

Custom Fit or Compromise? Role of Titanium Nails in Paediatric Long Bone Fracture Treatment

Giri R.K.¹, Paka V.K.², Kadiveti S.³, Thadiparthi V.K.⁴

^{1,2,3,4}King George Hospital, Visakhapatnam, Andhra Pradesh, India

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Corresponding author: Dr. Thadiparthi V.K.

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Abstract

Background: The management of paediatric long bone fractures has shifted significantly in recent years, moving from traditional conservative approaches toward surgical interventions. Surgical treatment with nails, external fixator and plating is associated with significant complication rates. Titanium elastic nailing system is introduced in view of tailor-made nature for paediatric bone. This prospective study evaluates the clinical, radiological, and functional outcomes of Titanium Elastic Nailing System (TENS) in managing diaphyseal long bone fractures in children aged 6 to 15 years.

Patients and Method: Thirty children with closed diaphyseal fractures of the femur, tibia, humerus, or forearm bones were treated with TENS and followed for a minimum of one year. Exclusion criteria included open fractures, polytrauma, syndromic conditions, and pathological fractures. Surgical technique involved careful avoidance of the physis and standardized nail placement. Postoperatively, patients received antibiotics, early mobilization protocols, and regular follow-up assessments.

Results: Radiological union was achieved within 12 weeks in 80% of cases, with full functional loading in most children by the same timeframe. According to Flynn's criteria, 70% of cases showed excellent outcomes and 30% satisfactory, with no poor results observed. Minor complications occurred in 30% of patients, including nail site pain, superficial infections, and minimal limb shortening. No major complications or reoperations were reported.

Conclusion: TENS demonstrated favourable outcomes in terms of early mobilization, high union rates, and minimal complications. Its minimally invasive nature and ability to preserve growth potential make it a reliable option for managing diaphyseal fractures in appropriately selected paediatric patients. Despite the study's limitations—such as a small sample size and lack of a control group—findings support TENS as an effective and safe treatment modality in paediatric orthopaedic trauma care.

Keywords: Diaphyseal Fractures, Flynn's Criteria, Nail Caps, Three-Point Fixation.

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Introduction

The management of paediatric long bone fractures has evolved significantly over the years. Traditionally, conservative treatment was the preferred approach, owing to the rapid healing potential in children and their ability to achieve spontaneous correction of angulation. These unique characteristics made non-operative management a reliable and widely accepted choice.

However, in recent times, operative treatment has gained increasing importance due to its ability to offer stable fixation, early mobilization, and predictable outcomes. Despite this, the ideal approach to managing paediatric long bone fractures remains a topic of ongoing debate. Surgical options for these fractures include external fixation, compression plating, and intramedullary nailing. Each modality comes with its own set of

potential complications such as pin track infections, loss of reduction, implant removal challenges, growth arrest, and avascular necrosis. Flexible intramedullary nailing, first introduced in 1979 by Professor Jean Prévot and his team, represented a significant advancement in surgical fracture management. Titanium Elastic Nailing (TEN) has emerged as a minimally invasive, efficient, and biomechanically stable method. It offers numerous advantages including solid fixation, accelerated healing, early return to daily activities, and a relatively low complication rate.

Despite its widespread use, there is no clear consensus on the superiority of Titanium Elastic Nailing over conservative methods in the paediatric population. This study aims to evaluate the clinical, radiological, and functional outcomes of elastic

