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Surgical Management of Paediatric Diaphyseal Long Bone Fractures using TENS-An Institutional Experience

Prasanna Anaberu[1], Madhan Jeyaraman[1*], Kartavya Chaudhari[1], Ajay SS[1], Likhith D[1] and Preethi Selvaraj[2]

[1]*Department of Orthopedics, JJM Medical College, Davangere, India*
[2]*Department of Community Medicine, SSSMCRI, Kancheepuram, India*

Abstract

Background: Children are at a high risk of injury with up to one of every four children sustaining an injury annually. A positive approach to patient care by the treating Orthopaedic surgeon should be done to improve the functional quality of patient's life. Due to the evolution of surgical implants, there is a paradigm shift over to internal fixation and early mobilization, with a return to normal function as early as possible.

Objectives: To prospectively review the efficacy, the functional outcome and the complications of TENS nailing in pediatric diaphyseal long bone fractures.

Materials and Methods: After the screening of patients, a total of 229 cases, which were enrolled in the study, were subjected for surgical management with TENS nailing. All the patients were followed up clinically and radiologically at the immediate post-op period and at the end of 1, 3, 6, 12 and 18 months. The efficacy and functional outcome of TENS nailing were charted according to DASH, Mayo's wrist, Harris Hip score, and Lysholm scores. The ranges of movements were documented with Flynn's criteria. All patients were offered with surgical implant removal at an average of 18 months post-surgical procedure that showed fracture union.

Results: Out of 229 cases, 140 cases were males and 89 cases were females with fall while playing followed by fall from a height being the most common mode of injury. The pattern of fractures was transverse in 109 cases, spiral in 53 cases, and oblique in 31 cases and comminute in 36 cases. All cases showed the union of fracture with an average of 13.37 ± 1.35 weeks. The functional range of movements (n=229) according to Flynn's criteria were excellent in 179 cases, good in 37 cases and poor in 13 cases. The most common complication encountered in this study was pain, superficial infection at the nail insertion site, followed by malunion, non-union, nail migration, and malalignment. Implant removal was done under loco-regional anesthesia in an average of 17.32 ± 3.49 months.

Conclusion: TENS is the ideal device for the treatment of pediatric diaphyseal long bone fractures, which is a load sharing internal splint that allows mobilization and maintenance of alignment and extremity length until bridging callus forms.

Keywords: Diaphysis; TENS; Intramedullary devices; Elastic nailing

Introduction

Fractures among children are more common with the risk being one out of every four children sustaining an injury per year and with the lifetime fracture risk is up to 40% for girls and 64% for boys [1]. Fractures having a considerable impact on the daily living and activity of affected children, they represent an important topic of public health.

Current research in pediatric long bone fractures focuses on defining the incidence and health care resources required to treat this injury, refining the indications for surgical intervention, decreasing the surgical failure rate through new implants and techniques and minimizing the duration and magnitude of disability post-injury. A holistic approach to patient care by the treating Orthopaedic surgeon should be done in order to intervene and improve a patient's life. In order to get satisfactory results following treatment of pediatric diaphyseal long bone fractures, a thorough knowledge about the surgical anatomy, indications, techniques, and usage of implants, functional outcome of the patients are a must for any surgeon. The traditional concept in the treatment of pediatric diaphyseal long bone fractures was splinting the fracture followed by prolonged immobilization. Due to the evolution of surgical implants, it has been switched over to internal fixation and early mobilization, with a return to normal function as early as possible. The proponents of surgical management prevent complications like rotational mal-alignment, non-union, ma lunion as compared to non-operative treatment. The advantages of flexible intramedullary nails as a fixation device are closed insertion of the device, with preservation of the fracture hematoma, absent periosteal stripping and minimal risk of infection at the fracture site. The preservation of endosteal blood supply as no reaming is required. The devices, when prebent, appropriately provide stable three-point fixation. Being the load-sharing devices, flexible nails can provide early mobilization and weight bearing [2,3].

Objectives

To prospectively review the efficacy, the functional outcome and the complications of TENS nailing in pediatric diaphyseal long bone fractures.

Materials and Methods

With level IV evidence, a prospective cohort study was performed from 2016 to 2019 in the Department of Orthopaedics, Bapuji hospital and Chigateri Government General hospital, JJM Medical College, Davangere, Karnataka, India. The cases for this study were recruited by convenient sampling technique. Among 289 clinically

***Corresponding author:** Madhan Jeyaraman, Department of Orthopedics, JJM Medical College, Davangere, India, Tel: +91 83106 00785; E-mail: madhanjeyaraman@gmail.com

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and radiologically confirmed diaphyseal long bone fracture cases, a total of 43 cases were excluded (Figure 1) and the remaining 246 cases underwent surgical management as per our study protocol. A total of 17 cases lost to follow up after surgical procedure in our study period. Hence 229 cases were taken into consideration for statistical analysis. The radiological assessment was done with AP and lateral views of full-length humerus, forearm, femur, and tibia. The functional outcome of fractures was assessed by Flynn's criteria for TENS nailing. The follow up of cases were done with regular clinical and radiological analysis at the immediate post-op period and at the end of 1, 3, 6, 12 and 18 months. All the patients were offered implant removal at an average of 18 months post-surgical procedure that showed clinical and radiological fracture union.

