to participate in the study were excluded.

A specially designed Case Record Form (CRF) was used to collect all the necessary information from the participants, including their medical histories, clinical examinations, and any pertinent research. Under aseptic precautions, surgeries were performed. All cases were observed up to 24 weeks on follow-up.

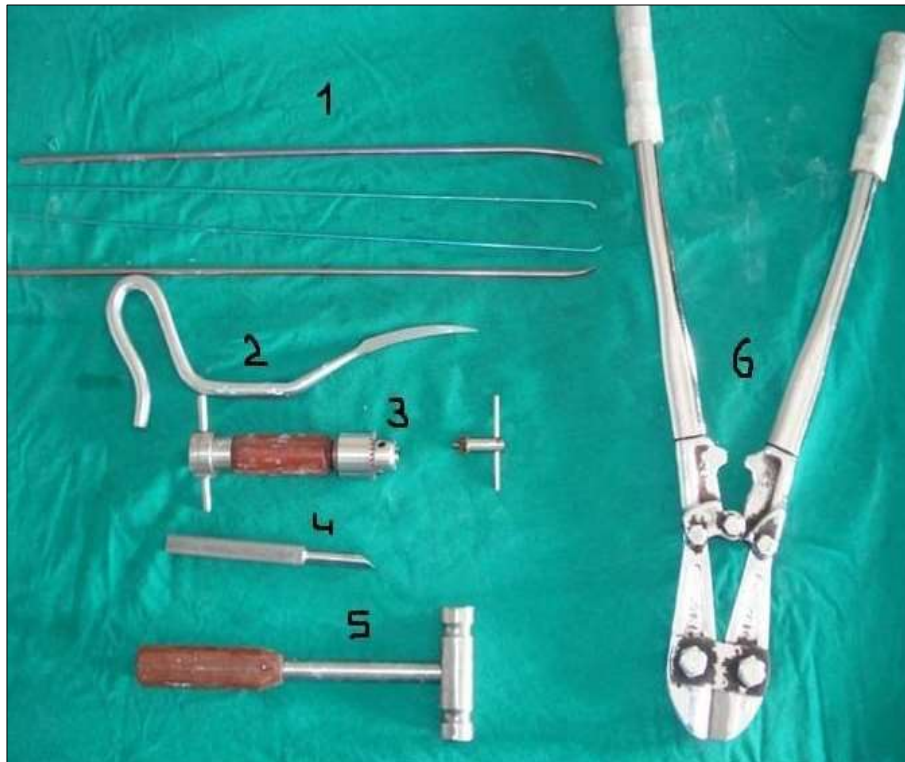
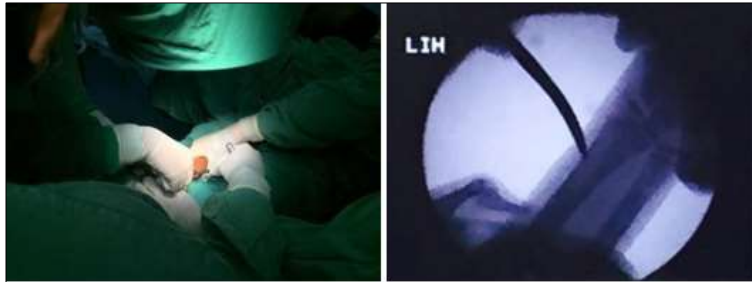


Fig 1: Titanium Elastic Nail System (TENS)





Making entry points in the bone with the help of Awl.



Insertion of Titanium nail with T handle



Cutting and then bending of remaining extra nail.



Incision and insertion of titanium nail for ulna.



C-arm view of the advancement of nails through the ulna & radius.

