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RESEARCH ARTICLE
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MINIMALLY INVASIVE FIXATION WITH TENS IN PEDIATRIC FOREARM FRACTURESCLINICAL AND FUNCTIONAL EVALUATION

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ABSTRACT

Background

Pediatric diaphyseal forearm fractures are commonly managed with closed reduction and casting; however, unstable or displaced fractures may require surgical intervention. Titanium Elastic Nailing System (TENS) has emerged as the preferred technique, offering minimally invasive stabilization, early mobilization, and rapid fracture healing compared to conventional methods.

Methodology

This prospective study was conducted at Government Medical College, Srikakulam, from November 2019 to November 2021. Thirty children aged 5–18 years with diaphyseal fractures of both radius and ulna were treated using TENS. All patients underwent closed or open reduction followed by intramedullary fixation. Clinical and radiological follow-up was performed for a minimum of six months. Outcomes were evaluated using Modified Anderson's AO criteria.

Results

Of the 30 patients, 24 were males and 6 females, with a mean age of 11.9 years. All fractures achieved union within 9–12 weeks postoperatively. Complications were minimal, with superficial infections in 3 cases and bursa formation at the nail entry site in 3 cases. There were no cases of deep infection, malunion, nonunion, nail migration, or neurovascular injury. Full range of elbow and wrist motion was restored in all patients, with 4 (13.3%) showing mild restriction in forearm rotation (10–20°) at 24 weeks.

Conclusion

TENS is an ideal method for treating pediatric diaphyseal forearm fractures, ensuring rapid union, stable fixation, early mobilization, and minimal complications. Its effectiveness surpasses traditional methods, making it a reliable choice for managing unstable fractures in children.

Introduction

Forearm shaft fractures are among the most common injuries in children, accounting for approximately 6% of all pediatric fractures. Traditionally, these fractures were managed conservatively using closed reduction and immobilization in an above-elbow plaster cast, which was

considered the gold standard for decades. In younger children under 10 years, mild angulation and deformity were often acceptable due to the excellent remodeling potential of growing bones. However, in older children and adolescents, residual deformities—particularly rotational malalignment—often fail to remodel adequately, leading to functional limitations in pronation and supination.

Conservative treatment of unstable or displaced diaphyseal fractures can result in complications such as redisplacement, loss of anatomical alignment, and stiffness, necessitating repeated manipulations or surgical correction. To overcome these limitations, surgical fixation techniques have gained popularity, particularly for unstable, irreducible, or re-displaced fractures, open injuries, and fractures in older children nearing skeletal maturity.

Among various surgical options, including plating, external fixation, and Kirschner wires, the Titanium Elastic Nailing System (TENS) has emerged as the preferred method for pediatric forearm fractures. TENS, based on the three-point fixation principle, offers several advantages: it is minimally invasive, preserves the soft tissue envelope, allows early mobilization, and promotes rapid fracture healing with minimal complications. Its elastic stability permits controlled micromotion at the fracture site, facilitating abundant callus formation while maintaining adequate alignment.

Given its rising popularity, this study aims to evaluate the functional and radiological outcomes of diaphyseal both-bone forearm fractures treated with TENS in children, assessing its efficacy, safety, and advantages over traditional conservative methods

AIM :

The aim of this study is to prospectively evaluate the functional and radiological outcomes of diaphyseal fractures of both radius and ulna in children treated with the Titanium Elastic Nailing System (TENS).

Objectives:

1. To evaluate the functional outcome of diaphyseal fractures of both radius and ulna in children treated with the Titanium Elastic Nailing System (TENS) using clinical and radiological assessment.
2. To assess the time to fracture union and overall recovery following TENS fixation.
3. To study procedure-related complications, including infection, loss of motion, implant-related issues, and other adverse outcomes.
4. To analyze the advantages of TENS in terms of early mobilization, minimal soft-tissue disruption, and reduced hospital stay compared with conventional methods like casting and plating.
5. To determine the role of TENS as a preferred treatment modality for unstable or displaced diaphyseal forearm fractures in the pediatric age group.

Methodology:

This prospective study was conducted in the Department of Orthopaedics, Government Medical College, Srikakulam, from November 2019 to November 2021. A total of 30 children, aged 5 to 18 years, presenting with diaphyseal fractures of both radius and ulna, were included.

Inclusion Criteria :

- Children aged 5–18 years..
- Diaphyseal fractures of both radius and ulna requiring surgical stabilization.
- Patients with closed or Gustilo-Anderson Grade I open fractures.
- Cases with failure of conservative management (redisplacement after casting).