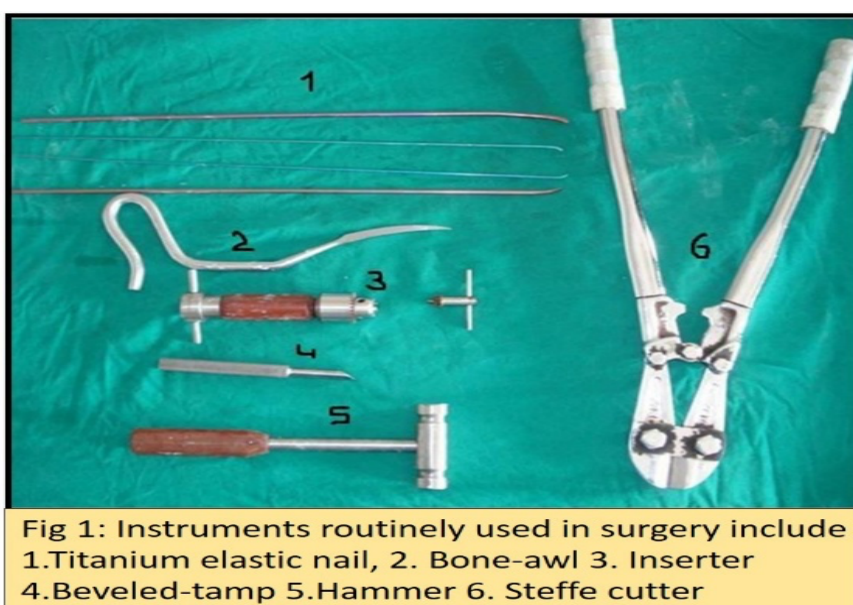
intramedullary nailing in the management of paediatric diaphyseal long bone fractures.

Patients and Method

This is a prospective study carried out over a period of two years at our institute involving 30 children who sustained closed diaphyseal fractures of various long bones like femur, humerus, tibia and forearm bones (radius and ulna) treated surgically with titanium elastic nailing system. Children aged between 6 to 15 years with closed long bone fractures were included in the study. Children with open fractures, multiple injuries, co-existing syndromes, pathological fractures, neuro muscular disorders were excluded from the study. Preliminary evaluation included clinical

examination to rule out other injuries, followed by x ray evaluation of the involved part including one joint above and below. Fracture was stabilized provisionally by application of plaster of Paris slabs until surgery. Routine blood investigation necessary for pre anaesthetic check-up were done. Informed written consent was obtained from the guardians prior to inclusion in the study group.

All children were operated either under general or spinal anaesthesia based on their age and involved fracture site. C arm was used to guide the entry points stayed in the diaphyseal segment of bone with sparing of physis. Inventory needed for surgery include bone awl, inserter, beveled-tamp, hammer and Steffe-cutter (Fig 1).



Procedure: Femur (retrograde): Vertical skin incision of 1cm was made on medial and lateral aspect of distal thigh about 2 cm proximal to distal physis. Soft tissue was separated using haemostat and an entry point was made using curved bone awl under C arm guidance to avoid damage to physis. Each nail of about 40% of diameter of bone at narrowest point was chosen.

Titanium nails were pre bent to their limit. Nail was introduced through the previously made entry point into the canal. Fracture site was reduced through controlled manipulation of segments. Once the nail crossed the fracture site, second nail of same diameter was introduced through the medial entry point. Lateral nail was pushed up to the level of base of greater trochanter. Medial nail was pushed up to the level of medial calcar. Care was taken to prevent coiling of one nail over other (corkscrew phenomenon) as it leads to instability/imbalance of forces between the two nails. Protruding nail ends

were cut leaving about 0.5 to 1cm and were bent away to prevent skin irritation. Tibia (antegrade): Skin incision was made 2cm distal to proximal physis while staying posterior to tuberosity physis. Nail were introduced in similar manner as in femur and pushed up to 2cm above the distal tibial physis. Nail tips were cut leaving 0.5 to 1cm and not bent to avoid skin irritation. Humerus (ante or retro grade): entry point made avoiding damage to physis Nail of appropriate size chosen and passed with the fracture held in reduction.

Radius and Ulna (Fig 2,3): Nail is passed from distal entry point for radius and proximal entry point for ulna. For diaphysis fractures, the entry point into the radius is either through Lister's tubercle right or adjacent to the radial styloid. Entry point for ulna fractures is made on the medial side distal to physis. Nail of usually 2 to 3mm are used. Single nail is used in ulna and radius shaft fractures due to the relatively small size of medullary canal.