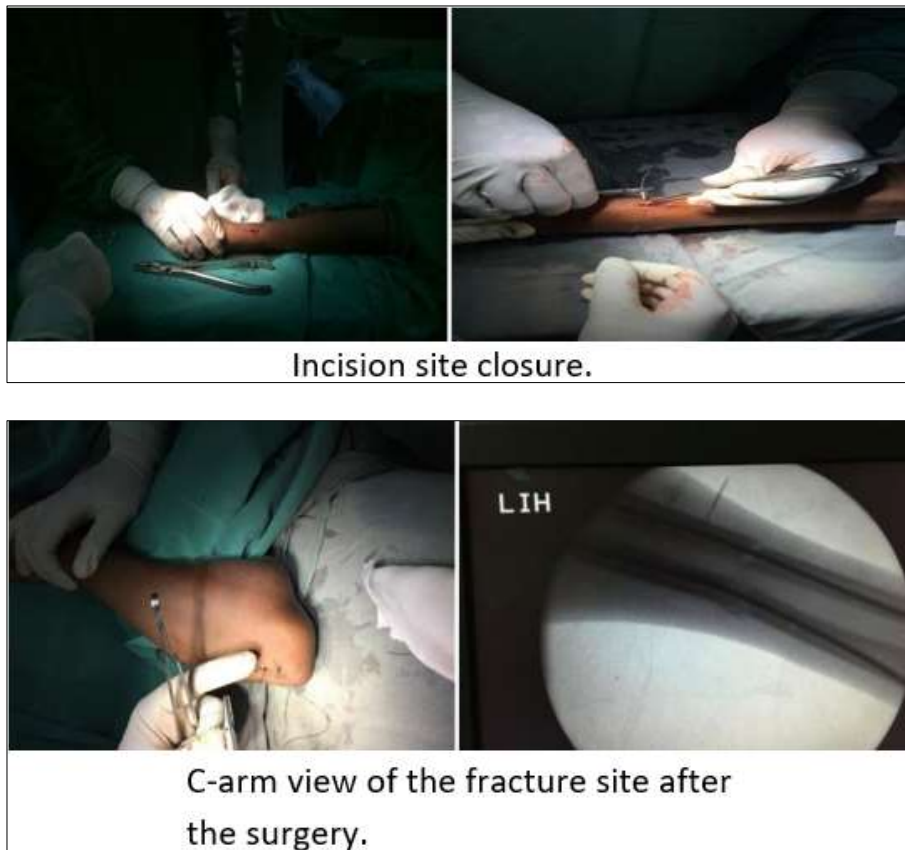


Fig 2: Intra-operative images

Post-operatively, the fracture was immobilized using plaster of Paris cast for 3 or more weeks. Static muscular strengthening exercises were initiated for all patients from 1st postoperative day onwards. Patients were discharged after the 10th postoperative day. After suture removal, patients were permitted to use crutches to walk. Full weight bearing was started 4-6 weeks after surgery. Assessment was done at 2, 6, and 12 weeks as well as at 24 weeks.

Results

30 patients with diaphyseal fractures of long bones were included in this study. 53.3% of patients belonged to 6-10 years of age group. The mean age of the study group was 10.03 years. Most of the patients were males; male to female ratio was 2:1. Half of the patients had sustained fractures due to road traffic accidents. 33.33% had a history of self fall and 16.6% of patients sustained fractures due to fall from height. The left side (60%) was more involved than the right side (40%). There are no cases of bilateral fractures in our study.

Fractures of long bones of lower limbs were more common, of which, femur was the most common bone involved (40%), followed by tibia (30%). Both forearm bones (radius and ulna) involvement was seen in 20% of cases, while only the humerus was involved in 10% of patients.

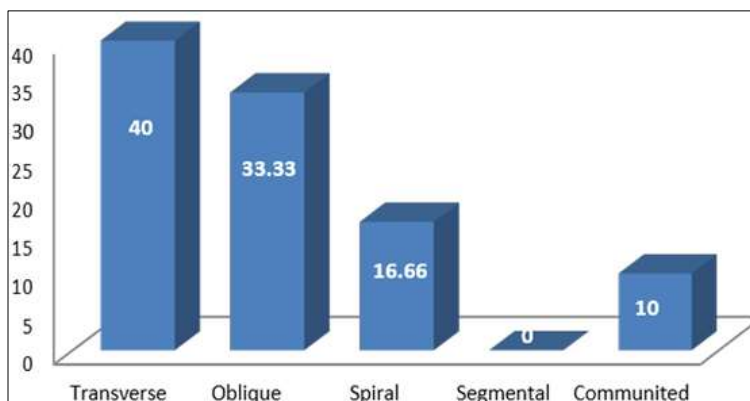


Fig 3: Pattern of fractures

3 (10%) of the fracture cases were comminuted, 10 (33.3%) were oblique, and five were spiral.

Transverse were the commonest pattern observed (40%).