Inclusion criteria

- Patients with age between 5-16 years
- Patients with simple and minimally displaced diaphyseal long bone fractures
- Patients with type 1 compound diaphyseal long bone fractures according to Gustilo Anderson classification for open fractures
- Patients who are medically fit for surgery
- Patients who have given written consent for treatment as per our protocol

Exclusion criteria

- Patients with age less than 5 years and more than 16 years
- Patients with undisplaced diaphyseal long bone fractures
- Patients with type 2 and 3 compound diaphyseal long bone fractures according to Gustilo Anderson classification for open fractures
- A patient who is medically unfit for surgery
- A patient who has not given written consent for treatment as per our protocol

After getting informed and written consent from the patient's attendees, the patients enrolled in the study were subjected for clinical examination, baseline investigations and radiographic analysis such as a plain x-ray of the affected part. The type 1 compound fractures were treated with IV antibiotics pre-operatively. All the cases were treated surgically with TENS nailing system and follow up according to our study protocol.

Principles of intramedullary elastic nailing system

Intramedullary elastic nailing system works on the principle of symmetric bracing action of two elastic nails having the same modulus of elasticity; each of which bears against the inner bone at three points. Such a construct produces flexural, translational, axial and rotational stability of the fractures. There are two types of intramedullary constructs of TENS namely C-C and C-S constructs. The modulus of elasticity of nail allows a biological environment that enhances the fracture reduction, the rate of fracture healing and quantity of callus formation (Figure 2).

Pre-requisites for intramedullary elastic nailing system

- The minimum of 2 nails of ideal length and diameter should be used to prevent the loss of reduction towards the side of stronger nail and malalignment
- Both the entry points should be at the same level
- Both the nails should be prebethe nt symmetrically to the same extent
- The nails should occupy 40% of the narrowest diameter of the diaphysis of the long bones (should be calculated by Flynn's formula)
- The nail construct should be contoured with a long bend such that apex of the convexity will be at the level of fracture to provide optimal 3-point fixation
- The nails should be passed from longer to the shorter segment
- The nails should be prebent so that the height of the curve is three

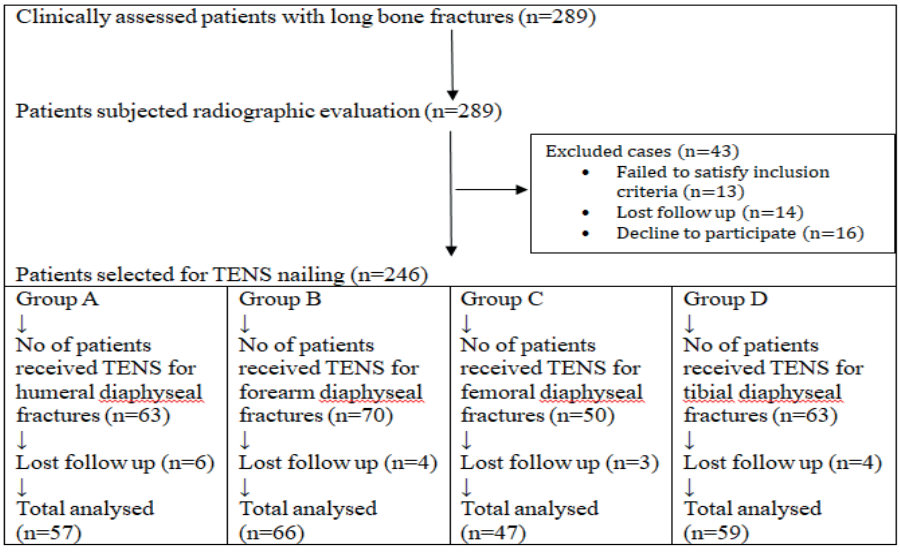


Figure 1: Representation of patient's selection.

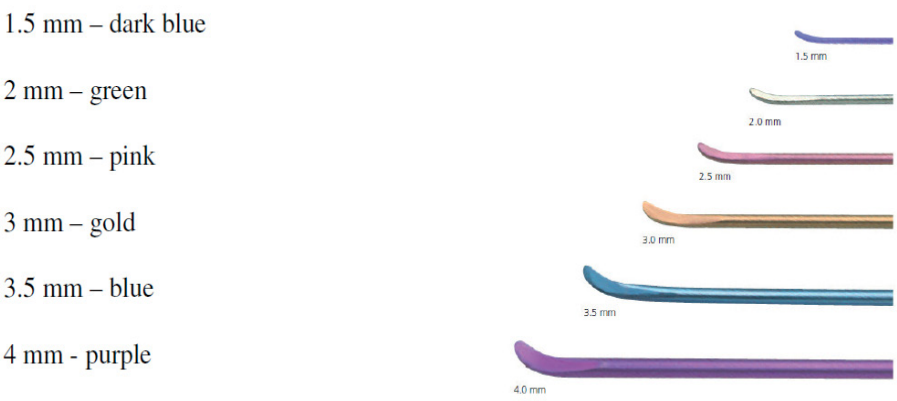


Figure 2: TENS nails.

times greater than the diameter of the medullary canal

- When inserted, nails should have maximum cortical contact at the fracture site in the opposite directions

Complications of TENS [4,5]

Major complications are defined as the complication which requires further surgery with long term morbidity. They are major angulation (>10°-sagittal/coronal, >10° malalignment) at final follow up, minor limb length discrepancy (<2 cm lengthening/shortening) at final follow up, deep infection, loss of reduction requiring further surgery, compartment syndrome, neurological damage and non-union leading to revision surgery.