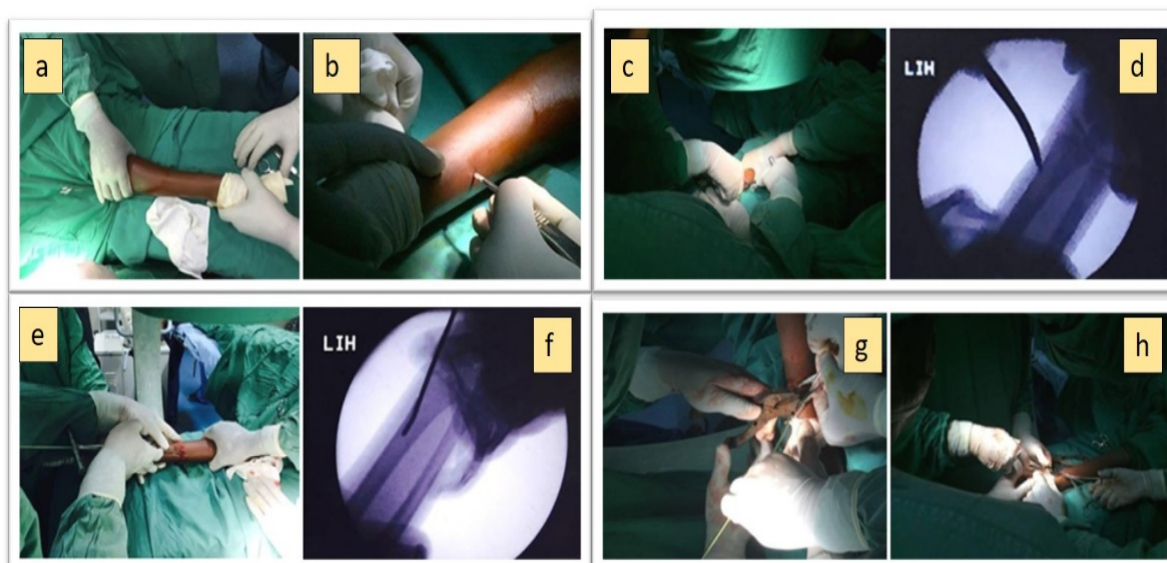


Fig 2: shows a) Positioning of forearm for making entry point in radius with entry point marked (b) under C arm guidance (c) (d) and made with bone awl. (e), (f), (g) and (h) Step wise introduction of titanium nail using t handle, guided by C arm images.

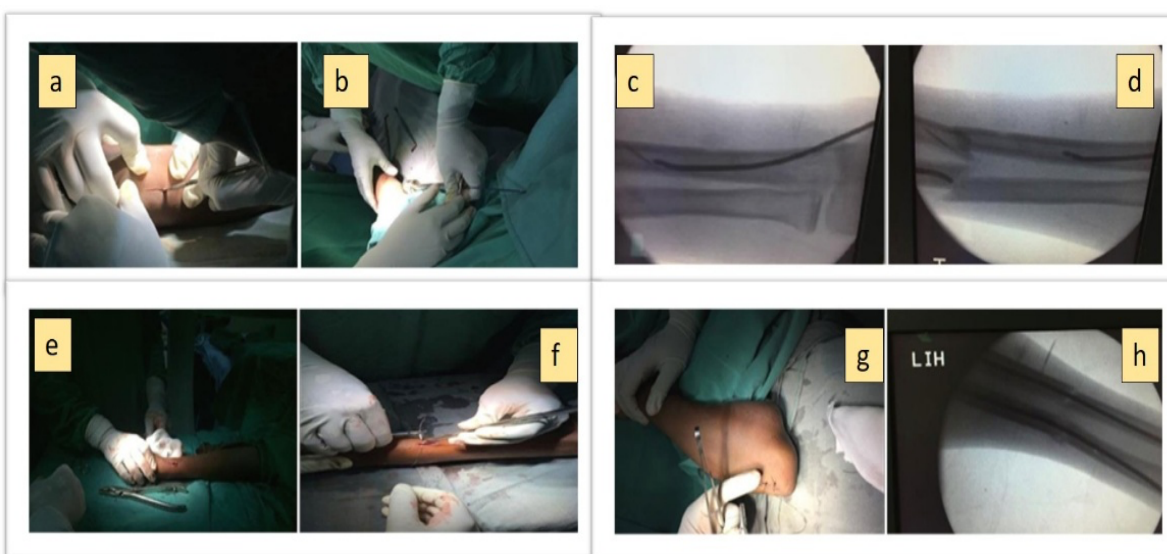


Fig 3: Steps of ulna nailing (a) skin incision and (b) nail passage after making entry point with awl. (c), (d) Serial C arm images taken to track the nail passage. (e), (f) (g) closure of incision site and final C arm image (h) showing well reduced radius and ulna shaft fracture with titanium nails in both bones.

