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Original Research Article

To Assess the Functional Outcome in A Closed Reduction Internal Fixation of Paediatric Diaphyseal Fracture Femur with Titanium Elastic Nailing System (TENS)

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Abstract:
In children, these injuries are of special concern because they not only disrupt the structural integrity of the femur but may also have long-term implications on growth, limb alignment, and function. The treatment of such fractures in the growing skeleton must therefore achieve a delicate balance between ensuring adequate stabilization and preserving the biological environment for bone healing and growth. Over the years, management strategies for pediatric femoral shaft fractures have evolved significantly— from conservative approaches such as traction and casting to surgical fixation methods that promote early mobilization and better functional recovery.

Keywords: Paediatric, Diaphyseal, Femur.
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Introduction

Pediatric diaphyseal femur fractures are among the most common and significant long bone injuries in children, accounting for approximately 1.6% of all pediatric fractures. They usually occur as a result of high-energy trauma such as road traffic accidents, falls from height, or sports-related injuries. The femoral shaft, being one of the strongest bones in the body, requires a considerable amount of force to fracture.[1] In children, these injuries are of special concern because they not only disrupt the structural integrity of the femur but may also have long-term implications on growth, limb alignment, and function. The treatment of such fractures in the growing skeleton must therefore achieve a delicate balance between ensuring adequate stabilization and preserving the biological environment for bone healing and growth. Over the years, management strategies for pediatric femoral shaft fractures have evolved significantly— from conservative approaches such as traction and casting to surgical fixation methods that promote early mobilization and better functional recovery.[2]

Among the surgical modalities available, closed reduction and internal fixation with Titanium Elastic Nails (TEN) has emerged as the preferred treatment for diaphyseal femur fractures in children aged between 5 and 15 years. The technique is minimally invasive, biologically friendly, and mechanically stable, allowing for early rehabilitation and faster return to daily activities.[3] Titanium Elastic Nailing is based on the principle of elastic stable intramedullary nailing, which provides internal splinting of the fracture while permitting micro-motion at the fracture site that promotes callus formation. The flexibility and biocompatibility of titanium make it an ideal material for pediatric intramedullary fixation, minimizing the risk of irritation or long-term complications. Additionally, this technique preserves the periosteal blood supply and growth plates, both of which are essential for optimal bone healing and continued growth in children.[4]

Functional and clinical outcomes following the use of Titanium Elastic Nails are generally favorable when compared to traditional methods such as traction, hip spica casting, or plating. Patients treated with TEN often experience reduced hospital stays, earlier weight-bearing, and improved muscle function due to early mobilization. From a biomechanical standpoint, the elastic nails provide three-point fixation within the medullary canal, maintaining alignment and rotational stability while

allowing physiological axial loading. This controlled stability fosters rapid callus formation, which is particularly advantageous in the pediatric population due to their higher osteogenic potential. Furthermore, the closed nature of the procedure minimizes soft tissue dissection and the risk of infection, contributing to better overall recovery profiles.[5] However, despite these advantages, the success of Titanium Elastic Nailing is not without challenges. The clinical and functional outcomes are closely associated with several factors including patient age, fracture pattern, weight, nail size, and surgical technique. Younger children or those with transverse or short oblique fractures tend to have excellent outcomes, while older or heavier children, and those with comminuted or long oblique fractures, may be more prone to complications. Improper nail selection or insertion technique can result in malalignment, rotational deformities, or limb length discrepancies. Additionally, prominent nail ends at the insertion site can cause soft tissue irritation, skin breakdown, or discomfort at the knee or hip, which may necessitate early nail removal.[6]

Methodology

The present research was designed as an analytical cross-sectional observational study. The purpose of this design was to evaluate and analyze the clinical, radiological, and functional outcomes of pediatric diaphyseal femoral fractures treated with Titanium Elastic Nailing System (TENS). The analytical cross-sectional nature of the study allowed for simultaneous assessment of exposure and outcome variables among participants during the defined study period. This design was chosen as it facilitated the examination of associations between fracture type, treatment method, and healing outcomes without the need for long-term follow-up beyond six months. Data collection, clinical evaluation, and radiological analysis were systematically performed according to standardized hospital protocols to ensure reliability and reproducibility.

Inclusion Criteria

1. Children and adolescents between 5 to 16 years of age.
2. Participants with closed diaphyseal fractures of the femur.
3. Fractures classified as Winquist and Hansen type 0, 1, or 2.
4. Fractures corresponding to AO classification 32A (simple) and 32B (wedge).
5. Participants and their parents/guardians who provided written informed consent to participate in the study.