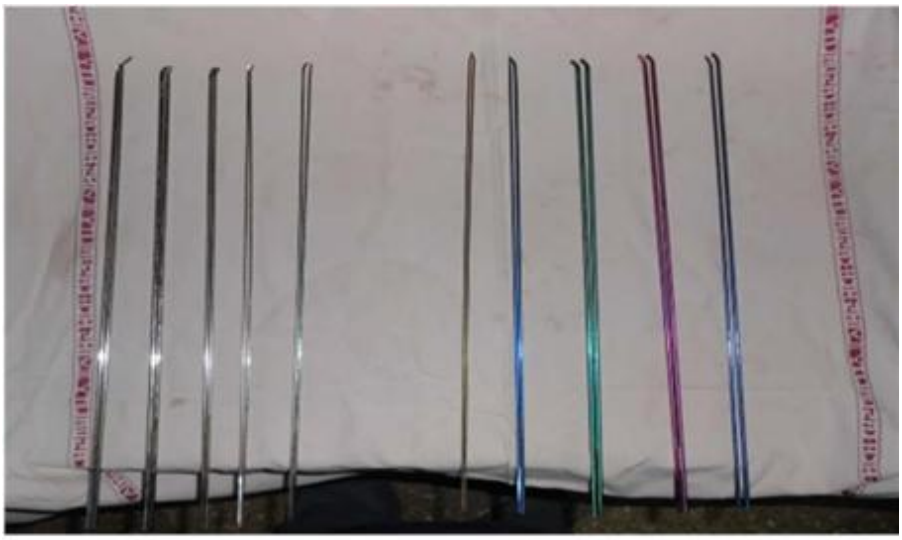
Exclusion Criteria :

- Children below 5 years or above 18 years.
- Pathological fractures (other than cystic lesions).
- Gustilo-Anderson Grade II and III open fractures.

- Patients with associated neurovascular injuries requiring repair.

Procedure :
All patients underwent closed or open reduction and internal fixation using Titanium Elastic Nailing System (TENS) under general or regional anesthesia. Nail selection was based on the rule of 40% of the internal diameter of the medullary canal at the isthmus, using two nails of identical diameter for opposing elastic stability.

Follow-up and Assessment :
Patients were followed at regular intervals up to 24 weeks postoperatively. Clinical and radiological evaluations were performed at each visit to assess fracture healing, range of motion, and complications. The Modified Anderson's AO criteria were used to evaluate functional outcomes.



INSTRUMENTATION SET

SURGICALTECHNIQUE
The nailing procedure was performed under general/regional anaesthesia with the patient in supine position and affected arm on a side table. A tourniquet was applied to the upper arm and was inflated only if required.
For the **ulna**, a stab incision was made on the proximal end of forearm over the lateral surface of the olecranon 2cm distal to physis under the fluoroscopy. A bone awl was introduced to create an oblique

entry hole in the ulna 2 cm distal to olecranon physis.The nail was prebent at 10 degrees at the tip and was introduced in the oblique entry hole and gently advanced and pushed distally.Fluoroscopy was used during reduction. If required, the fracture site was exposed by a small incision and reduction was achieved. The bent tip of pin aided in the reduction and the pin was pushed into the distal ulna, stopping short of the physis under the fluoroscopic guidance. The pin was cut closer to the bone,leaving enough end for easy removal later but without damaging the skin. The skin was sutured over the cut end and skin over the incision which was made for exposing the fracture site, if given was closed too.

For the **radius**, a 2 cm long incision was made on the dorsal aspect of the distal end of forearm over the radius medial to lister's tubercle proximal to the radial physis under fluoroscopy. A blunt dissection was made to avoid injury to superficial branch of radial nerve and extensor tendons.An oblique entry hole was similarly made over dorsal aspect of radius as in case of ulna.The pre bent nail was advanced through fracture site as in case of ulna and was stopped short of physis at the level of bicipital tuberosity.

POSTOPERATIVE CARE

1. Patients were kept nil orally 4 to 6 hours post operatively.
2. IV fluids / blood transfusion were given as needed.
3. Analgesics were prescribed according to the need of the patient.
4. The limb was kept elevated over a pillow.
5. IV antibiotics were given for 1 day and switched over to oral antibiotics on the 2nd day and continued till 1 week.
6. Sutures removed on 10th postoperative day and patients were discharged.

Post-operatively, all patients are immobilized with above elbow POP slab and it was continued upto 3 weeks. It was discontinued after 3 weeks and active movements were encouraged.

Follow up

Assessment done at 3,6,9,12,and 24weeks.A teach followup, patients are assessed clinically and radiologically, and the complications were noted.

Implant Removal

Nail removal was done at1-year post operatively.

RADIOLOGICALASSESSMENT

X-ray forearm full length with both elbow and wrist joints-AP and Lateral.

Alignment

Sagittal/Coronal angulation (in degrees -<10or>10)
Rotational malalignment (in degrees - <10 or >10)
Circumferential callus formation –good/adequate /poor.
Visibility of fracture line– seen clearly/masked /not seen.

COMPLICATIONS

Minor complications

a. When they resolved without additional surgery.
b. Not resulting in long term morbidity.

Major complications

a. When further operation was required
b. Long term morbidity ensued

MINOR COMPLICATIONS:

1. Pain at the entry point of the nail.
2. Minor angulation (< 10^0 – sagittal/coronal; <10^0 rotational mal alignment) at final follow-up (24 weeks).
3. Inflammatory reaction to nails.
4. Superficial infection at the site of nail insertion
5. Delayed union.

MAJOR COMPLICATIONS

1. Minor angulation (> 10^0 – sagittal/coronal; >10^0 rotational mal alignment) at final follow-up (24 weeks).
2. Deep infection.
3. Loss of reduction requiring new reduction or surgery.
4. Surgery to revise nail placement.
5. Compartment syndrome requiring surgery.
6. Neurological damage after nailing.
7. Delayed or non union leading to revision.
8. Nerve palsy.