Post operatively limb was immobilized in a Plaster of Paris slab for a minimum of three weeks.

Intra venous antibiotic and analgesics were administered as per the child's age and weight. Three days of injectable antibiotics were administered, followed by seven days of oral broad-spectrum antibiotics. Suture removal was done around 10th post-operative day.

Physical therapy: For stable fractures day one static muscle strengthening exercise were advised. At

two weeks patients with lower limb fractures were allowed to walk with crutches. Full weight bearing was resumed at four weeks after surgery.

In unstable fractures crutch walking was delayed until four to six weeks before full functional loading was gradually permitted, depending on the patient and their pain tolerance.

Follow up: Assessment was done at two, four, six, twelve, twenty-four weeks and one year (Fig 4). At each follow up patients were assessed

radiologically, clinically and for complications. At follow up stiffness of joints, wound infection, range of movements, any mal alignment, limb length discrepancy and pain were clinically evaluated. Radiological evaluation included time of radiological union, disimpaction in both antero-posterior and lateral views and nail migration or penetration. Complications were categorized as

major if were associated with prolonged morbidity or needed further surgical interventions.

Other complications which resolved without additional surgery and did not result serious morbidity were considered as minor in nature.

Flynn's scoring criteria was used to evaluate the functional outcome after surgery.

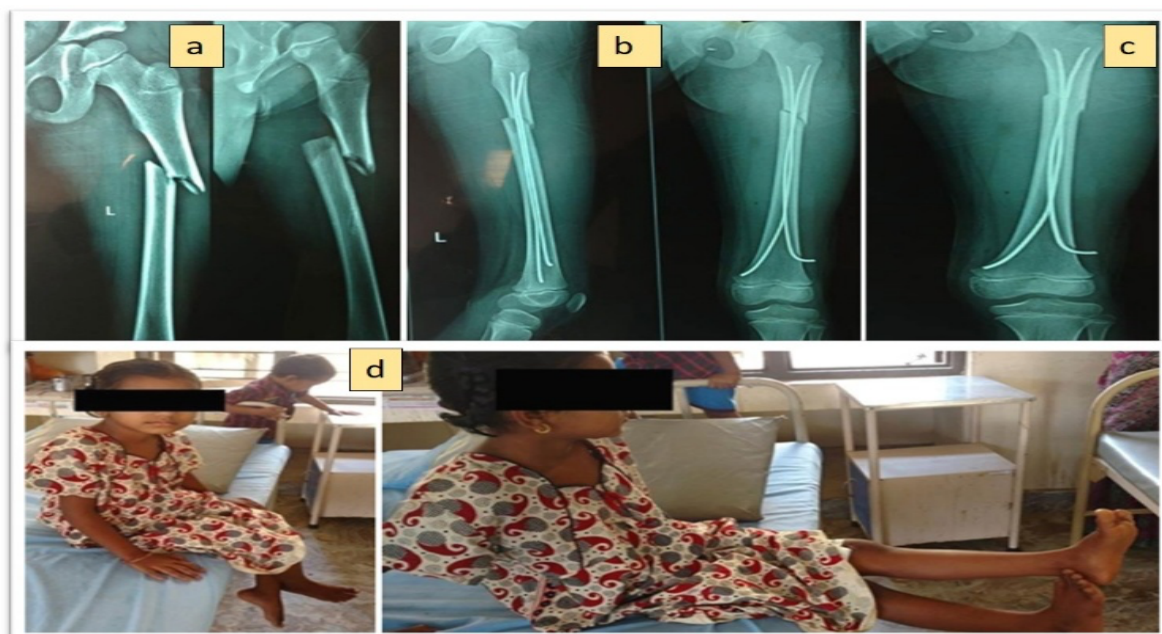


Fig 4: Pre operative x ray showing fracture of femur shaft (a) with angulation of segments. (b) immediate post operative x ray of the same patient showing well reduced fracture with three point fixation by titanium nails. (d) At six month follow up clinical evaluation of knee joint with good range of flexion and extension movements.