Exclusion Criteria

1. Pathological fractures resulting from bone diseases or tumors.
2. Segmental fractures involving multiple diaphyseal levels.
3. Polytrauma patients with multiple skeletal or visceral injuries.

All participants fulfilling the inclusion criteria were enrolled after obtaining written informed consent from their parents or legal guardians.

Results

1. **Age Distribution of Study Participants:** The study included 60 participants aged 5–16 years. The largest proportion belonged to the 9– 12 year age group comprising 28 cases (46.7%). The 13–16 year age group accounted for 18 cases (30.0%). The youngest age group, 5–8 years, included 14 cases (23.3%). Thus, nearly half of the study population was concentrated in the 9–12 year category, while approximately one-third were adolescents aged 13–16 years. The least representation was observed in children aged 5–8 years. Overall, the distribution demonstrates predominance of mid-childhood cases within the study cohort.

Table 1: Age Distribution of Study Participants (n = 60)

Age group (years)	Number of cases n (%)
5–8	14 (23.3%)
9–12	28 (46.7%)
13–16	18 (30.0%)
Total	**60 (100)**

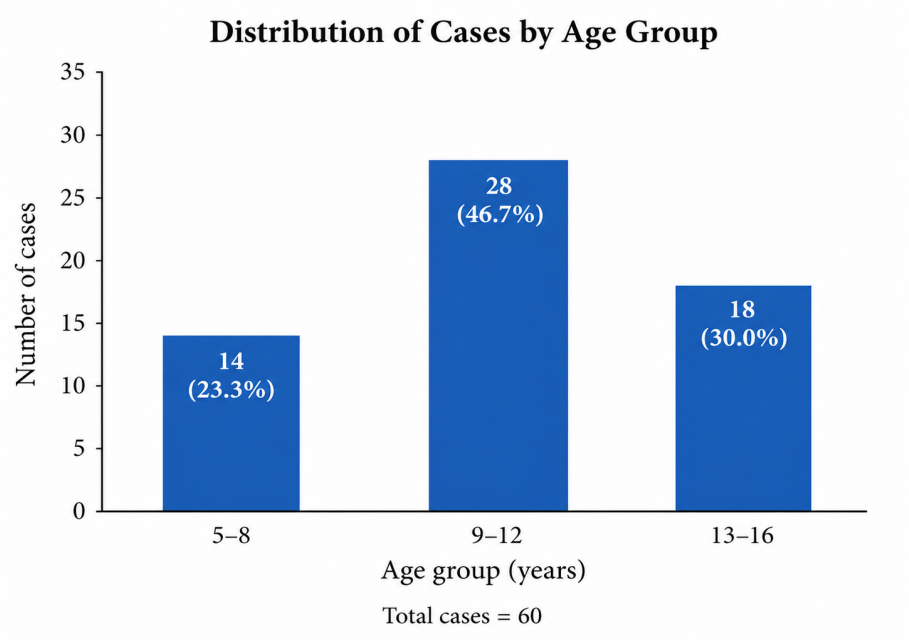

Figure: 1 Graphical representations of Age Group (years)

2. **Gender Distribution:** Among the 60 participants, 41 were males (68.3%) and 19 were females (31.7%). Male participants constituted more than two-thirds of the study population, with a male-to-female ratio of approximately 2.2:1. Females accounted for less than one-third of cases. Thus, the study cohort demonstrated a clear predominance of male patients compared to female patients.