The median period from trauma to surgery was 3.96 days, with surgery being performed in less than two days on 11 (36.6%) patients. 7 (23.3%) patients were operated three to four days after trauma, and 3 patients were operated 5-7 days later (10%). Most fracture procedures (27 cases; 90%) were finished in 30 to 90 minutes. The average operative period was 59.9 minutes. The average duration of hospital stay was 9.26 days.

Table 1: Time for union

Time of Union	No of Patients	%
<12 Weeks	24	80.00
12-18Weeks	5	16.70
18-24 Weeks	1	3.30
Total	30	100.00

The average time for fracture union was 12.1 weeks, 24 patients (80%) were able to complete the process within 3 months.

Within 12 weeks, both functional loading for the upper limb and unsupported full weight-bearing walking were for 22 patients (73.33%).

Table 2: Range of movements at 24 weeks

Range of movements in degrees	No of Patients	%
Full range	28	93.33
Mild restriction	2	6.66
Moderate restriction	0	0
Severe restriction	0	0
Total	30	100

All of the patients in the current study exhibited full ranges of motion in the hip, ankle, elbow, wrist, and forearm, however, two (6.66%) of them had slight limitations in knee flexion and forearm supination after 12 weeks (10-20% of restriction of ROM).

According to Flynn *et al.*, scoring, 21 patients had excellent outcomes, and 9 had satisfactory outcomes. No poor outcomes were noted in the present study.

Table 4: Complications

Complications	No of cases	Percentage
Pain at the site of nail insertion	3	10
Migration of nails	1	3.33
Infection (Superficial)	1	3.33
Shortening<2cms	2	6.66
Limitation of joint movements (mild i.e. 10-20% of ROM)	2	6.66

Out of 30 patients, 9 patients developed complications (minor). Three persons (10%) reported having pain at the site of nail insertion during the follow-up examination; however, by the end of the 12-week follow-up, all these cases had vanished. One case of superficial infection (3.3%) was reported, which subsided after antibiotic therapy. Shortening was experienced by two individuals (6.66%) (One tibia and one femur, each reduced by 0.7cm). No significant difference in limb heights was noted in the present study (i.e. >2cm). Nail was pulled out in one case (0.33%).

No patients had rotational mal-alignment, anteroposterior angulation, or varus or valgus angulation.

As it preserves the epiphyseal growth plate, prevents bone damage, provides a load-sharing, internal splint that is biocompatible, and has a low risk of infection of the bone, the development of the TENS technique has put an end to criticism of surgical management of pediatric long bone fractures.

Discussion

30 patients with diaphyseal fractures of long bones were admitted to the Department of Orthopedics, Andhra Medical College, Visakhapatnam over 2 years period. The patients in this study had a mean age of 10.03 years, with most of them (53.3%) belonging to ages between 6 -10 years and 46.66% being between 11 – 15 years. J.N.Ligier *et al* [7] and Atul Bhaskar *et al* [8] had similar mean ages in their studies (10.2 years and 10 years, respectively).

Male to female ratio is 2:1, with 20 boys (66.6%) and 10 (33.3%) girls. Comparable to other research in the literature, the sex incidence is low. J. N. Ligier *et al* [7] (67% males; 32.3% females) and Furlan D *et al* [9] (69.9% boys, 30.05% girls) had similar gender distribution in their studies.

With 15 (50%) instances, RTA injuries were the most common mode of injury in the current study followed by 10 (33.3%) patients with self-falls, and five (16.6%) patients with fall from height.

J. M. Flynn *et al.*^[10] research of 234 incidents revealed that 136 (58.1%) of them included RTA, 46 (19.6%) were self-inflicted falls, and the remaining 43 (28.8%) fell from height.

Femur fractures were most common (40%), followed by tibial fractures (30%). Humerus was involved in 10%. H. Till *et al.*^[11] reported 23 (30%) femoral, 14 (20%) tibial, 5 (7.14%) humeral, and 28 (40%) forearm fractures.

12 of the fractures were transverse (40%), 3 (10%) were comminuted fractures, 10 (33.3%) were oblique fractures, and 5 (16.7%) were spiral fractures. J. N. Ligier *et al.*^[7] looked at 123 femur fractures and found that 47(38.2%) were transverse fractures, 25 (20.3%) were comminuted fractures, seven (23.3%) were oblique fractures, 19 (15.4%) were spiral fractures, and four (3.2%) were segmental fractures. Arun Kumar *et al.*^[12] discovered that 10 (33%) of the 30 long bone shaft fractures they studied were transverse, 7 (23%) oblique, 8 (27%) spiral, and 5 (17%) comminuted.