Minor complications are defined as the complication which does not require additional surgery without long term morbidity. They are pain at the site of nail insertion, minor angulation (<10°-sagittal/coronal, <10° malalignment) at final follow up, minor limb length discrepancy (<2 cm lengthening/shortening) at final follow up, inflammatory reaction to nails, superficial infection at the site of nail infection and delayed union.

Grading of Flynn's criteria

Excellent-When there was anatomical or near anatomical alignment, no limb length discrepancy with no preoperative problem. Good-When there was acceptable alignment and limb length with a resolution of the preoperative problem. Poor-When there was unacceptable alignment and limb length with the unresolved preoperative problem (Table 1).

Modalities of treatment instituted

All cases were given pre-operative IV antibiotics and tetanus toxoid injection. All cases were operated under general or spinal anesthesia. All cases were tried for closed reduction and percutaneous TENS nailing. The cases with failed closed reduction proceeded with open reduction of the fracture and percutaneous TENS nailing were performed. **Group A:** Humerus: The humeral diaphyseal fractures were approached in a retrograde fashion. A 1 cm longitudinal incision was made laterally at the level of the lateral epicondyle and medially at the level of the medial epicondyle. Under image intensifier, the cortex was opened with a bone awl (Table 2). The nails of same diameter and length were inserted from either side into the medullary canal simultaneously and passed across the fracture site and driven proximally to within 1 cm to 2 cm of the proximal humeral physics.

Variables	Excellent	Good	Poor
Limb length discrepancy	<1.0 cm	<2.0 cm	>2.0 cm
Malalignment	Upto 5°	5°-10°	>10°
Unresolved pain	Absent	Absent	Present
Other complications	None	Minor and resolved	Major and/or lasting morbidity
Additional criteria in the study			
Range of movements	Full range	Mild restriction	Moderate to severe restriction
Time for union	8-12 weeks	13-18 weeks	>18 weeks
Unsupported weight bearing	8-12 weeks	13-18 weeks	>18 weeks

Table 1: Flynn's criteria [6].

Age group (years)	No. of males	No. of females
5-8	47	29
8-12	51	37
12-16	42	23
Total	140	89

Table 2: Patient's demography according to age group.

Group B: Radius and Ulna: The radial diaphyseal fractures were approached via ascending technique 2 cm proximal to the distal epiphyseal plate (Table 3). Under image intensifier, the cortex was opened with a bone awl. A single nail of 40% of the medullary canal was inserted and driven across the fracture site to reach the proximal radius. The ulnar diaphyseal fractures were approached via descending technique from the tip of the olecranon process. A single nail was inserted under image intensifier guidance to reach the distal end of ulna after crossing the fracture site (Figure 3)

Group C: Femur: The femoral diaphyseal fractures were approached in a retrograde fashion. A 1 cm longitudinal incision was made laterally at the level of the lateral condyle and medially at the level of medial condyle 1 cm above the superior pole of the patella on either side. Under image intensifier, the cortex was opened with a bone awl. The nails of same diameter and length were inserted from either side into the medullary canal simultaneously and passed across the fracture site and driven proximally to reach above the lesser trochanter (Figure 4).

Group D: Tibia: The tibial diaphyseal fractures were approached in an antegrade fashion. A 1 cm longitudinal incision was made laterally and medially at the level of tibial tuberosity below the physeal plate. Under image intensifier, the cortex was opened with a bone awl. The

Segmental classification	No. of males	No. of females
Humerus	36	21
Forearm	43	23
Femur	28	19
Tibia	33	26
Total	140	89

Table 3: Patient's demography according to segmental classification.

Figure 3: Insertion of humeral nail.

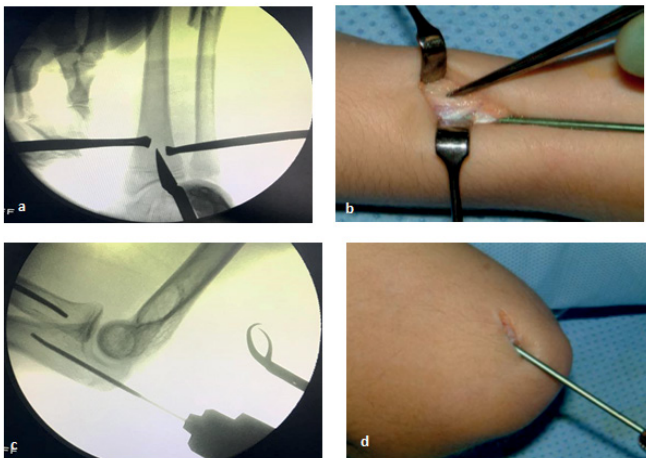


Figure 4: (a) Entry point for radial nail; (b) Insertion of radial nail; (c) Entry point for ulnar nail; (d) Insertion of ulnar nail.

nails of same diameter and length were inserted from either side into the medullary canal simultaneously and passed across the fracture site and driven distally to reach the tibial plafond. Since tibia is in a triangular fashion, the nails should be driven from the posterior aspect of the medullary canal to prevent genu recurvatum.

The size of the elastic nails was selected to be approximately 40% of the diameter of the medullary canal, and two equally sized elastic nails should be used to prevent asymmetric force on opposite cortices. The ends of the nails should protrude just enough to make attachment of the extractor possible. Finally, the placement of nails was checked under fluoroscopy. Then wound is closed in layers and a sterile dressing was applied (Figure 5).

