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Complications of Titanium Elastic Nailing System (TENS) in Pediatric Long Bone Fractures: A 5-Year Review of 204 Cases

Abstract
***Background:** Titanium Elastic Nailing System (TENS) is a popular fixation method for pediatric long bone fractures due to its minimally invasive nature and favorable outcomes. However, few complications have been reported, including soft-tissue irritation, joint stiffness, limb length discrepancy, malunion, and growth plate abnormalities. This study reviews our 5-year experience with TENS in children, focusing on complication rates and types.*

***Methods:** We retrospectively analyzed 204 pediatric long bone fracture cases (femur, tibia, humerus, radius, ulna) treated with TENS over the past 5 years. Patient ages ranged from 5–15 years. Data on fracture location, type of fracture, management, and post-operative complications were collected, with a minimum follow-up of 12 months. Complications were defined and categorized (entry-site bursitis, knee stiffness, limb length discrepancy, malunion, chronic osteomyelitis, implant-related issues). Descriptive statistics were used to calculate complication rates.*

***Results:** Of 204 cases, 184 (90.2%) were uneventful. A total of 20 complications (9.8% of cases) were recorded. Minor complications (e.g., soft tissue impingement and transient knee stiffness, limb length discrepancy) constituted the majority, whereas major complications (nonunion or significant malunion, chronic osteomyelitis) were rare. Soft tissue impingement was the most common issue (n=6, 3%), followed by malunion (n=4, 2%), knee stiffness (n=3, 1.5%), limb length discrepancy >1 cm (n=3, 1.5%), chronic osteomyelitis (n=2, 1%), and implant-related problems (n=2, 1%).*

***Conclusion:** TENS is a safe and effective treatment for pediatric long bone fractures with a low complication rate. The majority of complications (around 9.8% in our series) were minor and technique-related. Careful attention to surgical technique – such as proper nail sizing, avoidance of excessive nail protrusion, and appropriate post-operative protocols – can further minimize these complications. Our findings align with literature reports that TENS complications are generally manageable and do not preclude its advantages of early mobilization and biological healing.*

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I. Background

Titanium Elastic Nailing System (TENS), also known as elastic stable intramedullary nailing (ESIN) [1], has become a mainstay in managing long bone fractures in children. TENS involves inserting two flexible titanium nails into the intramedullary canal to achieve a stable three-point fixation of the fracture [2]. This technique spares the physis (growth plate) and periosteum, enabling effective stabilization while harnessing the child's healing potential [3]. Compared to traditional casting or traction methods, TENS allows earlier mobilization and shorter hospitalization [1], with superior radiographic alignment and fewer long-term deformities [4].

Despite the overall success of TENS, it is not free of complications. The pediatric orthopedic literature has identified few complications associated with elastic nailing, most of which are minor and resolve after nail removal or with conservative management [3]. Prominent among these are soft tissue impingements (often manifesting as bursitis or skin pain at the nail insertion site) [8] and knee joint stiffness due to irritation or prolonged immobilization [7]. More serious but less frequent issues include limb length discrepancy (LLD) from overgrowth or growth disturbance [9], malunion (healing with angular or rotational deformity) [6], chronic osteomyelitis [3], and implant-related problems such as nail migration or breakage [10].

This study retrospectively analyzes 204 pediatric long bone fractures treated with TENS over a five-year period, focusing on complication rates, risk factors, and management strategies.

II. Materials and Methods

This retrospective observational study was conducted at a tertiary care pediatric orthopedic center and included all pediatric patients treated with the Titanium Elastic Nailing System (TENS) for long bone fractures between January 2018 and December 2022. Institutional ethical approval was obtained prior to data collection.

Inclusion criteria comprised patients aged 5 to 15 years who sustained acute diaphyseal fractures of long bones (femur, tibia, humerus, radius, ulna) and were managed with TENS. Exclusion criteria were: (1) open fractures requiring alternative fixation methods, (2) pathological fractures, and (3) patients lost to follow-up before completing 12 months of postoperative monitoring.

Complications were categorized as either minor (requiring conservative management) or major (necessitating surgical intervention).

Minor complications includes soft tissue impingement and transient knee stiffness, limb length discrepancy. whereas major complications includes nonunion or significant malunion, chronic osteomyelitis

A total of 270 patients with long bone fracture from age 5-15 presented at our casualty from 2018 - 2022 out of which 42 cases were open fractures and 24 were lost to follow up leaving us with 204 patients which were included in the final analysis. All procedures were performed under general anesthesia using standardized TENS technique. Nail diameter was selected to approximate 40% of the narrowest medullary canal diameter, and appropriate entry points were determined based on anatomical location. Intraoperative fluoroscopy was utilized to confirm satisfactory reduction and three-point fixation.

Patients were followed at regular intervals (2 weeks, 6 weeks, 3 months, 6 months, and 12 months), with clinical and radiographic assessments at each visit. Union was defined as the presence of bridging callus across at least three cortices on orthogonal radiographs, in conjunction with absence of pain or tenderness at the fracture site on clinical examination.

Data variables included patient age, sex, fracture location and type, time to union, and any complications arising during treatment or follow-up. Complications were categorized as minor (managed conservatively) or major (requiring surgical intervention). Descriptive statistics were used to analyze frequencies and percentages of complications across the cohort.

