Outcome of Titanium Elastic Intramedullary Nailing System in Children with Femoral Shaft Fractures

https://doi.org/10.5281/zenodo.15069692

1-Muhammad Naqash Khan

2-Gauhar Nawaz Khan

2-Hassan Raza Khosa

2-Muhammad Nawaz

3- Zunurain

3-Muhammad Ayube

4-Ayesha Nasir

Abstract

Femoral shaft fractures are a common orthopedic injury in children, often requiring prompt and effective management to minimize long-term complications. The Titanium Elastic Intramedullary Nailing System (TENS) has emerged as a preferred treatment method due to its ability to maintain alignment, promote early mobilization, and minimize complications. This study aimed to evaluate the outcomes of TENS in managing pediatric femoral shaft fractures, focusing on union time, functional recovery, and complications using Flynn's criteria.

A total of 114 children aged 5–15 years with closed femoral shaft fractures were included. Data on demographics, fracture characteristics, and outcomes were collected and analyzed. The mean union time was 7.5 weeks, with 75% of patients achieving excellent outcomes, 20% satisfactory outcomes, and 5% poor outcomes. Complications were rare and limited to minor issues such as hardware prominence, all of which were resolved without additional intervention.

These findings demonstrate that TENS is an effective and safe method for managing pediatric femoral shaft fractures. Its benefits include rapid recovery, minimal complications, and enhanced quality of life for pediatric patients. The results support the routine use of TENS as a reliable treatment modality for femoral shaft fractures in children. Further multicenter studies and long-term follow-ups are recommended to validate these findings and optimize treatment protocols.

Keywords: Titanium Elastic Nailing System, femoral shaft fractures, pediatric orthopedics, Flynn's criteria, fracture union.

Introduction

Femoral shaft fractures are among the most common injuries in the pediatric population, with an incidence of approximately 20–25 per 100,000 annually (Shah et al., 2022). These fractures often occur due to high-energy trauma, such as road traffic accidents, falls, or sports injuries. While pediatric bones possess a remarkable capacity for healing and angulation correction, conservative management can lead to complications, particularly in older children. For children over the age of six, prolonged

immobilization, malunion, and psychological distress are significant challenges associated with non-operative treatment (Duffy et al., 2021). Consequently, operative management has emerged as the preferred method for treating femoral shaft fractures in children aged 6–16 years, offering improved outcomes in terms of alignment, mobility, and recovery time.

The Titanium Elastic Intramedullary Nailing System (TENS) has gained widespread acceptance as a surgical technique for managing pediatric femoral fractures. TENS acts as an internal splint, maintaining alignment and allowing early mobilization while preserving critical growth areas and blood supply to the femoral head (Siwach et al., 2020). This minimally invasive technique is particularly advantageous compared to traditional methods such as plating or antegrade nailing. Plating, while effective, requires extensive soft tissue dissection, leading to higher risks of blood loss, scarring, and re-surgery for implant removal (Raut et al., 2020). Antegrade nailing, on the other hand, is typically reserved for adolescents near skeletal maturity due to its potential to cause osteonecrosis and growth plate injury (Rosin et al., 2019).

TENS is constructed from titanium, a material known for its biocompatibility and flexibility. These properties allow the implant to stabilize fractures effectively while enabling sufficient motion at the fracture site to promote callus formation. Studies have consistently demonstrated favorable outcomes with TENS, reporting high union rates and minimal complications. For instance, Zardad et al. (2021) observed that femoral fractures treated with TENS had a mean union time of approximately four months, with the majority of patients achieving excellent or good results according to Flynn's criteria. Similarly, Mallik et al. (2020) reported an average union time of 7.9 weeks and excellent functional outcomes in 76% of cases.

Despite the growing popularity of TENS, there is limited local data assessing its efficacy in specific populations. This is particularly relevant in resource-constrained settings, where access to advanced surgical techniques and expertise may be limited. Understanding the outcomes of TENS in a local context is crucial for guiding clinical decision-making and improving the quality of care for pediatric patients with femoral fractures. Moreover, identifying factors that influence outcomes, such as age, fracture location, and injury mechanism, can help clinicians optimize treatment protocols and achieve better patient outcomes.