Results

All 30 patients enrolled in the study were successfully followed up for a minimum period of one year with no lost in follow up cases. Fracture union time was less than 12 weeks in 24 patients (80%), between 12 to 18 weeks in 5 patients (16.7%) and over 18 weeks (3.3%) in one patient. Full range of movements were regained in 28 (93.33%) patients by 24 weeks post-surgery. Two patients had mild restriction of movements by 24 weeks but later regained full range by the end of one year. 24 patients returned to total functional loading in less than 12 weeks, 5 patients returned to total functional loading in between 12-18 weeks, one patient with comminuted humerus fracture took 20 weeks for functional loading. Excellent results were obtained in 70% of patients, whereas 30% patients had satisfactory results according to Flynn et al. Scoring. None of them reported poor outcome. 16 (53.33%) of the patients were less than 10 years age and the remaining 14 (46.66%) were aged between 11 to 15 years. Mean age of the

patients in the study was 10.03 years. 20 (66.66%) of the children were males and 10 (33.33%) were females. Road traffic accidents (50%) were the most common mode of injury followed by self-fall (33.33%) and fall from height (16.66%). Femur (40%) was most common bone involved followed by tibia (30%), forearm bones (20%) and humerus (10%). Left side was involved in 18 (60%) children, while right side was involved in the remaining 12 (40%).

Most observed fracture pattern was transverse (40%), followed by oblique (33%), spiral (16%) and comminuted (10%) variants. Most of the children were operated within seven days following trauma with only three patients needing more than a week to operate. 14 patients were operated under one hour, 14 needing 90 minutes and 2 patients over 90 minutes and less than 2 hours. All except two were discharged by 10th post-operative day. Minor complication needing no further surgical intervention were noticed in nine patients (30%). Pain at the nail insertion site was complained by

three children. Nail migration, superficial infection was observed in one child each. Superficial infection subsided with oral antibiotic therapy. Shortening of less than 2ccm was observed in two children.

Discussion

There is general agreement that conservative management remains appropriate for children under five years of age. However, for children aged five to sixteen, there is no clear consensus regarding the optimal treatment modality [1]. While non-operative management continues to be widely used, it is often associated with longer hospital stays, increased costs, and complications such as limb length discrepancy, malalignment (angulation and rotational deformities), and prolonged immobilization [2,3,4].

As a result, surgical management has gained prominence, particularly for older children and in cases where conservative treatment may not yield satisfactory outcomes [5]. Nonetheless, surgical approaches—such as intramedullary nailing—carry their own risks, especially the potential for physeal (growth plate) damage. Managing paediatric fractures is uniquely challenging due to the smaller bone size, presence of open physis, and immature vascular patterns. Titanium Elastic Nailing (TENS) has emerged as a valuable alternative that avoids damage to the physis while offering stable internal fixation. Both the American Academy of Orthopaedic Surgeons (AAOS) and the UK's National Institute for Health and Care Excellence (NICE) recommend Elastic Stable Intramedullary Nailing (ESIN) for diaphyseal femoral fractures in children aged 4 to 12 years [6,7].

TENS is a minimally invasive technique that requires only a small incision, thereby preserving soft tissues and offering better cosmetic outcomes. Compared to other surgical options such as plating, TENS typically involves shorter operative times, reduced hospital stays, and easier implant removal with minimal soft tissue disruption [8]. Its biocompatibility, elasticity, and load-sharing nature facilitate early mobilization, maintain fracture alignment, and avoid permanent deformation or adverse reactions such as metal sensitivity [9].