III. Results

A total of 204 pediatric long bone fractures were managed using the Titanium Elastic Nailing System (TENS) over the 5-year study period. Of these, 184 cases (90.2%) progressed to uneventful radiographic and clinical union. The remaining 20 cases (9.8%) were associated with one or more post-operative complications.

Complications were categorized as either minor (requiring conservative management) or major (necessitating surgical intervention). The distribution of complications is summarized below:

- Soft tissue impingement: 6 cases (3%)
- Malunion: 4 cases (2%)
- Knee stiffness: 3 cases (1.5%)
- Limb length discrepancy (LLD) >1 cm: 3 cases (1.5%)
- Implant-related complications (e.g., nail migration or breakage): 2 cases (1%)
- Chronic osteomyelitis: 2 cases (1%)

Minor complications accounted for the majority of cases (n = 17, 8.5%). These included entry-site bursitis, transient joint stiffness, and mild limb length discrepancy. All minor complications resolved with conservative measures, such as physiotherapy, activity modification, and local care.

Major complications were observed in 4 patients (2%). These involved 2 cases of chronic osteomyelitis and 2 case of significant implant-related failure were managed surgically.

No cases of deep infection, neurovascular compromise, or permanent functional impairment were reported during the follow-up period. The mean time to clinical and radiographic union across the cohort was not reported in this section but was consistently documented in patient records.

These findings demonstrate a low overall complication rate associated with TENS in pediatric long bone fractures, with the vast majority being minor, self-limiting, and amenable to conservative management.

IV. Discussion

Titanium Elastic Nailing System (TENS) has become widely accepted as a reliable and minimally invasive method for stabilizing pediatric long bone fractures. Our five-year experience involving 204 cases supports its overall safety and efficacy, with a relatively low complication rate of 9.8%, aligning with the findings of other published series【1】.

Among the complications observed, entry-site irritation or bursitis was the most frequent, affecting 3% of cases. This issue is most commonly attributed to prominent nail ends causing soft-tissue irritation at the insertion site. Previous studies, including those by Lascombes et al. and Luhmann et al., have underscored the

importance of trimming and adequately burying the nail ends to prevent this complication【4】. In our cohort, all such cases were mild and successfully managed with conservative treatment, without the need for surgical revision.

Knee stiffness represented another relatively common complication, occurring in 1.5% of patients, mainly following femoral nailing. This is a well-recognized outcome, often resulting from prolonged immobilization or mechanical irritation by prominent nail ends. Our experience supports the findings of Flynn et al., who emphasized the role of early physiotherapy in minimizing postoperative stiffness【3】. Importantly, all cases in our series resolved without requiring surgical intervention, highlighting the value of timely rehabilitation protocols【7】.

Limb length discrepancy (LLD) was also noted in a small proportion of patients, with discrepancies ranging from 1 cm to 1.5 cm. Notably, two of these cases were associated with post-fracture overgrowth, a common phenomenon in children, particularly after femoral shaft injuries. As previously documented by Scott et al., mild overgrowth is usually self-limiting and rarely requires surgical correction【5】. In our series, no interventions were needed, although regular follow-up remains essential for early detection of significant discrepancies【9】.

Malunion occurred in 2% of cases and was primarily linked to inadequate initial reduction. These cases involved mild angular deformities without clinical impact, and none required corrective surgery. Nonetheless, this finding reinforces the importance of achieving stable three-point fixation — a biomechanical principle established by Ligier et al.【2】 — and verifying alignment intraoperatively through multiplanar imaging. While children possess a strong capacity for bone remodeling, especially in the coronal and sagittal planes, attention must be paid to prevent rotational deformities【10】.

In contrast to the predominantly minor complications, chronic osteomyelitis was rare but clinically significant, observed in two patients (1%). Both cases required revision surgery, reflecting the importance of achieving sufficient stability and preserving periosteal integrity during the initial procedure and dressing and maintaining aseptic precaution during surgical procedure. Our findings are in line with those of Narayanan et al., who reported that nonunion is more likely to occur when fractures are inadequately stabilized or when extensive soft tissue disruption is present【3】.

Implant-related complications were similarly uncommon, with two cases involving nail migration and breakage. These issues were likely attributable to suboptimal nail sizing or incomplete fracture reduction. As suggested by Lascombes et al., selecting a nail diameter that approximates 40% of the medullary canal is crucial in maintaining fixation and preventing mechanical failure【4】. Our data support this recommendation, emphasizing the importance of technical precision during nail selection and placement.

Taken together, the complications encountered in our series were generally minor, self-limiting, and manageable without additional surgery. This reinforces the position of TENS as a safe and effective technique for pediatric long bone fractures when meticulous attention is paid to surgical technique and postoperative care. Looking ahead, future research should aim to evaluate long-term functional outcomes and compare TENS with alternative fixation methods, particularly in complex or high-energy fracture patterns【13】, as well as in older children where biomechanical demands may differ【15】.

V. Conclusion

TENS remains an excellent method for treating pediatric long bone fractures. While complications occur in approximately 9.8% of cases, they are mostly minor and manageable. Proper nail sizing, correct insertion technique, and structured rehabilitation protocols are crucial in reducing complications. Our findings support the continued use of TENS as a primary method for treating long bone fractures in children.

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