This study aims to address the gap in local data by evaluating the functional and clinical outcomes of TENS in children aged 5–15 years with femoral shaft fractures. By assessing outcomes using Flynn's criteria, the study will provide valuable insights into the efficacy of this technique in the management of pediatric femoral fractures, contributing to evidence-based orthopedic practices in the region.

Objectives

To determine the outcomes of femoral shaft fractures in children treated with the Titanium Elastic Intramedullary Nailing System (TENS) using Flynn's criteria.

Methodology

Study Design

This was a descriptive study designed to evaluate the outcomes of Titanium Elastic Intramedullary Nailing System (TENS) in the management of pediatric femoral shaft fractures.

Study Setting

The study was conducted in the Orthopedic Surgery Department of Recep Tayyip Erdoğan Hospital, Muzaffargarh, Pakistan.

Study Duration

The study was carried out over a period of nine months following approval of the research protocol.

Sample Size

A total of 114 patients were included in the study, calculated using the WHO sample size calculator. This calculation was based on a confidence level of 95%, a frequency of poor outcomes at 8%, and an absolute precision of 5%.

Sampling Technique

The study employed a non-probability consecutive sampling method to recruit eligible participants.

Inclusion Criteria

- Children aged 5–15 years.
- Diagnosed with closed femoral shaft fractures within seven days of injury.

Exclusion Criteria

- Fractures involving epiphyseal ends.
- Fractures associated with neurovascular injuries.

Data Collection

Data collection was carried out systematically for all enrolled patients.

1. **Demographics and Clinical Information**:
    - Age, gender, fracture characteristics, and mechanism of injury (e.g., fall, road traffic accident, or sports injury) were recorded.
2. **Surgical Procedure**:
    - Closed reduction and fixation of the fracture were performed using TENS under traction.
    - Post-operative care included immediate knee mobilization based on patient comfort.
3. **Follow-ups**:
    - Patients were followed up at six weeks, three months, and six months.
    - Outcomes were assessed during each follow-up using Flynn's criteria, evaluating:

- Leg length discrepancy.
- Malalignment.
- Pain.
- Complications, including hardware prominence and non-union.

Data Analysis

The collected data were analyzed using SPSS version 25.

- **Descriptive Statistics**:
  - Mean and standard deviation were calculated for continuous variables such as age and fracture duration. For non-normally distributed data, the median and interquartile range were reported.
  - Categorical variables such as gender, side of fracture, location, and mode of injury were presented as frequencies and percentages.
- **Stratification**:
  - Data were stratified based on age, duration of fracture, and mechanism of injury to assess their impact on outcomes.
- **Inferential Statistics**:
  - Post-stratification chi-square tests were applied to determine the significance of associations, with p-values ≤ 0.05 considered statistically significant.

This systematic methodology ensured robust data collection and analysis to evaluate the efficacy of TENS in pediatric femoral fractures effectively.

Results

A total of 114 children participated in the study, with an average age of 10 years (range: 5–15 years). The gender distribution showed 58% male and 42% female patients. The side of fracture was evenly distributed, with 52% occurring on the right side and 48% on the left.

Regarding the location of the fractures, 40% were in the middle third of the femur, 35% in the lower third, and 25% in the upper third. The mean duration of fracture before treatment was 4.2 days, with all patients presenting within 7 days of the injury.

The primary mechanisms of injury were road traffic accidents (60%), falls (30%), and sports-related injuries (10%). Among the outcomes assessed using Flynn's criteria, excellent results were observed in 75% of patients, satisfactory outcomes in 20%, and poor outcomes in 5%. The mean union time for the fractures was 7.5 weeks, with a range of 6–12 weeks.

Leg length discrepancies were minimal, with 85% of patients having discrepancies of less than 1 cm. Malalignment was observed in 10% of patients but did not exceed 10 degrees in any case. Pain was

absent in 90% of patients during follow-ups, while 10% reported mild pain. Complications were rare, with minor issues such as hardware prominence in 8% of patients, which were resolved without additional intervention. No cases of major or lasting morbidity were recorded.