All patients were advised for slab immobilization of the affected limb for 4 weeks in the post-surgical period. All the patients were advised not to perform lift any heavy objects and not to weight bear over the affected limb for a minimum of 4 weeks to 6 weeks (Figure 6). The patients were trained for active and passive range of movements and exercises. Then all patients were allowed for partial weight bearing at the end of 8 weeks to 10 weeks and full weight bearing at the end of 12 weeks. All the patients were reviewed clinically and radiologically in the immediate post-op period, at the end of 1st, 3rd, 6th, 12th and 18th month. The efficacy and functional outcome of TENS nailing were charted according to DASH, Mayo's wrist, Harris Hip score and Lysholm knee scores at every follow up (Figure 7).

All the patients were offered implant removal at an average of 18 months post-surgical procedure that showed clinical and radiological fracture union (Figure 8).

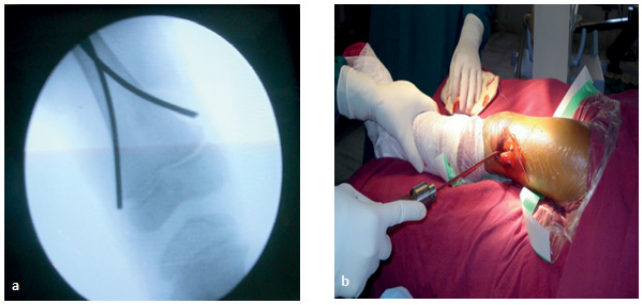


Figure 5: (a) Entry point for femoral nail; (b) Insertion of femoral nail.

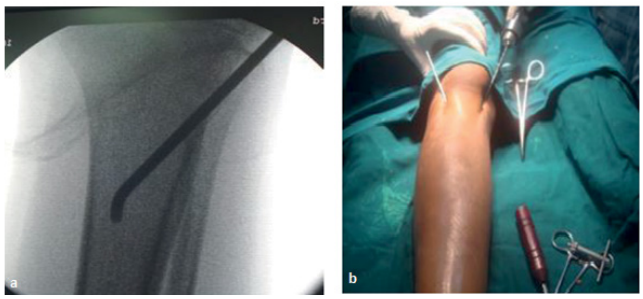
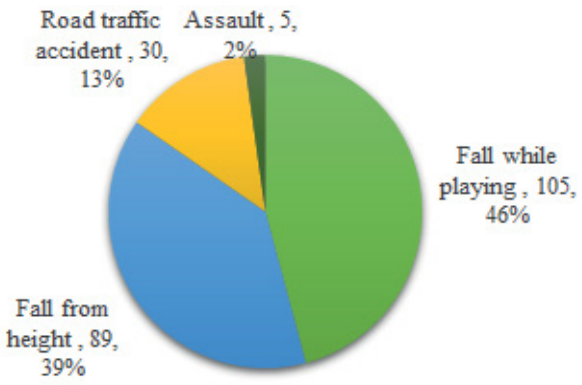


Figure 6: (a) Entry point for femoral nail; (b) Insertion of tibial nail.



Graph 1: Mode of injury.

Results

A total of 229 cases, who were under regular follow up in the post-surgical period, were taken into consideration for statistical analysis. The descriptive analytical statistics were reported as mean (SD), frequencies (percentage) and were evaluated statistically with IBM SPSS Statistics for Windows, Version 20.0, IBM Corp, Chicago, IL.

Demographic data

Among 229 cases, 140 cases (61.13%) were males and 89 cases (38.86%) were females (Figure 9). All the patients belong to age between 5 to 16 years of age (Tables 2 and 3).

Mode of injury

Among 229 cases, 105 cases (45.85%) sustained an injury due to fall while playing, 89 cases (38.86%) fall from a height, 30 cases (13.10%) due to a road traffic accident and 5 cases (2.18%) (Figure 10).

Type of fracture pattern

Among 229 cases, the pattern of fractures was transverse in 109 cases (47.59%), spiral in 53 cases (23.14%), oblique in 31 cases (13.53%) and comminuted in 36 cases (15.72%) (Graph 2).

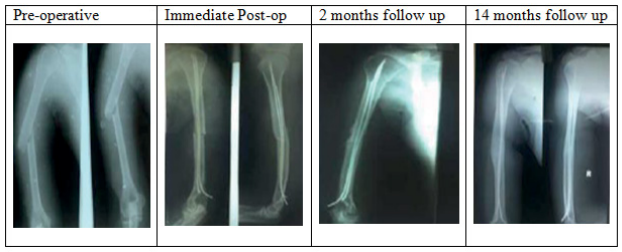


Figure 7: Radiographs of Humeral TENS.

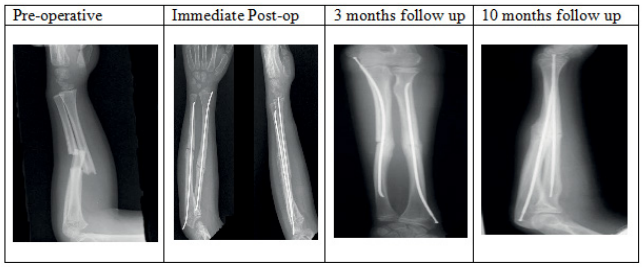


Figure 8: Radiographs of Forearm TENS.

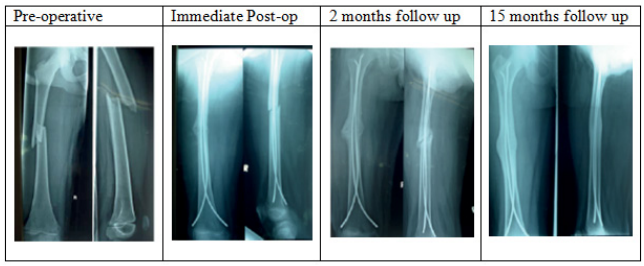


Figure 9: Radiographs of Femur TENS.