The fundamental principle of TENS is three-point fixation, which provides rotational, translational, and axial stability. Micromotion at the fracture site encourages healing through callus formation. Advantages include early functional recovery, preservation of the physis, minimal scarring, and straightforward implant removal. TENS nails are inserted into the medullary canal of long bones and maintain fracture reduction through elastic bracing. The technique resists angular forces and axial loading [10]. Recent advances—including pre-bent

nails, end caps, and refined surgical techniques—have further improved the outcomes of TENS in paediatric fracture management [11]. End caps minimize nail tip irritation and increase stability by improving axial load distribution [12].

Strict adherence to proper surgical technique is crucial for optimizing outcomes in diaphyseal fractures [13]. TENS is applicable to a range of long bones including the humerus, forearm, femur, and tibia. In cases where closed reduction is unsuccessful, open reduction may be necessary. Notably, Pace et al. reported satisfactory outcomes in the management of open fractures using ESIN, with faster union and better results compared to external fixation [14].

Despite its benefits, TENS is not without complications. Reported complication rates vary between 14% and 42% [15]. Common complications include skin irritation at the nail entry site, nail prominence, infection, and implant migration. Less frequent but serious complications include osteomyelitis, malunion, non-union, neurovascular injury, premature physeal closure, limb length discrepancy, and compartment syndrome.

One of the most frequent complications is nail tip prominence, which may lead to skin irritation and necessitate early implant removal before adequate callus formation. This is particularly problematic in areas with limited soft tissue coverage, such as the olecranon (ulna), distal femur, and proximal tibia. Conversely, excessively deep nail burial can make implant removal difficult or unsuccessful. Therefore, achieving the correct balance in nail placement is essential for optimal outcomes. To prevent nail tip irritation, it is recommended that nails be placed away from the physis, avoid acute bends near the entry point, and occupy approximately 80% of the medullary canal diameter. The use of nail caps and proper end trimming also help reduce complications. In cases of skin breakdown, appropriate wound closure following nail adjustment is necessary.

Fracture bracing failure may result from incorrect orientation of the nail bend, which should ideally correspond to the fracture site. Improper technique can lead to fracture blowout, nail backing out, and tip prominence. Awareness of these risks and meticulous surgical technique can minimize such issues. Refractures—particularly in the forearm—have been reported at rates of 6–10% and are often associated with incomplete union. Rare complications include nerve palsy and tendon entrapment.

This study has several limitations. The small sample size limits the generalizability of the results. Additionally, the lack of a comparator group (such

as patients managed conservatively or with alternative surgical methods) hinders direct comparison. Another limitation is the inclusion of fractures from various anatomical sites, which may obscure site-specific outcomes or complications. Lastly, the absence of standardized clinical and patient-reported outcome measures limits the ability to assess functional recovery objectively.

Conclusion

The management of paediatric bone injuries presents unique challenges distinct from adult orthopaedic care. Paediatric bones differ in structure and healing potential, particularly due to the presence of open growth plates (physis), making the application of adult treatment protocols inappropriate. Titanium Elastic Nailing System (TENS) offers a suitable solution for long bone fractures in children, particularly those aged six years and older. This technique allows for the preservation of the physis, significantly reducing the risk of growth disturbances. In addition, TENS is a relatively minimally invasive procedure that supports early mobilization and faster recovery, which is particularly beneficial for the paediatric population. When the fundamental principles of TENS application are followed—such as proper patient selection, implant sizing, and technique—outcomes tend to be highly favourable, with minimal complications. However, it is important to acknowledge the existence of a learning curve associated with mastering the technique. With experience, surgeons can effectively navigate the nuances of paediatric bone handling and achieve consistent results. In conclusion, TENS represents a reliable and effective treatment option for paediatric fractures in appropriately selected cases. Its minimally invasive nature, along with the ability to preserve growth potential, makes it a preferred method in modern paediatric orthopaedic practice. Emphasizing proper technique and understanding the distinct characteristics of paediatric bone are key to optimizing outcomes and minimizing risks. As surgical expertise with TENS continues to evolve, it holds the promise of improving functional recovery and quality of life in paediatric fracture management.

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