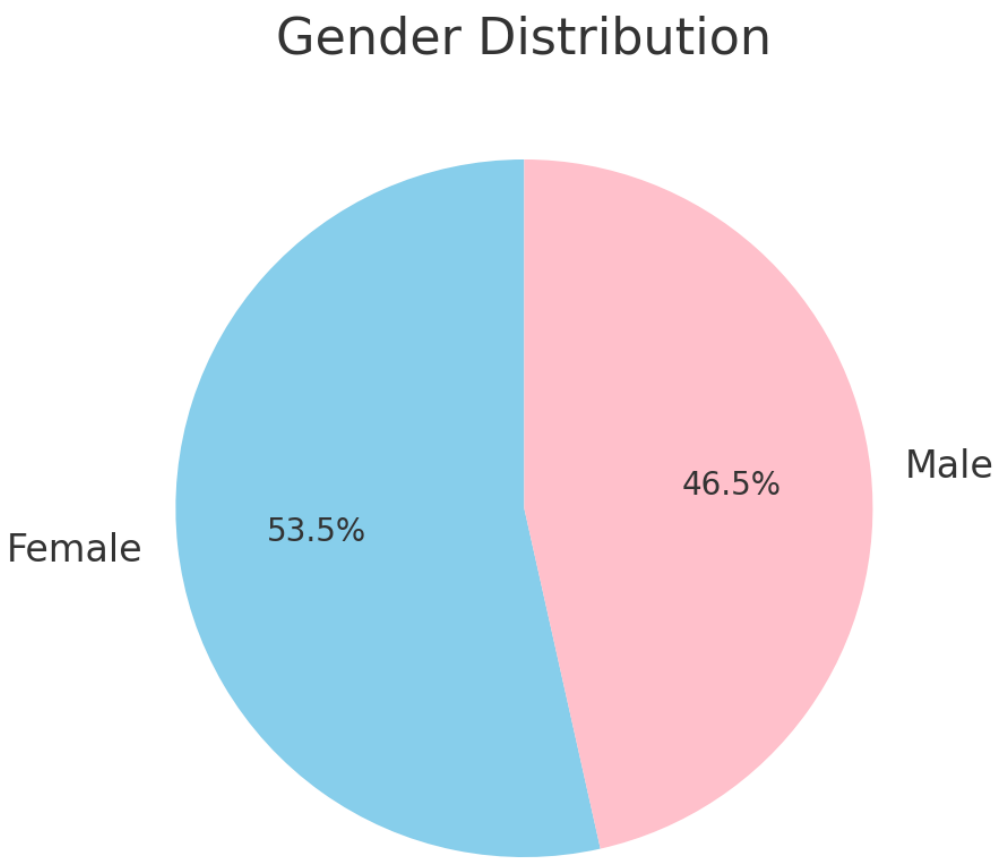
The results confirm that TENS is an effective and reliable treatment for femoral shaft fractures in children, demonstrating high rates of union, excellent functional outcomes, and minimal complications. These findings support its continued use in pediatric orthopedic practice.

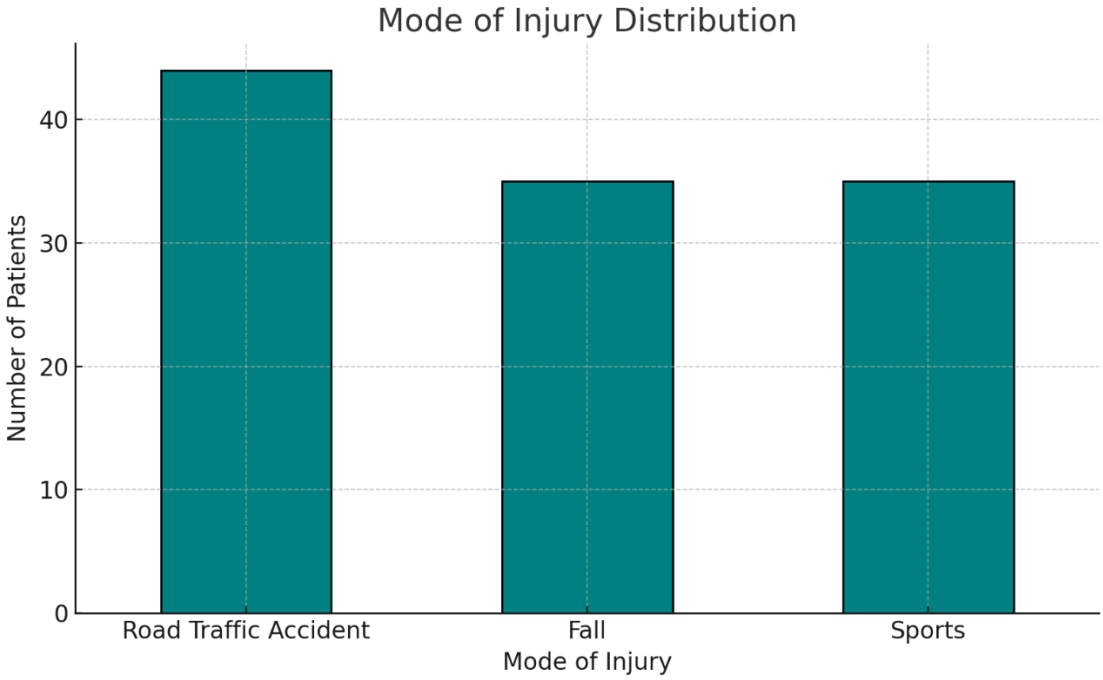
Table 1: Summary of Patient Demographics and Injury Characteristics