Study design

The outcome of Titanium Elastic Nail Fixation was studied in a surgical studyof30patientshavingDiaphysealfracturesofbothbonesintheforearm.

Table 1: AGE DISTRIBUTION OF PATIENTS STUDIED

AGE IN YEARS	NUMBER OF PATIENTS	%
6-10	12	40
11-18	18	60
TOTAL	30	100

Graph1:AGE DISTRIBUTION OF PATIENTS STUDIED

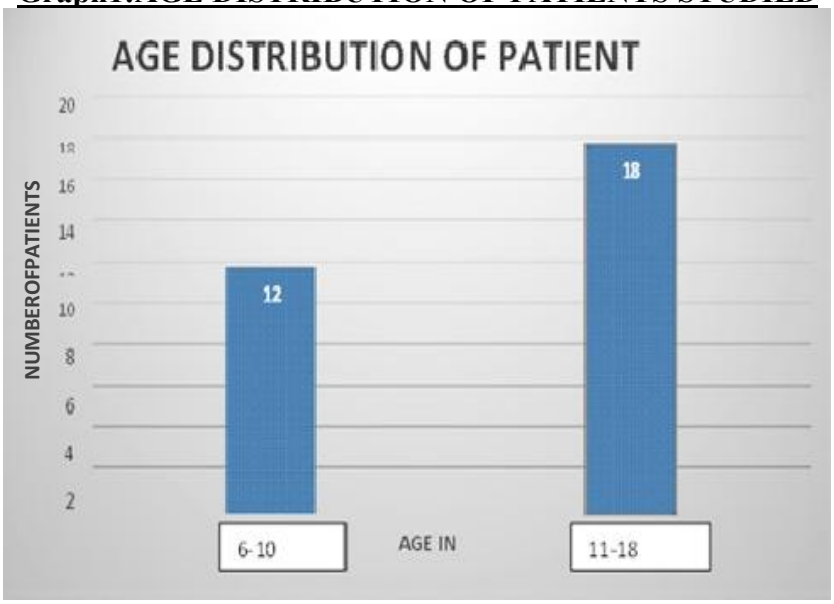


Table2: GENDER DISTRIBUTION OF PATIENTS STUDIED

GENDER	NUMBER OF PATIENTS	%
MALE	24	80
FEMALE	6	20
TOTAL	30	100

Graph2: GENDER DISTRIBUTION OF PATIENTS STUDIED

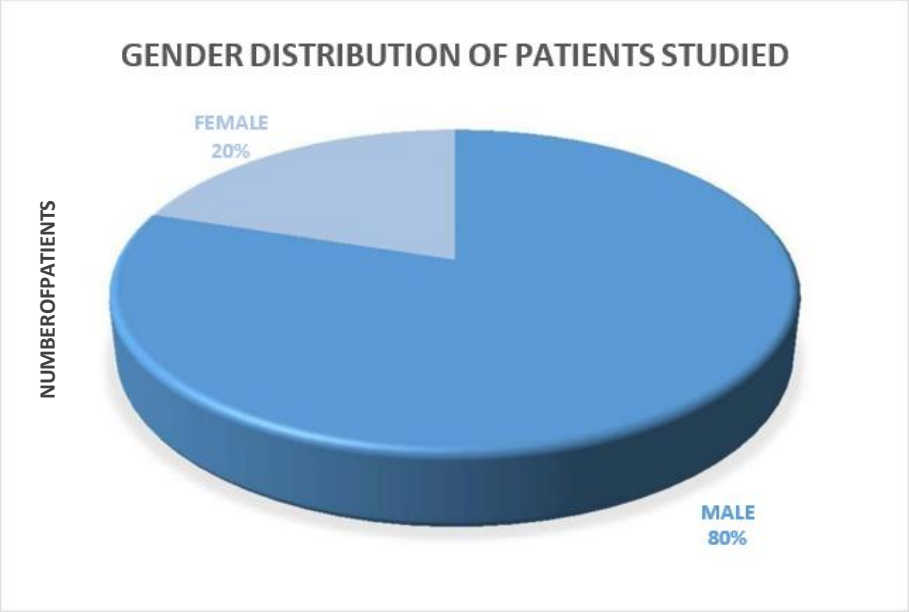


Table3:TYPE OF FRACTURE

TYPE OF FRACTURE	NUMBER OF PATIENTS	%