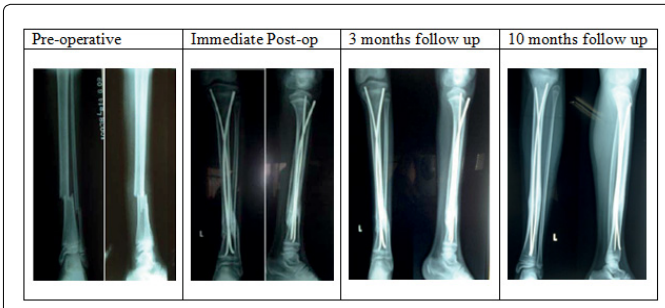
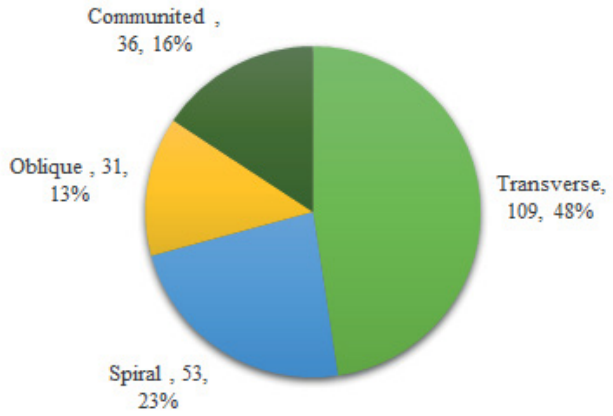


Figure 10: Radiographs of Tibia TENS.



Graph 2: Type of fracture pattern.

Nature of fracture

Among 229 cases, 184 cases had simple fractures and 45 cases had type 1 compound fractures (Graph 3).

Closed v/s open reduction of fractures

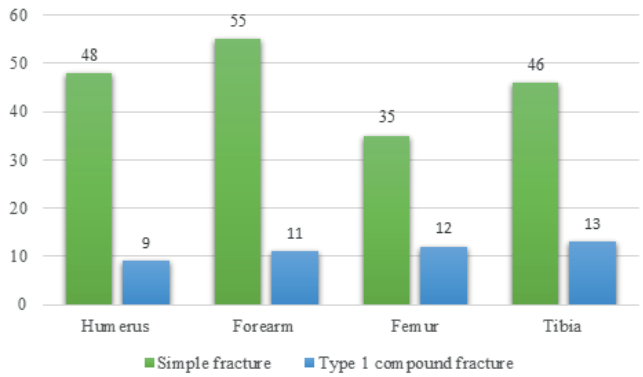
Among 229 cases, 169 cases (73.79%) were operated with closed reduction of fractures and percutaneous TENS nailing and 60 cases (26.20%) underwent an open reduction of fractures and percutaneous TENS nailing (Figure 11). The open reduction of fractures was due to delayed presentation to hospital for management, inadequate immobilization of fracture fragments, the interposition of soft tissues and failed closed reduction (Graph 4).

Details of surgery

The simple fracture cases were operated with an average of 2.71 ± 0.53 days ranging from 2.10-3.29 days of admission. Type 1 compound fracture cases were operated with an average of 4.93 ± 0.92 days ranging from 3.01-6.27 days of admission (Figure 12). All compound fracture cases were treated with IV antibiotics and regular dressings. No intraoperative complications were noted during the surgical procedure (Figure 13).

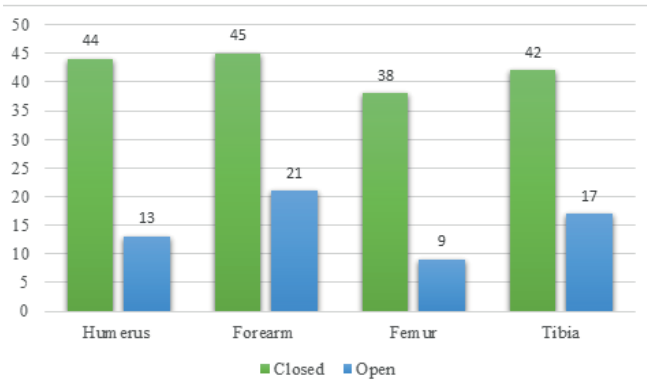
Duration of fracture union

All the cases were followed up serially as per our protocol with serial clinical and radiographical examinations. The mean radiological union of humeral fractures was 13.23 ± 1.92 weeks, radius and ulna 12.29 ± 0.12 weeks, femur 14.05 ± 1.79 weeks and tibia 13.93 ± 1.57



Graph 3: Nature of fracture.

Figure 11: showing breakage of TENS nail in radius.



Graph 4: Reduction of fractures.

Figure 12: Showing migration of TENS from ulna.

Figure 13: Showing non-union of radius post TENS treated with LCP.

weeks (Figure 14). All cases showed the union of fracture with an average of 13.37 ± 1.35 weeks. A total of 2 cases (0.87%) showed signs of established non-union after 9 months of post-procedure (Figure 15).

Range of movements

All cases were trained with active and passive joint mobilization

Figure 14: Showing breakage of TENS nail in humerus and non-union of humerus.