Table 2: Gender Distribution

Gender	Number of cases n (%)
Male	41 (68.3)
Female	19 (31.7)
Total	**60 (100)**

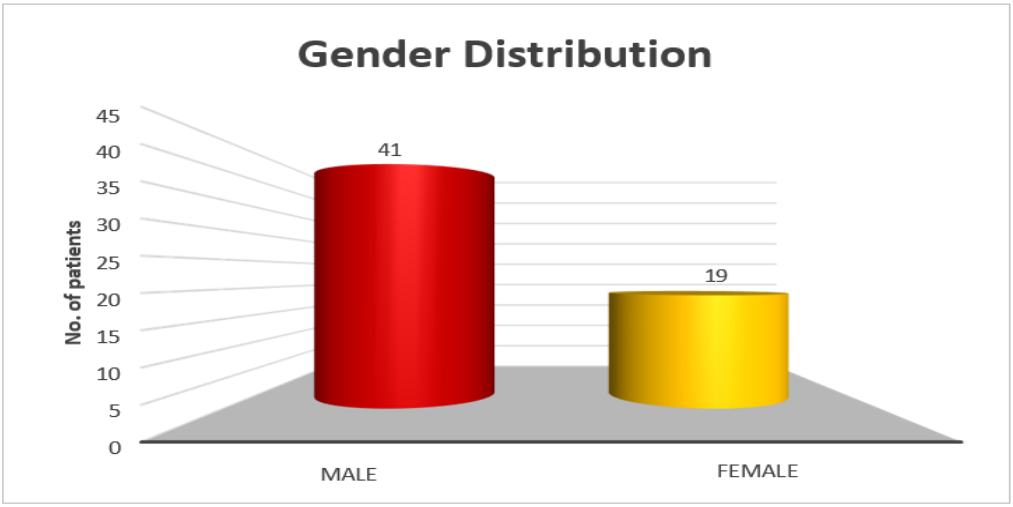

Figure 2: Graphical representations of Gender Distribution

3. **Mode of Injury:** Fall from height was the most frequent mode of injury, observed in 24 cases (40.0%). Road traffic accidents accounted for 22 cases (36.7%). Direct trauma was reported in 8 cases (13.3%), while sports injuries constituted 6 cases (10.0%). Together, fall from height and road traffic accidents contributed to 46 cases (76.7%) of total injuries, representing the majority of trauma mechanisms in the study population.

Table 3: Mode of Injury

Mode of injury	Number of cases n (%)
Road Traffic Accident	22 (36.7)
Fall from height	24 (40.0)
Direct trauma	8 (13.3)
Sports injury	6 (10.0)
Total	**60 (100)**

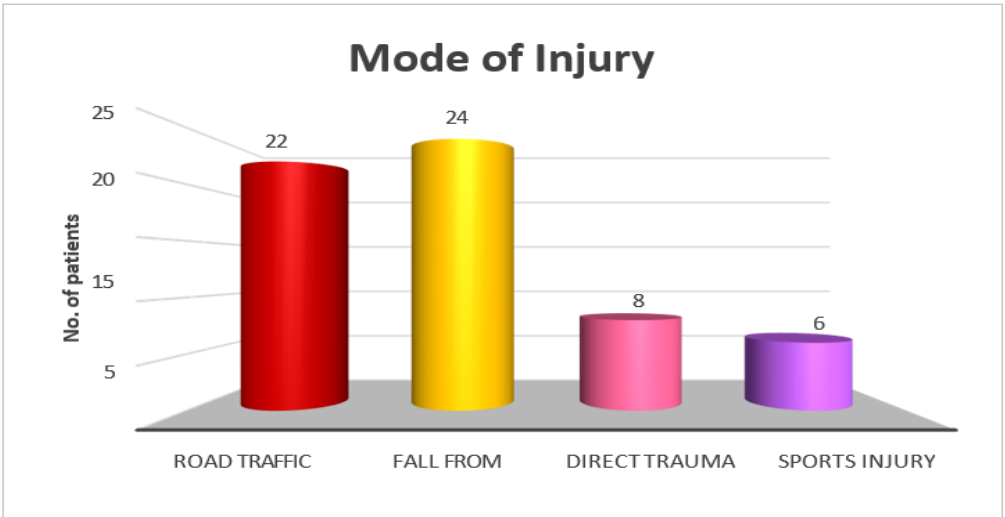

Figure: 3 Graphical representations of Mode of injury

4. **Associated Injuries:** Most participants had no associated injuries, comprising 58 cases (96.7%). Minor soft tissue injuries were observed in only 2 cases (3.3%). No major associated injuries were recorded. Therefore, the study population largely consisted of isolated femoral shaft fractures without additional trauma.

Table 4: Associated Injuries

Associated injury	Number of cases n (%)
Minor soft tissue injury	2 (3.3)
None	58 (96.7)
Total	**60 (100)**