SIMPLE	27	90
TYPE 1 OPEN	3	10
TOTAL	30	100

Graph3: TYPE OF FRACTURE

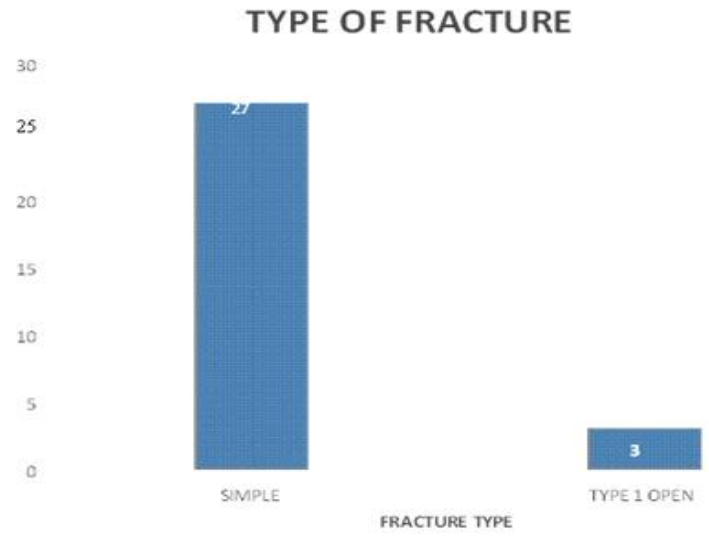


Table 4: LEVELOFFRACTURE

LEVEL OF FRACTURE	NUMBER OF PATIENTS	%
PROXIMAL 1/3rd	10	33.3
MIDDLE 1/3rd	15	50
DISTAL 1/3rd	5	16.7
TOTAL	30	100

Graph 4: LEVELOFFRACTURE

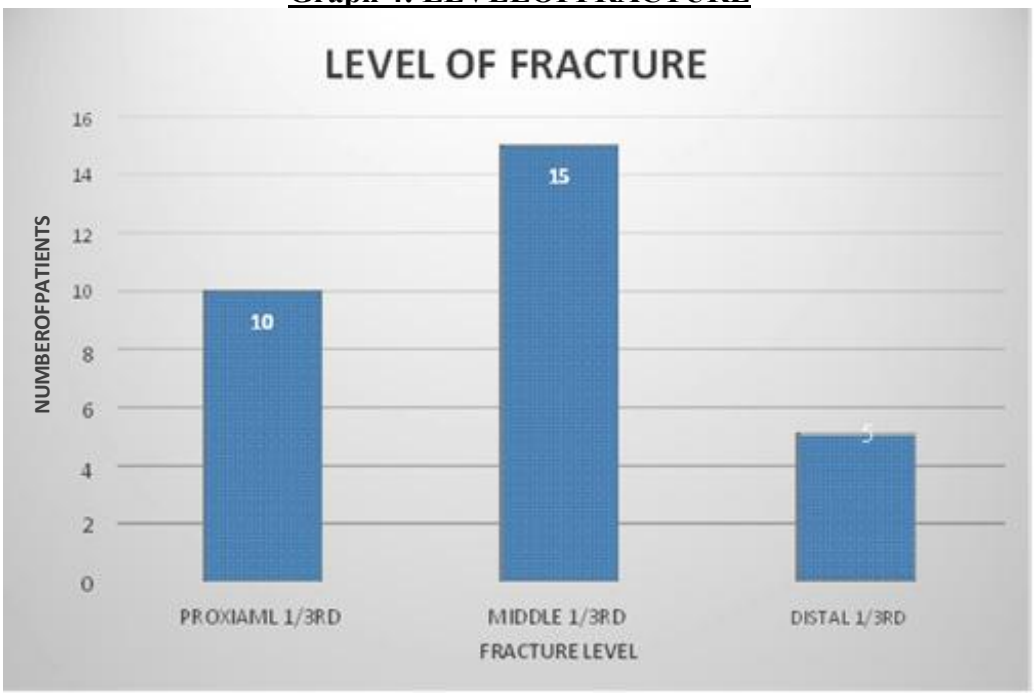


Table 5 :TYPEOFFRACTUREREDUCTIONDURING SURGERY

TYPE OF FRACTURE REDUCTION	NUMBER OF PATIENTS	%
CLOSED	24	80
OPEN	6	20
TOTAL	30	100

Graph 5: TYPEOFFRACTUREREDUCTIONDURING SURGERY

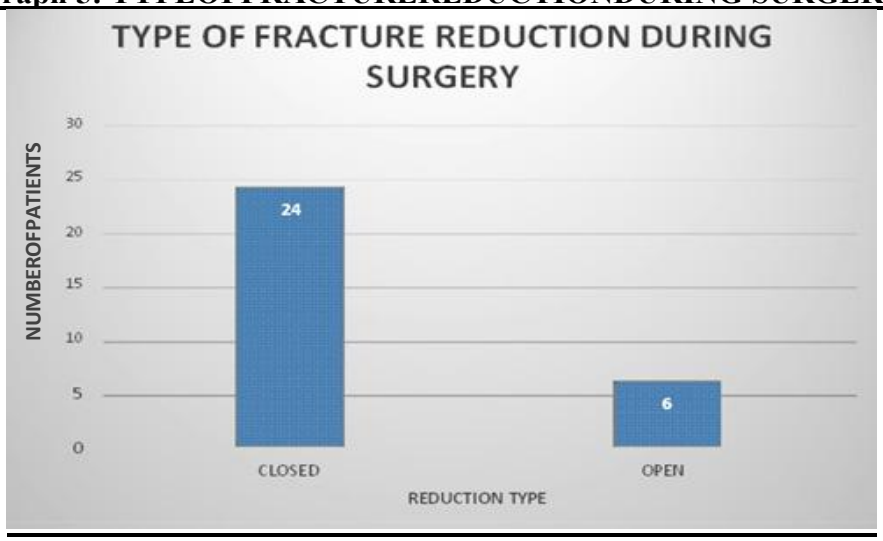


Table 6: DURATIONOFSURGERYINMINUTES

DURATION OF SURGERY(IN MINS)	NUMBER OF PATIENTS	%