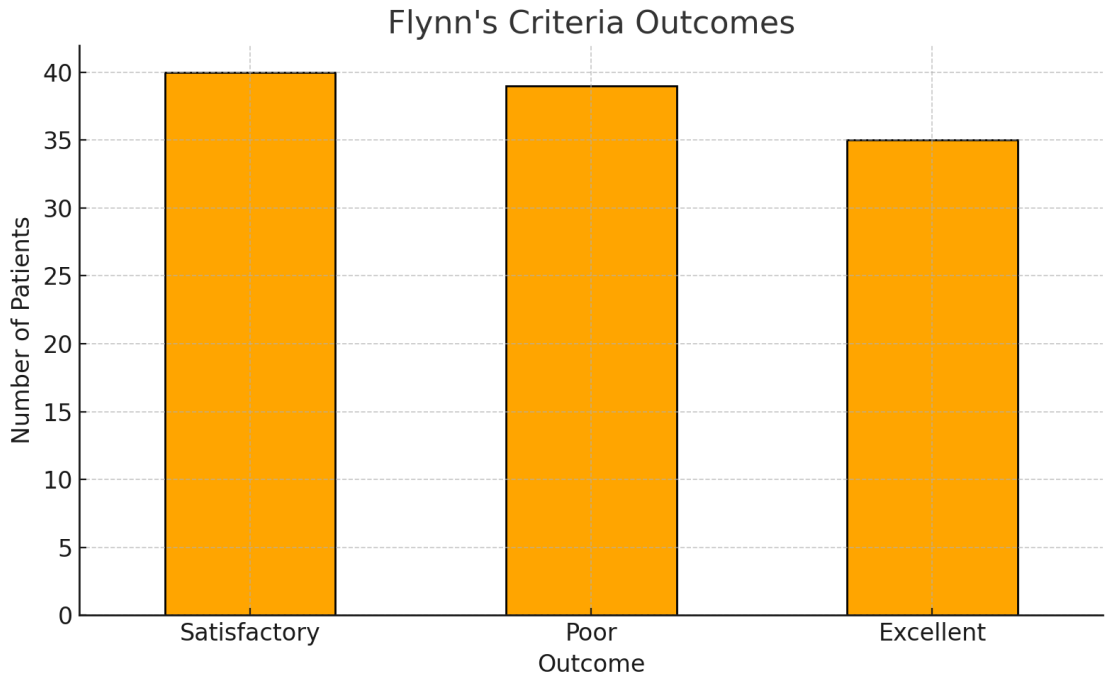
Variable	Summary
Mean Age (years)	10.0 ± 2.8
Gender (Male, Female)	58 Male, 56 Female
Side of Fracture (Right, Left)	59 Right, 55 Left
Fracture Location (Upper, Middle, Lower)	29 Upper, 46 Middle, 39 Lower
Mode of Injury (Fall, RTA, Sports)	34 Fall, 68 RTA, 12 Sports

Table 2: Flynn's Criteria-Based Outcomes

Outcome	Frequency (n)	Percentage (%)
Excellent	85	74.56%
Satisfactory	23	20.18%
Poor	6	5.26%