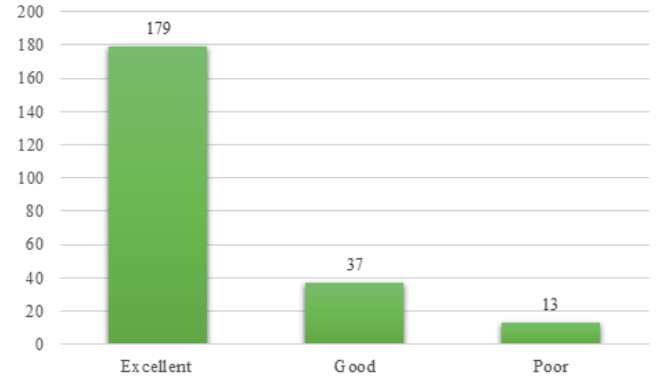
Figure 15: Showing non-union of humerus posted TENS treated with DCP.

exercises after the clinical sign of fraction union. The functional assessment was made with DASH, Mayo's wrist, Harris Hip score, and Lysholm scores. Out of 229 cases, the range of movements according to Flynn's criteria was excellent in 179 cases (78.16%), good in 37 cases (16.15%) and poor in 13 cases (5.67%). The poor range of movements (n=13) were due to deep infection 3 cases, non-union 3 cases, breakage of nail 2 cases and nail migration 5 cases (Table 4).

Complications

The most common complication encountered in our study was pain 27 cases (11.79%), superficial infection at the nail insertion site 13 cases (5.76%), followed by deep infection 3 cases (1.31%), malunion 6 cases (2.62%), non-union 3 cases (1.31%), nail migration 5 cases (2.18%), limb lengthening 3 cases (1.31%), varus angulation 6 cases (2.62%), valgus angulation 2 cases (0.87%), rotational angulation 2 cases (0.87%), sinking of nail into medullary cavity 3 cases (1.31%) and breakage of nail in 2 case (0.87%) (Table 5).

The superficial infection at the nail insertion site was treated by IV antibiotics for 5 days followed by oral antibiotics for 5 days with regular dressings. Deep infection cases were treated with culture sensitive IV antibiotics for 2 weeks followed by oral antibiotics for 4 weeks with



Graph 5: Range of movoements.

Grading	Humerus	Radius and Ulna	Femur	Tibia
Excellent	44	46	38	51
Good	12	13	7	5
Poor	1	7	2	3
Total	57	66	47	59

Table 4: Grading.

Complications	Humerus	Radius and Ulna	Femur	Tibia
Pain	6	12	5	4
Superficial infection at the nail insertion site	2	4	4	3
Deep infection	-	1	2	-
Malunion	1	2	1	2
Non-union	1	1	-	1
Nail migration	-	3	-	2
Nerve injuries	-	-	-	-
Limb lengthening	-	-	2	1
Limb shortening	-	-	-	-
Varus angulation	1	2	2	1
Valgus angulation	-	-	2	-
Anterior angulation	-	-	-	-
Posterior angulation	-	-	-	-
Rotational angulation	1	-	1	-
Sinking of nail into medullary cavity	-	1	2	-
Breakage of nail	1	1	-	-

Table 5: Complications.

Figure 16: Showing tibial TENS removal after fracture union.

serial radiographic analysis. Non-union cases were counseled for the second surgical procedure with dynamic compression plating. All nail migration cases were tracked regularly with the advice of nail removal once when clinical and radiological signs of fracture union were observed. The cases with malalignment and angulation got corrected in due course of bony remodeling after the nail removal. Nail breakage case went into non-union of fracture and later implant removal followed by plating was done (Figure 16).

Clinically and radiologically united fracture patients were offered with implant removals which were done under loco-regional anesthesia in an average of 17.32 ± 3.49 months.

Discussion

The current research on trauma management drastically changes to keep pace with the increasing severity and complications of the fractures. The management of fracture focuses on surgical procedure with early rehabilitation and early return to activities with improved functional quality of life. The goal of treatment in pediatric diaphyseal long bone fractures is to achieve length and avoid mal-alignment and create a favorable environment for fracture and soft tissue healing [3-7].

In our study, we have considered the use of intramedullary titanium elastic nailing system with C-C nail construct for pediatric diaphyseal long bone fractures. TENS works through the principle of two opposing balancing forces gives enough stability at the fracture site to allow early ambulation [8].

Significance of titanium implants

In recent times, titanium implants were increasingly used for elastic intramedullary nailing. Titanium elasticity limits the amount that the nail is permanently deformed during insertion. By limiting the stress shielding, the elasticity of the nail promotes the callus formation. Titanium has excellent soft tissue biocompatibility [9].

Humeral fractures

Sumeet et al. operated 13 pediatric patients with humeral shaft fractures with TENS showed a high union rate with minimum complications in 23 months follow up period [10]. Kornah AB et al. reviewed surgically managed 28 closed humeral diaphyseal fractures using ESNF showed excellent, good, fair and poor in 17, 8, 2, 1 case respectively according to DASH score. They concluded for treating adult humeral shaft fractures holds good with elastic nailing system [11]. Zivanovic VD et al. retrospectively reviewed 32 patients with humeral shaft fractures managed with ESNF and concluded ESIN as the surgical method of choice for displaced humeral fractures in children and adolescents without any significant complications [12].