< 30	6	20
30-60	18	60
> 60	6	20
TOTAL	30	100

Graph 6: DURATIONOFSURGERYINMINUTES

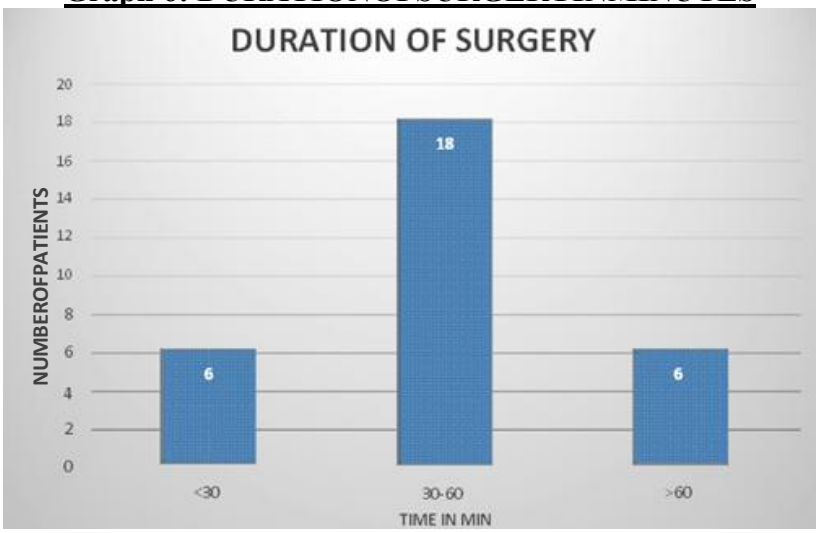


Table 7:COMPLICATIONS

COMPLICATIONS	NUMBER OF PATIENTS	%
MINOR	10	33.3
MAJOR	-	-
NIL	20	66.7
TOTAL	30	100

Graph 7: COMPLICATIONS

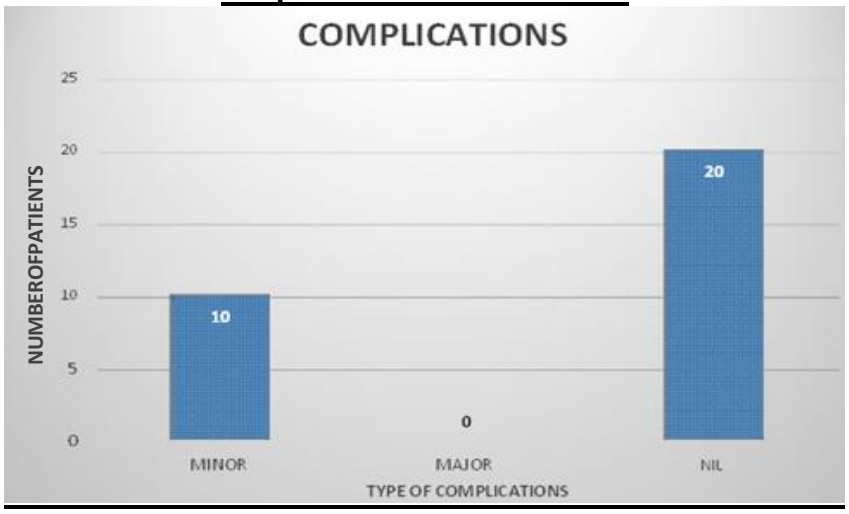


Table 8: COMPLICATIONS

COMPLICATIONS		NUMBER OF PATIENTS	%
PAIN		5	16.7
SUPERFICIAL	INFECTION	3	10
	DEEP	-	-
COMPARTMENT SYNDROME		-	-
INFLAMMATORY REACTION TO NAILS		-	-
MAL UNION		-	-
DELAYED UNION		-	-
NON UNION		-	-
REFRACTURE		-	-
NAIL MIGRATION		-	-
RUPTURE OF TENDONS		-	-
BURSITIS		3	10
NERVE PALSY		-	-

Graph8: COMPLICATIONS:

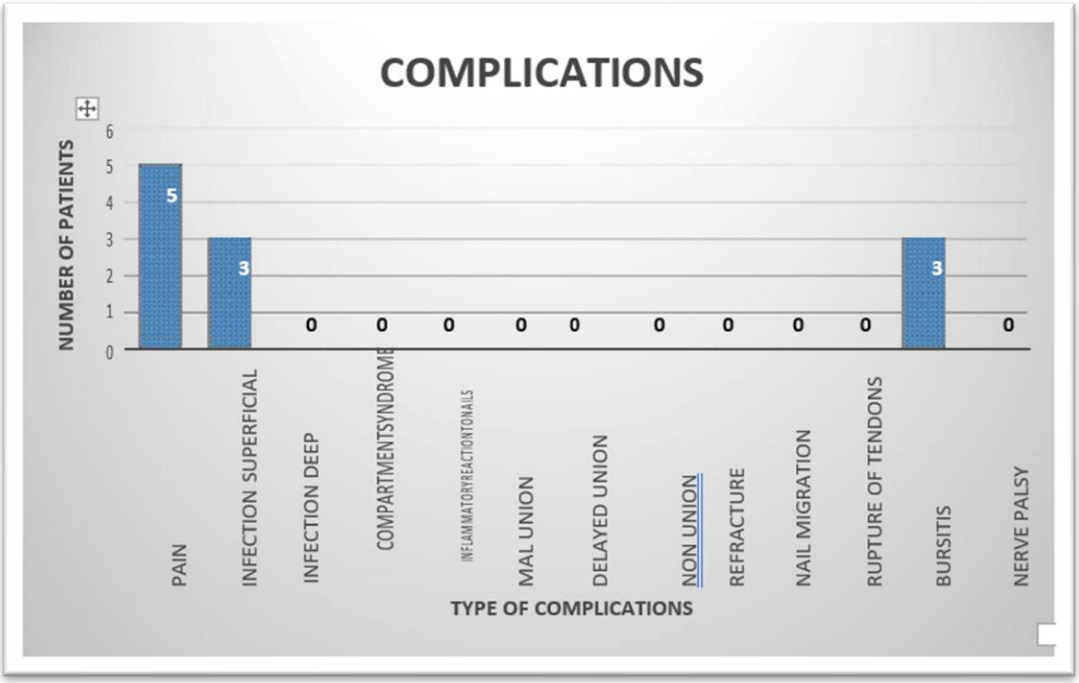


Table 9: TIME OF UNION:

TIME OF UNION(IN WEEKS)	NUMBER OF PATIENTS	%
≤ 6	6	20
6 - 9	18	60
9-12	6	20
TOTAL	30	100

Graph 9: TIME OF UNION:

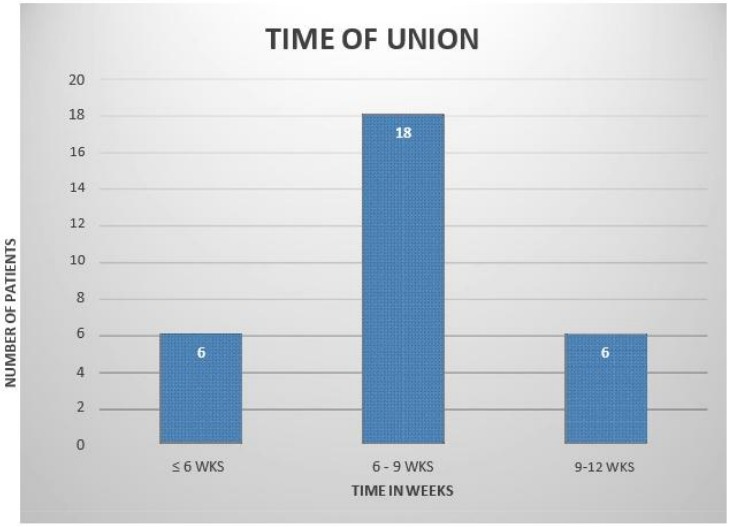


Table 10: LOSS OF MOVEMENTS AT 24 WEEKS:

LOSS OF MOVEMENTS AT 24 WEEKS	Number of Patients	%
ELBOW	FLEXION -	
	EXTENSION	
	< 100	26
	100 - 300	4
FOREARM SUPINATION	> 300	-
	< 100	26
	100 - 300	4
FOREARM PRONATION	> 300	-
WRIST	DORSIFLEXION	-
	PALMARFLEXION	

Graph 10: LOSS OF MOVEMENTS AT END OF 24 WEEKS:

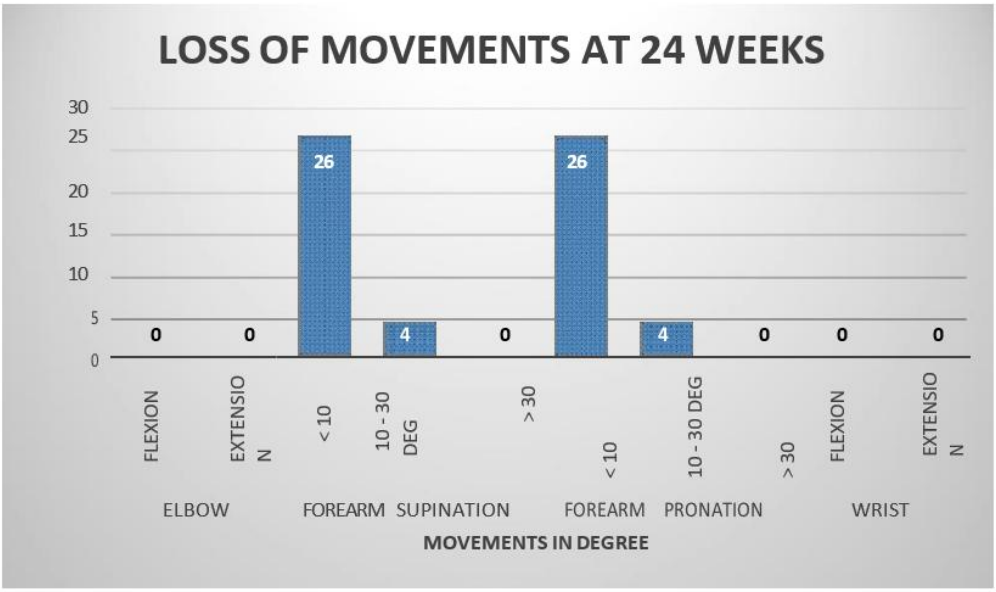


Table 11:OUTCOME AT 24 WEEKS:

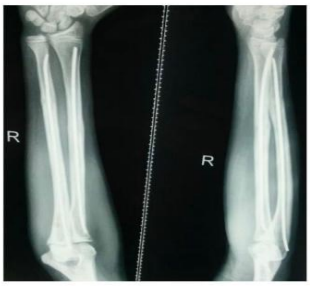
OUTCOME	NUMBER OF PATIENTS	%
EXCELLENT	25	83.3
GOOD	5	16.7
FAIR	-	-
POOR	-	-
TOTAL	30	100

Graph 11: OUTCOME AT 24 WEEKS:

RADIOLOGICAL AND CLINICAL PHOTOGRAPHS
CASE NO – 01

PRE OPERATIVE

POST OPERATIVE 6TH WEEK



POST OPERATIVE 12TH WEEK

IMPLANT REMOVAL

SUPINATION

PRONATION

WRIST DORSIFLEXION

WRIST PALMARFLEXION

CASE NO – 02

PRE OPERATIVE

POST OPERATIVE 3RD WEEK

POST OPERATIVE 9TH WEEK

POST OPERATIVE 12TH WEEK

SUPINATION

PRONATION

WRIST DORSIFLEXION

WRIST PALMARFLEXION

DISCUSSION

Age incidence:

In present study, the majority of children with both bones forearm fractures were in age group of 11-16 years constituting 60% of total patients. The remaining patients (40%) were in age group of 6-10 years. Mean age of our study was 11.9 years among 30 patients studied ranged from 5 – 16 yrs. Garg NK *et al* (2008)[126]studied children ranged from 5-16years with a mean of 11.8 years. Qidwai SA *et al* (2001)[127]studied children ranged from 5-16years with a mean of 11 years. Relative increased occurrence in older children(11-16 years) can be due to their more participation in outdoor sporting and playful activities

STUDIES	AGE INCIDENCE (Average) IN YEARS
Present study	**11.9**
Garg NK *et al* (2008)	**11.8**
Qidwai SA (2001)	**11**

Sex Incidence:

In the current study, there were 24 male children with forearm fractures, accounting for 80% of total patients, and six female children with forearm fractures, accounting for 20% of total patients. The sex incidence is similarly comparable to findings from other studies In their study ,Mohammed H *et al* (2009)[128]in which males comprised 90.5% and females comprised 9.5% of total patients .In their study,Mahesh Goyal *et al*(2013),[129]there were 27 male children with fracture of forearm constituting

90% of total patients and three female children with fracture of forearm constituting 10% of total patients.

STUDIES	SEXINCIDENCE(%)	
	MALE	FEMALE
Present study	**80**	**20**
Mohammed H *etal* (2009)	**90.5**	**9.5**
Mahesh Goyal *etal* (2013)	**90**	**10**

1.Type of fracture

There were 27 simple (closed) fractures constituting 90%oftotalpatients. There were three compound (open) fractures (Gustilo and Anderson type I) constituting 10% of total patients.This is in accordance to the study conducted by Kang S N*etal*(2011)[132],in which 9% patients had open fracture and remaining (91%) were closed. This is because of the fact that the injuries in children are low energy injuries.

STUDIES	TYPEOFFRACTURE(%)	
	SIMPLE	OPEN
Present study	**90**	**10**
Kang S N*etal* (2011)	**91**	**9**

1.Level of fracture

There were fracture of shaft of forearm bones at proximal 1/3rd in10 patients (33.33%).2 Patients a age group of 6-10 years and 8 were among age group of 11-16 years. There were fracture forearm at middle 1/3rd in 15 (50%). Among these 15 patients, 4 were among age group of6-10 yearsand11 among age group of 11-16 years. There were fracture forearm at distal 1/3rd in 5 (16.67%) who were in age group of 6-10 years.

The incidence of proximal third fractures (33.33%) was similar in study conducted by CelebiL *et al* (2007)[133]in which mean age of patient was 10.6 which is similar to mean age group of four study(11.6).As per the findings, proximal fractures are likely to occur in older children (>10 years) and distal fractures are more quite common in younger children (<10 years)

1.Method of reduction

Closed reduction and internal fixation with flexible intra medullary nails was accomplished under fluoroscopy in 24 patients (80%) comprising of total patients. However, 6 patients (20%), required open reduction and internal fixation, especially in whom who presented late to hospital.

According to Mohammed H et al (2009)[128]'s study of 21 children with forearm fractures, 4 patients (19%) received open reduction and internal fixation with TENS while 19 patients had closed reduction and internal fixation with TENS. This is due to the fact that radius is difficult to manipulate while doing CRIF in case when especially fracture involves proximal one third and often ORIF is required.

STUDIES	METHODOFREDUCTION (%)	
	CLOSED	OPEN
Present study	**80**	**20**
Kang S N*etal*(2011)	**81**	**19**

2.Duration of surgery

In the present study,duration of surgery was <30mins in6(20%) cases, 30-.60 mins in18 (60%) cases, >60 mins in another 6 (20%) cases.The difficulty in reducing and passing the nail across the fracture site was one of the 6 situations in which the time exceeded 60 minutes.The duration of surgery in our study was40.64minutesin average. This is more or less in accordance to study conducted by Ali AM *etal*(2010)[134]on children with forearm fractures managed by ESIN in which mean operating time was 36 minutes.