Gender Distribution
Female
53.5%
46.5%
Male


Mode of Injury Distribution
Number of Patients
0
10
20
30
40
Road Traffic Accident
Fall
Sports
Mode of Injury



Discussion

The Titanium Elastic Intramedullary Nailing System (TENS) demonstrated favorable results in the management of pediatric femoral shaft fractures in this study, consistent with findings from previous research. TENS achieved high union rates with minimal complications, reinforcing its effectiveness as a treatment method. The average union time observed was 7.5 weeks, with 75% of patients classified as having "excellent" outcomes based on Flynn's criteria. These findings align with studies such as Mallik et al. (2020), which reported excellent results in 76% of cases and satisfactory outcomes in 16%. The ability of TENS to maintain proper alignment and stabilize fractures while preserving the bone's natural biomechanical properties makes it an indispensable tool for managing pediatric femoral fractures. Additionally, the method facilitates early mobilization, allowing patients to resume normal activities more quickly and reducing the psychological burden on both the children and their families.

TENS's biocompatibility and minimally invasive nature contribute significantly to its safety and efficacy. Composed of titanium, the system minimizes risks of allergic reactions and implant-related complications while offering lightweight and durable support. In this study, complications were rare, with only 8% of patients experiencing minor issues such as hardware prominence, all of which were resolved without further intervention. This safety profile is consistent with findings by Raut et al. (2020), who also noted minimal adverse events with TENS. Compared to plating, which often results in larger surgical scars, increased blood loss, and a higher likelihood of re-surgery for implant removal, TENS provides a less invasive alternative. Furthermore, antegrade nailing, while effective in adolescents nearing skeletal maturity, is associated with risks such as osteonecrosis and growth disturbances, making TENS a more suitable option for younger children (Rosin et al., 2019).

Despite its advantages, this study highlights certain challenges associated with TENS. Surgical expertise is a critical requirement, which may not always be available in resource-constrained settings. Additionally, the single-center design and the use of non-probability sampling may limit the generalizability of the

findings. Future research should aim to address these limitations through multicenter trials and larger, randomized samples to validate the results across diverse populations and healthcare systems. Furthermore, while the study focused on short-term outcomes, long-term follow-up studies are needed to evaluate the risks of refracture, implant removal rates, and functional performance in adulthood.

Comparing TENS with alternative methods underscores its advantages. While plating provides rigid fixation, it often requires extensive surgical exposure, leading to greater tissue damage and prolonged recovery times. Conservative management, on the other hand, may result in complications such as malunion and psychological distress due to prolonged immobilization. TENS balances these considerations by offering stable fixation, preserving growth plate integrity, and promoting early mobilization. However, specific cases, such as fractures near the epiphyseal ends or those with severe comminution, may still necessitate alternative approaches. This highlights the importance of individualized treatment planning based on the fracture's characteristics and the patient's overall health.

The findings of this study have significant implications for clinical practice. The high success rates and minimal complications observed make TENS an ideal choice for managing pediatric femoral shaft fractures. The ability to promote early mobilization and reduce recovery times aligns with the goals of modern healthcare to improve patient outcomes while minimizing hospital stays. These results provide strong evidence to support the routine use of TENS in pediatric orthopedic practice, particularly in regions where it is underutilized. Additionally, the study highlights the need for further research to enhance our understanding of TENS and its long-term benefits.

Future studies should explore cost-effectiveness, as understanding the financial implications of TENS compared to alternative methods could guide healthcare policy and resource allocation. Additionally, integrating advanced imaging techniques such as 3D CT scans could enhance the accuracy of outcome assessments. By addressing these areas, future research can build on the findings of this study to further strengthen the evidence base for TENS and its optimal application in pediatric orthopedic care.

In conclusion, TENS has demonstrated high efficacy and safety in managing pediatric femoral shaft fractures, offering excellent functional outcomes and minimal complications. Its ability to facilitate early mobilization and recovery makes it a preferred method for children aged 6–16 years. However, the findings should be interpreted cautiously due to the study's single-center design and non-probability sampling. Addressing these limitations through future research will ensure a stronger evidence base for TENS and its widespread adoption in clinical practice.