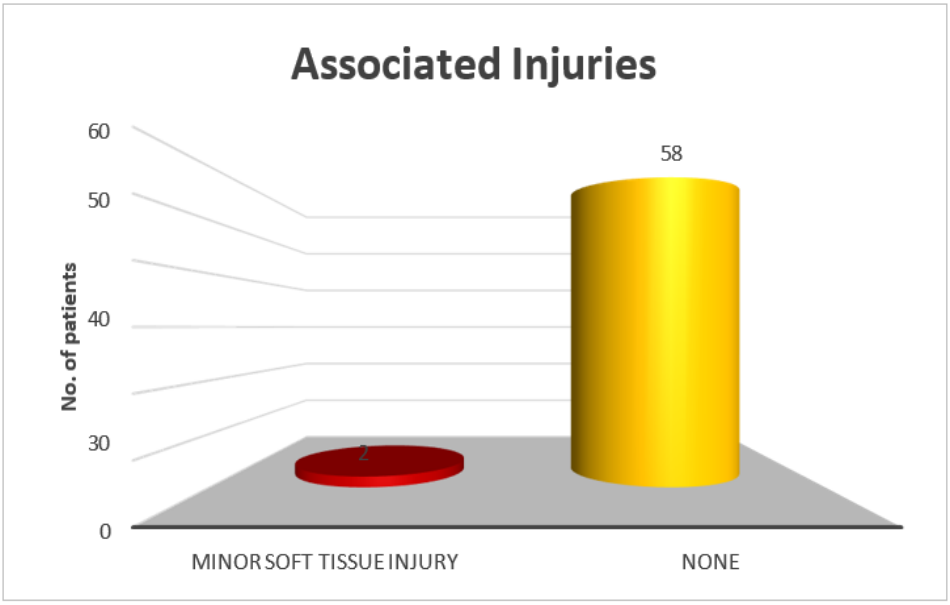

Figure: 4 Graphical representations of Associated injuries

5. **Winquist–Hansen Classification:** Type 1 fractures were the most common, seen in 39 cases (65.0%). Type 0 fractures were present in 11 cases (18.3%), while Type 2 fractures were identified in 10 cases (16.7%). Thus, nearly two-thirds of the fractures belonged to Type 1, whereas Types 0 and 2 together accounted for 35.0% of cases.

Table 5: Winquist–Hansen Classification

Type	Number of cases n (%)
Type 0	11 (18.3)
Type 1	39 (65.0)
Type 2	10 (16.7)
Total	**60 (100)**

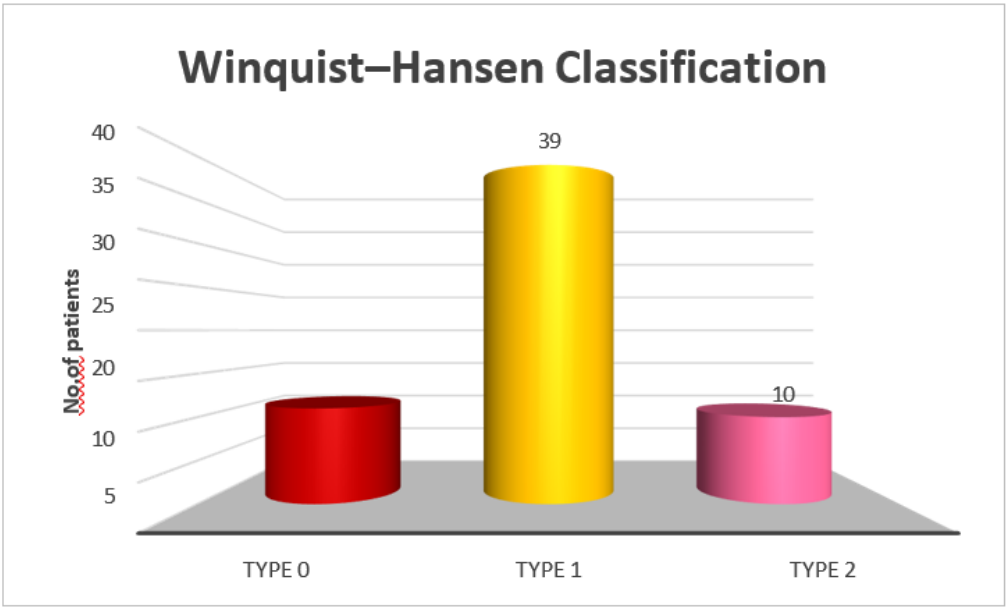

Figure 5: Graphical representations of Winquist-Hansen Classification

Discussion

The present study primarily involved school-age children, with the largest proportion belonging to the 9–12 year age group. Pediatric femoral shaft fractures demonstrate a clear age- related epidemiological pattern, particularly in active ambulatory children. Previous studies have consistently shown that the peak incidence occurs in school-going children due to increased outdoor activity, independent mobility, and higher exposure to trauma. Nascimento et al. reported similar age characteristics in children aged 5–14 years treated with titanium elastic nails, emphasizing that active children constitute the largest treated population because of higher physical activity levels and exposure to injury mechanisms [7]. Sinha et al. also observed a comparable age distribution with a mean age of 8.87 years, reinforcing that mid- childhood represents the most commonly affected group [8].