STUDIES	DURATIONOFSURGERY(INMIN)
Present study	**40.64**
AliAM*etal*(2010)	**36**

3.Complications

In our study three(10%)patients had infection which was superficial at entry point of nail and three patients had bursa at entry point accounting for 33.33% of minor complications. In late postoperative period and none had deep infection, malunion, nonunion, refracture or nail migration, compartment syndrome, nerve palsy or rupture of tendon. This is in accordance to the study by Berger P *et al*(2005)[135]in which there was superficial infection in 6% (2 out of 30) patients with none of the patients reported deep infection, compartment syndrome, nerve palsy, nonunion, malunion, refracture or nail migration.

4.Time of union

In our study union was achieved in<6wks in6 (20%)of the patients and 6-9wks in 18 (60%) and 9-12wks in 6(20%). Average time to union was 9wks. The average time for union was 9 weeks, whereas the average time for union was 7weeks in the study conducted by Kapoor V *et al*(2005)[136]on forearm fractures in children treated by TENS. This difference could be due to our follow up interval which was at 3, 6, 9, 12, 18 and 24 weeks.

5.Loss of movements

In our study at 24weeks none of the patients had loss of movements at wrist and elbow.This is in accordance to the study conducted by Fernandez F *etal*(2005)[137]which was done to compare the outcome between plating and nailing (ESIN) in forearm fractures in children wherein there was no restriction of movement at wrist and elbow in group of patients managed by TENS.At24weeks,26(86.56%)patients had loss of movement at forearm by less than 10^0,4(14.3%)patients had loss of movement at forearm by 10^0-$30^0$and no patient had loss of movement at forearm by more than30^0.The final results of movement at forearm at 24 weeks in study are in accordance to similar study conducted by Kapoor V *etal*(2005),[136]in which16%ofpatients had loss of motion at forearm.

6. **Outcome at 24Weeks**

In the present study, in 26(86.66%)cases ,the final outcome was excellent and good in 4 (13.33%) cases and there were no poor outcome .The final result is in accordance with study conducted by Kanellopoulos AD *et al* (2005)[138] in which 90.3% had excellent results. Mahesh Goyal *etal* 89% had excellent outcome among 30patients studied.

STUDIES	OUTCOMEAT24WEEKS		
	EXCELLENT	GOOD	POOR
Present study	**86.66**	**13.33**	**-**
Kanellopoulos AD *etal* (2005)	**90.3**	**9.7**	**-**
Mahesh Goyal *etal*	**89**	**11**	**-**

CONCLUSION

We conclude that the TENS is an excellent approach for treating diaphyseal both bones forearm fractures in children based on our experience and the outcomes obtained. It promotes quick union at the fracture site while also providing stability, making it excellent for early mobilisation. When compared to other treatment options, it has a reduced complication rate and a better prognosis.

TENS nail is a simple, rapid, fast, reliable, and effective treatment for paediatric diaphyseal both bones forearm fractures in children aged 5 to 18, with less operating time, less blood loss, less exposure to radiation, a shorter stay at hospital,and a fair bone healing period.TENS may be considered a physiological way of treatment because of its early mobilisation, faster healing, and minimum disruption of bone growth.

TENS is utilised to keep the forearmin a stable position. TENS is a safe, minimally invasive, and physeal-protective method for treating both bone diaphyseal fractures in children

REFERENCES

1. MetaizeauJ P. *Etal*, Osteosynthes is in children: techniques and indications ChirPédiatr1983;69:495-511.
2. Metaizeau JP. Osteosynthèse chez l' Enfant : Embrochage Centro Médullaire Elastique Stable. Sauramps Med Dif - fusion Vigot, Montpellier, 1988, pp 61-102.
3. Beaty JH, Austin SM, Warner W C*etal*. Interlocking intramedullary nailing of femoral shaft fractures in adolescents: preliminary results and complications.
4. Price CT, Scott DS, Kurzner ME, Flynn JC Malunited forearm fractures in children. J Pediatr Orthop 1990; 10:705–712.
5. Sarmiento A, Ebramzadeh E, Brys D, Tarr R Angular deformities and forearm function. J Orthop Res 1992; 10:121–133
6. Tarr R, Garfinkel AI, Sarmiento A- the effects of angular and rotational deformitiesofbothbones ofthe forearm:anin vitro study.JBone JointSurg Am 1984; 66-A:65–70
7. Daruwalla JS A study of radioulnar movements following fractures of the forearm in children. Clin Orthop 1979; 139:114–120.
8. Fuller DJ, McCullought CJ Malunited fractures of the forearm in children. J Bone Joint Surg B 1982; 64:364–367
9. Kay S, Smith C, Oppenheim WL Both Bone midshaft forearm fractures in children. J Pediatr Orthop 1986; 6:306–310.
10. Lieber J, Joeris A, Knorr P, Schalomon J, Schmittenbecher PP ESIN in forearm fractures. Eur J Trauma 2005; 31:3–11