In our study, there were 36 males and 21 females with humeral diaphyseal fractures. There were 48 simple and 9 types 1 compound diaphyseal humeral fractures. The mean radiological union of fractures was 13.23 ± 1.92 weeks. Out of 57 cases, we observed excellent results in 44 cases, good in 12 cases and poor in 1 case. The mean DASH score at the final follow up was 27.20 ± 4.55. The complications in humeral TENS nailing were pain 6 cases, superficial infection at the nail entry site 2 cases, malunion 1 case, non-union 1 case, varus angulation 1 case, rotational angulation 1 case, and nail breakage 1 case.

Forearm fractures

Kelly AB et al. showed uncomplicated radiographic union at a mean 3.6 months who got operated 485 patients with intramedullary nails of both bone forearm fractures [13]. Mohammed et al. proved a low complication rate with high rates of the union in 79 children who underwent flexible titanium elastic nail in displaced fracture of shaft of both bone forearm [14]. Byung Sung Kim et al. retrospectively reviewed the results of 40 patients with IM nailing for pediatric forearm fractures and reported good and excellent in 38 and 2 cases respectively according to Daruwalla criteria with the restoration of forearm rotation. Even though the fracture was located at the MDJ of the radius, intramedullary nail fixation maintained adequate stability for both forearm bone fractures in adolescents [15].

In our study, there were 43 males and 23 females with both bone forearm diaphyseal fractures. The most common mode of injury involved in this group is fall while playing followed by fall from height. There were 55 simple and 11 types 1 compound diaphyseal forearm fractures. The mean radiological union of fractures was 12.29 ± 0.12 weeks. Out of 66 cases, we observed excellent results in 46 cases, good in 13 cases and poor in 7 cases. The mean Mayo's wrist score at the final follow up was 81.78 ± 3.12. The complications in radial and ulnar TENS nailing were pain 12 cases, superficial infection at the nail entry site 4 cases, deep infection 1 case, malunion 2 cases, non-union 1 case, nail migration 3 cases, varus angulation 2 cases, sinking of the nail into medullary cavity 1 case and nail breakage 1 case.

Femoral fractures

Ibrahim M et al. studied the complications associated with fracture shaft of femur in 10 children managed with TENS, proved no complications associated with surgery and improved functional quality of life of the patients [16]. Roop Singh et al. conducted a study with 35 pediatric patients with femoral diaphyseal fractures were stabilized with two titanium nails. Overall results observed were excellent to

satisfactory in 33 and poor in 2 patients. All the fractures healed with an average time to union of 9.6 weeks. The return to school was early with an average of 7.8 weeks. TENS proved to be an ideal implant for pediatric femoral fracture fixation [17]. Saikia et al. concluded intramedullary fixation titanium elastic nailing is an effective treatment of diaphyseal fractures of the femur in properly selected patients of the 6-16 years age group after a mean of 26 months of follow up [18].

In our study, there were 28 males and 19 females with femoral diaphyseal fractures. The most common mode of injury involved in this group is fall while playing followed by fall from height. There were 35 simple and 12 types 1 compound diaphyseal femoral fractures. The mean radiological union of fractures was 14.05 ± 1.79 weeks. Out of 47 cases, we observed excellent results in 38 cases, good in 7 cases and poor in 2 cases. The mean Harris Hip score at the final follow up was 85.08 ± 3.72. The complications in femoral TENS nailing were pain 5 cases, superficial infection at the nail entry site 4 cases, deep infection 2 cases, malunion 1 case, limb lengthening 2 cases, varus angulation 2 cases, valgus angulation 2 cases, rotational angulation 1 case and sinking of the nail into medullary cavity 2 cases.

Tibial fractures

Sankar NW et al., who studied the effectiveness of TENS for 19 pediatric tibial shaft fractures, have shown 12 excellent, 6 satisfactory and 1 poor result according to Flynn's classification. Elastic stable intramedullary nailing with titanium elastic nails is an effective surgical technique which allows rapid healing of tibial shaft fractures with an acceptable rate of complications [19]. Kapil Mani et al. retrospectively reviewed 45 patients with TENS for tibial fractures in children and concluded TENS is a simple, easy, rapid, reliable and effective method of pediatric tibial fractures in patients with operative indications [20].

In our study, there were 33 males and 26 females with tibial diaphyseal fractures. The most common mode of injury involved in this group is fall while playing followed by fall from height. There were 46 simple and 13 types 1 compound diaphyseal tibial fractures. The mean radiological union of fractures was 13.93 ± 1.57 weeks. Out of 59 cases, we observed excellent results in 51 cases, good in 5 cases and poor in 3 cases. The mean Lysholm score at the final follow up was 84.17 ± 3.02. The complications in tibial TENS nailing were pain 4 cases, superficial infection at the nail entry site 3 cases, malunion 2 cases, non-union 1 case, nail migration 2 cases, limb lengthening 1 case and varus angulation 1 case.

Advantages of elastic nailing system

- Elastic intramedullary nails are subjected to smaller bending loads than plates because it is closer to the mechanical axis than the usual plate position on the external surface [21,22]
- Nails can act as load sharing devices in fractures with cortical contact if the nail is not locked at both proximal and distal ends, it will act as a gliding splint and allow fracture compression as the extremity is loaded
- In midshaft fractures, nails that fill the medullary canal automatically re-establish osseous alignment
- Nailing does not need extensive periosteal stripping which is required for plate application
- With image intensification these can be inserted in a closed manner, without exposing the fracture site, thus decreasing the infection rate and soft tissue scarring with higher union rate and fewer chances of iatrogenic radial nerve palsy

Disadvantages of Elastic Nailing System

- Migration and backing out of nails are more common [21,22]
- Higher rate of non-union of fractures
- Malunion of fractures due to rotatory instability
- In the case of distal entry of nail, there can be a limitation of joint movements, myositis, and iatrogenic fracture
- Nailing interferes with the endosteal blood supply of the bones.