Male predominance was evident in the present study. This finding corresponds with earlier reports in pediatric femoral fractures. Studies by Govindasamy et al. and Pogorelić et al. documented a significantly higher number of male patients compared to females, attributed to increased participation of boys in outdoor physical activities, sports, and risk-prone behavior [9,10]. The gender difference is therefore not related to biological susceptibility but to environmental exposure and behavioral factors.

Regarding the mechanism of injury, falls from height and road traffic accidents accounted for the majority of cases. This pattern is consistent with reported pediatric trauma epidemiology. Tella and Aldhilan identified self-fall as the most common cause of injury in pediatric long bone fractures, particularly among ambulatory children [11]. Similarly, Nascimento et al. observed that femoral fractures in children frequently result from moderate-to-high energy trauma [7]. The predominance of isolated fractures in the present study, with very few associated injuries, indicates that most injuries were localized trauma rather than polytrauma, which corresponds with findings reported in ESIN-treated cohorts [12].

Fracture morphology also plays an important role in treatment selection and outcome. In the present study, Type 1 fractures were most common. This is clinically relevant because elastic intramedullary nailing is biomechanically best suited for stable transverse and short oblique fracture patterns. Sinha et al. emphasized that mid-diaphyseal fractures with

minimal comminution represent ideal candidates for titanium elastic nailing and produce optimal outcomes [9]. The literature indicates that fracture stability determines both healing behavior and complication risk.

Side involvement in the present study was nearly equal, indicating random trauma distribution rather than anatomical predisposition. Previous pediatric fracture studies similarly report no consistent laterality pattern [13].

Overall, the demographic and injury characteristics of the present cohort closely resemble those described in earlier pediatric femoral fracture literature. The study population therefore represents a typical pediatric diaphyseal femur fracture group, supporting the external validity of outcome analysis and allowing meaningful comparison with previous ESIN and TENS studies. Radiological healing in the present study followed a predictable biological pattern. Early callus formation was observed in the majority of patients at 4 weeks, followed by bridging callus at 12 weeks and complete union in most patients by 24 weeks. Pediatric bone has a high osteogenic potential, and elastic intramedullary fixation promotes secondary bone healing through controlled micromotion at the fracture site. Mishra et al. reported mean callus formation at 3.5 weeks and radiological union at approximately 9.5 weeks, which corresponds closely to the progression observed in this study [69]. Similarly, Pogorelić et al. documented fracture union at a mean of 8.5 weeks after ESIN fixation [10].

Early mobilization was another important finding. A majority of children achieved full weight bearing by 12 weeks. Nascimento et al. reported partial weight bearing at an average of 3.3 weeks and rapid return to daily activities following TEN fixation [7]. Saseendar et al. demonstrated earlier fracture union and earlier weight bearing in TEN-treated patients compared with spica casting [14]. These findings highlight that elastic stable intramedullary fixation provides sufficient stability to allow progressive loading without compromising healing.

Functional outcome assessed using Flynn's criteria revealed that the majority of patients achieved excellent or satisfactory results. Comparable findings have been reported consistently in the literature. Mishra et al. observed excellent outcomes in 80% and good outcomes in 20% of patients [15]. Govindasamy et al. reported 83% excellent and 17% satisfactory results [9], while Suggu et al. demonstrated excellent results in 73.3% of cases [16]. The reproducibility of favorable outcomes across multiple studies indicates the reliability of the TENS technique.

The mechanism underlying this functional recovery relates to the biomechanical properties of elastic nails. The nails act as an internal splint while preserving periosteal blood supply and fracture hematoma. Controlled axial micromotion stimulates callus formation and avoids stress shielding

Therefore, the radiological healing pattern, weight-bearing progression, and functional recovery observed in this study confirm that TENS provides stable fixation while preserving fracture biology. The outcomes are consistent with established pediatric orthopedic evidence supporting elastic intramedullary nailing as an effective treatment modality.

Conclusion

The present study evaluated the functional and clinical outcomes of pediatric diaphyseal femur fractures treated with closed reduction and internal fixation using the Titanium Elastic Nailing System and analyzed the association between complications and final outcome. The results demonstrated predictable radiological healing with early callus formation, progressive union, and restoration of weight bearing in the majority of patients. Most children achieved satisfactory or excellent functional outcomes according to Flynn's criteria, confirming the effectiveness of elastic intramedullary fixation in the pediatric age group.

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