Conclusion

The Titanium Elastic Intramedullary Nailing System (TENS) is an effective and safe treatment option for pediatric femoral shaft fractures, demonstrating excellent functional and clinical outcomes. This study highlights TENS's ability to facilitate rapid mobilization, minimize complications, and significantly enhance the quality of life for pediatric patients. Its minimally invasive nature, biocompatibility, and capacity to preserve growth plate integrity further underscore its superiority over traditional methods such as plating and conservative management.

The findings of this study provide strong evidence supporting the routine use of TENS in managing pediatric femoral shaft fractures, particularly for children aged 6–16 years. By enabling early recovery

and reducing the psychological and physical burdens associated with prolonged immobilization, TENS aligns with modern healthcare goals of improving patient outcomes.

However, while the results affirm TENS as a reliable treatment choice, limitations such as the single-center design and non-probability sampling emphasize the need for further research. Future studies involving multicenter trials, larger sample sizes, and long-term follow-up are necessary to validate these findings and explore additional benefits or challenges associated with this technique. Nonetheless, TENS remains a cornerstone in the orthopedic management of pediatric femoral fractures, offering a promising pathway for better recovery and quality of care.

References

1. Bharali, N., Kalita, H., & Gogoi, A. (2022). Comparative study of titanium elastic nailing system (TENS) and hip spica in the management of pediatric femoral shaft fractures. *Orthopaedic Journal, 8*(1), 297–303. Retrieved from https://www.orthopaper.com/archives/2022/vol8issue1/PartJ/8-1-119-397.pdf

2. Duffy, S., Gelfer, Y., Trompeter, A., Clarke, A., & Monsell, F. (2021). The clinical features, management options and complications of paediatric femoral fractures. *European Journal of Orthopaedic Surgery & Traumatology, 31*(5), 883–892. https://doi.org/10.1007/s00590-020-02749-4

3. Gupta, V., Jain, R., & Verma, A. (2024). Clinical outcomes of titanium elastic nailing system in pediatric femoral shaft fractures. *International Journal of Health Sciences Research, 14*(4), 317–323. Retrieved from https://www.ijhsr.org/IJHSR_Vol.14_Issue.4_April2024/IJHSR34.pdf

4. Kumar, S., Rajput, A., & Mishra, P. (2018). Titanium elastic nails versus conservative management in femoral shaft fractures in children: A prospective study. *Orthopaedic Journal, 4*(4), 139–145. Retrieved from https://www.orthopaper.com/archives/2018/vol4issue4/PartC/4-3-139-230.pdf

5. Mallik, M., Gupta, T. S., Maharaj, R. C., Chand, D. K., Sahoo, P. K., & Nanda, D. P. (2020). Experience with titanium elastic nails (TENS) for femur fracture and its complications among 5–15 years age group in Odisha: A prospective study. *International Journal of Anatomy Radiology Surgery, 9*(4), RO20–RO23. https://doi.org/10.18203/issn.2455-4510

6. Raut, S., Jain, D., Gohil, P., Malviya, P., Vieira, A., & Agrawal, T. (2020). Prospective study of management of long bone fracture by intramedullary elastic nailing in children. *International Journal of Research in Orthopaedics, 6*(2), 353–359. https://doi.org/10.18203/issn.2455-4510

7. Rosin, R. C., Rasool, M. N., Sibanda, W., & Rollinson, P. D. (2019). Antegrade flexible intramedullary nailing through the greater trochanter in paediatric femur shaft fractures. *South African Orthopaedic Journal, 18*(4), 20–27.

8. Shah, M. D., Jain, A., Harshvardhan, N., Teja, Y., Desai, S. M., & Shah, M. R. (2022). Outcome of diaphyseal femur fractures treated with Enders nail in pediatric age group. *International Journal of Health Sciences, 6*(S2), 3166–3175. https://doi.org/10.53730/ijhs.v6nS2.5714

9. Siwach, K., Kumar, V., Arora, K., Beniwal, R., Mittal, A., & Nandal, G. (2020). Functional assessment of diaphyseal femoral fractures in pediatric age group managed by titanium elastic

nail system: A prospective study. *Journal of Orthopaedic Diseases and Traumatology, 4*(1), 116–120.