Titanium elastic nailing system has significantly decreased the time in hospitalization resulting in the early return of the patients to their home environment. TENS should be considered to be the physiological method of surgical treatment of pediatric diaphyseal long bone fractures. The surgical technique offered by TENS was relatively simple, minimally invasive and biological healing with callus occurs.

Conclusion

The ideal device for the treatment of pediatric diaphyseal long bone fractures would be a simple, load sharing internal splint that allows mobilization and maintenance of alignment and extremity length until bridging callus forms. Thus, titanium elastic nailing system has offered a major advantage of surgical management with decreased morbidity and increased the functional quality of life in pediatric diaphyseal long bone fractures.

References

1. Cooper C, Dennison EM, Leufkens HG, Bishop N, Avan STP (2004) Epidemiology of childhood fractures in Britain: A study using the general practice research database. J Bone Miner Res 19:1976-1981.
2. Franklin CC, Robinson J, Noonan K, Flynn JM (2012) Evidence-based medicine: Management of pediatric forearm fractures. J Pediatr Orthop 32: S131-S134.
3. Salem KH, Lindemann I, Keppler P (2006) Flexible intramedullary nailing in pediatric lower limb fractures. J Pediatr Orthop 26: 505-509.
4. Gordon JE, Gregush RV, Schoenecker PL, Dobbs MB, Luhmann SJ (2007) Complications after titanium elastic nailing of pediatric tibial fractures. J Pediatr Orthop 27: 442-446.
5. Flynn JM, Hresko T, Reynolds RA, Blasier RD, Davidson R, et al. (2001) Titanium elastic nails for pediatric femur fractures: a multicenter study of early results with analysis of complications. J Pediatr Orthop 21: 4-8.
6. Flynn JM, Jones KJ, Garner MR, Goebel J (2010) Eleven year's experience in the operative management of pediatric forearm fractures. J Pediatr Orthop 30: 313-319.
7. Venkatesh GSK, Bathina P, Kommera S (2016) Comparative study of CC and CS construct with enders nail in diaphyseal fractures of femur in pediatric age group. Tech Orthop 31: 133-136.
8. Heinrich SD, Drvaric DM, Darr K, MacEwen GD (1994) The operative stabilization of pediatric diaphyseal femur fractures with flexible intramedullary nails: A prospective analysis. J Paediatr Orthop 14: 501-507.
9. Ligier JN, Metaizeau JP, Prevot J, Lascombes P (1988) Elastic stable intramedullary nailing of femoral shaft fractures in children. J Bone Joint Surg Am 70: 74-77.
10. Garg S, Dobbs MB, Schoenecker PL, Luhmann SJ , Gordon JE (2009) Surgical treatment of traumatic pediatric humeral diaphyseal fractures with titanium elastic nails. J Child Orthop 3: 121-127.
11. Bahaa AK, Abdel AS, Mohamed A, Abdel AAL (2017) Elastic stable intramedullary nailing for closed diaphyseal fractures of humerus in adults a case series of 28 patients. J Trauma Treat 6: 400.
12. Dragoljub VZ, Andjelka RS, Zoran LR, Zoran OM, Nikola MB, et al. (2019) Elastic stable intramedullary nailing of humerus fractures in children. Int J Clin Exp Med 11: 2950-2964.

13. Brian AK, Benjamin JS, Donald SB, Daniel JH, Michael PG (2016) Pediatric forearm fractures with in situ intramedullary implants. J Child Orthop 10: 321-327.

14. Mohammad R, Kaushal KS, Ayush BS, Maneesh KG, Ranjan KJ (2016) Flexible intramedullary titanium elastic nailing of fracture shaft of radius and ulna in children at a tertiary care teaching hospital. Ortho and Rheum Open Access J 2: 555-584.

15. Byung SK, Yong SL, Sung Yk, Jae HO, Sun GL, et al. (2017) Flexible intramedullary nailing of forearm fractures at the distal metadiaphyseal junction in adolescents. Clinics in Orthopedic Surg 9: 101-108.

16. Mohammed I, Meganath P, Kausar N (2016) Tens in fractures shaft of the femur in children. Int J of Orthopaedics Sci 2: 74-76.

17. Singh R, Sharma SC, M GNK, Singla A (2006) Titanium elastic nailing in pediatric femoral diaphyseal fractures. Indian J Orthop 40: 29-34.

18. Saikia KC, Bhuyan SK, Bhattacharya TD, Saikia SP (2007) Titanium elastic nailing in femoral diaphyseal fractures of children in 6-16 years of age. Indian J Orthop 41: 381-385.

19. Wudbhav N, Sankar KJ, Jones BDH, Lawrence W (2007) Titanium elastic nails for pediatric tibial shaft fractures. J Child Orthop 1: 281-286.

20. Kapil MKC, Parimal A, Arun S (2016) Titanium elastic nailing system for tibia fractures in children: Functional outcomes and complications. J Nepal Med Assoc 55: 55-60.

21. Schmittenbecher PP, Fitze G, Godeke J (2008) Delayed healing of forearm shaft fractures in children after intramedullary nailing. J Pediatr Orthop 28: 303-306.

22. Slongo TF (2008) Ante and retrograde intramedullary nailing of humerus fractures. Oper Orthop Traumatol 20: 373-386.