In the present study, 11 patients were operated on within 2 days of trauma, 7 were operated on between the 3rd and 4th day of trauma, 9 were operated on between 5th and 7th days of trauma and 3 were operated on after 7 days of trauma. Gamal *et al.*^[13] operated on 56.1% of cases in the study between 3 and 4 days after damage, 21.2% of cases between 3 & 4 days, and 22.7 percent of cases after 7 days. There were 3.9 days on average between the trauma and surgery. K.C. Saikia *et al.* operated on 77.27% of patients within 7 days of the injury^[14].

Duration of surgery in most of the cases (n=14) was 61-90 mins, while 13 cases were operated in between 30-60 mins. The procedure for one patient with a forearm bone fracture was 30 minutes. For 2 cases it was 91-120 mins as the procedure took longer than anticipated due to the difficult reduction and nail going through the fracture site.

In a study by K C Saikia *et al.*^[14], the surgery could last anywhere between 50 and 120 minutes around 70 minutes.

The average stay in the hospital in the current study was 9.26 days which was similar to the study done by Arun Kumar C *et al.* (9.9days).¹²

In the present study, it took 12.1 weeks on average to reach union. In union time in a study by Atul Bhaskar *et al.*^[8], the average length of fracture union was 10.5 weeks.

Unsupported full weight-bearing walking for the lower limb and activity for the upper limb was resumed in the current study within 12 weeks for most of the patients (73.33%). The time it took to resume regular activities was 11.5 weeks on average. Wudbhav N. Sankar *et al.*^[15] permitted complete weight bearing within an average of 8.65 weeks.

Complications

Nail insertion site pain: During the first follow-up assessment in the current study, 3 (10%) participants reported feeling pain where the nail was inserted. All these patients had fully healed from this pain at the end of the 16-week time frame. J. M. Flynn *et al.* reported 38 (16.2%) instances of pain at the nail insertion site out of 234 fractures that were treated with elastic nails^[10].

Infection: A significant drawback of external fixation application is pin tract infection. One patient had a superficial infection (3.3%) that was treated with antibiotics. J.M. Flynn *et al.* discovered 4 (1.7%) cases with superficial infection at the site of nail insertion out of 234 fractures treated with titanium elastic nails^[10].

Range of motion: 2 patients (6.66%) in the current study had a mild limitation of movement; the rest all displayed a complete range of movements. 1 patient had a 50-degree limitation in supination at the time of the last check-up, but no additional surgery was done because the deformity was in the non-dominant forearm and did not affect everyday activities. The other patient had a 50-degree supination restriction.

Limb length discrepancy: This is the second-most common consequence after shaft of femur fractures in children & adolescents. 2.67% of patients in the present study had a shortening of 2cm. However, there were no patients with significantly different limb lengths (i.e., >2 cm).

There was no change in leg length between the 19 tibial shaft fractures that Wudbhav N. Sankar operated^[15]. 4 children who received spica therapy for pediatric femoral shaft fracture showed > 2 cm of shortening, in a study by John Ferguson *et al.*¹⁶

Nail back out: Nail back out was observed in 1 (3.33%) patient in the present study. Atul Bhaskar *et al.*^[8] found that out of 60 instances, 3 patients had nail back out - one in the radius and two in the femur which required early removal.

Mal-alignment: Children who sustain femoral shaft fractures frequently develop some degree of angular deformity, but this typically corrects itself as they grow. However, no patients developed fracture mal-alignment in the present study.

Other complications: One patient in our study had proximal migration of the medial nail. The nail was removed after creating a cortical window. Similar proximal nail migration was observed by Baron E *et al.* in their study^[17].

Assessment of Outcome according to Flynn *et al.* scoring

In the present study, 21 (70%) had excellent outcomes and 9 (30%) patients had satisfactory outcomes. There were no poor outcomes observed.

Table 5: Comparison of outcomes.

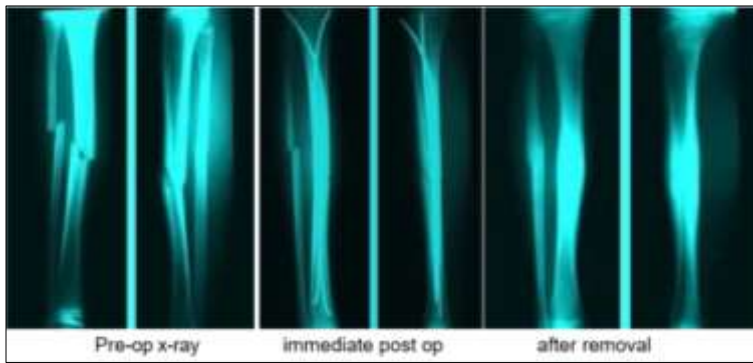
Study	Outcome		
	Excellent (%)	Satisfactory (%)	Poor (%)
Present study	70	30	-
Gamal El Adl <i>et al</i>	75.7	24.3	-
J. M. Flynn <i>et al</i>	65	25	10
Wudbhav N. Sankar	63.15	31.57	5.26
K. C. Saikia <i>et al</i>	59	27.2	13.6

Case No: 1



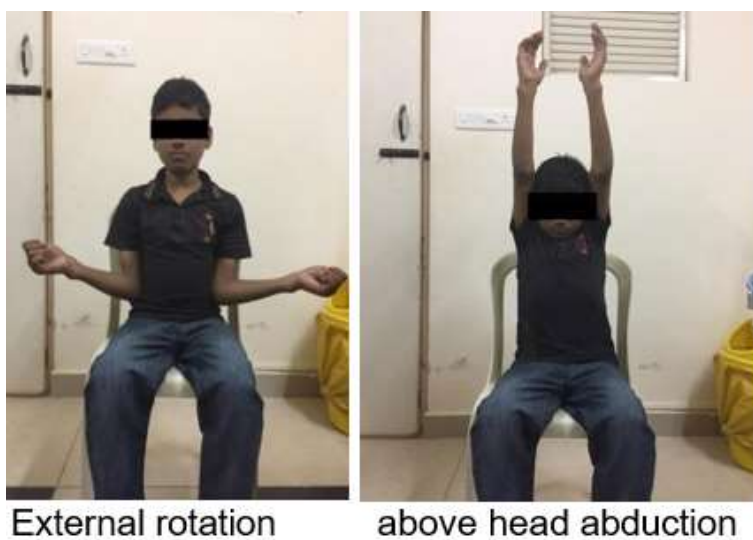
Results: Excellent

Case: 2



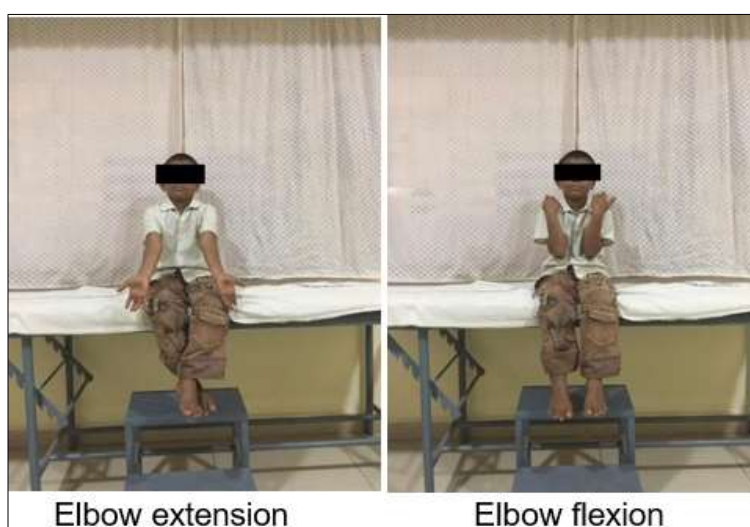
Results: Excellent

CASE: 3



The results were excellent.

Case: 4



Results: excellent.

Conclusion

Based on our research and expertise, we conclude that the TITANIUM ELASTIC NAILING SYSTEM method is the most effective way to treat pediatric long bone diaphyseal fractures. It offers stability that is ideal for early mobilization as well as elastic mobility that promotes fast union at the fracture site. It is less complex and gives good outcomes, with minimal hospital stay. TENS procedure promotes early functional loading, quick healing, and less disruption of bone growth.

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