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Treatment of Pediatric Femoral Shaft Fracture by Titanium Elastic Nails

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Abstract:
Objective: *This study evaluates the effectiveness of titanium elastic nails (TENS) in treating pediatric femoral shaft fractures.* ***Methods:*** *A total of 56 pediatric patients, aged 6 to 14 years, with femoral shaft fractures were included in the study. The patients were treated with TENS at Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh (BSMMU) from July 2011 to June 2012. The study recorded gender distribution, mechanism of injury, fracture classification, and clinical outcomes.* ***Results:*** *The majority of fractures resulted from road traffic accidents (60.7%), and the most common fracture type was closed, with 70% of fractures classified as Grade-I. Clinical results showed that 71.4% of patients achieved excellent outcomes, while 17.9% had successful results, and 10.7% had poor outcomes. Radiological union was achieved in all cases within an average of 8 weeks. Complications included varus and valgus angulation in 3.6% and 1.8% of cases, respectively, and entry site irritation in 7.1% of patients. Limb length discrepancy of less than 1.5 cm was observed in 5.4% of cases but was clinically insignificant. Nail removal was required in one case due to wound breakdown at the entry site.* ***Conclusion:*** *The study demonstrates that TENS is a safe and effective method for managing pediatric femoral shaft fractures, offering benefits such as early mobilization, load-sharing stability, and minimal disruption to the fracture site. However, attention must be given to potential complications such as entry site irritation and angular deformities, which can be minimized with careful surgical technique and appropriate nail sizing. Further research is recommended to explore the long-term outcomes of TENS compared to other fixation methods.*

Keywords: *Paediatric, femoral, shaft fracture, titanium*

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I. Introduction

Femoral shaft fractures, along with subtrochanteric and supracondylar fractures, make up approximately 1.6% of pediatric bone injuries. These fractures are a significant challenge in pediatric orthopedics, frequently requiring specialized management by orthopedic surgeons. Historically, various fixation techniques have been utilized, including plate fixation, rigid intramedullary nailing, Ender's nailing, and titanium elastic nailing (TENS). Despite advancements in these methods, the debate over the ideal implant for managing femoral shaft fractures in children persists [1,2].

An ideal implant for pediatric femoral shaft fractures should provide a simple and effective solution, offering load-sharing capabilities while preserving proper alignment and limb length. It should also allow for early mobilization, facilitating recovery while ensuring stability until bridging callus forms [3]. Among the available options, TENS has gained popularity due to its minimally invasive nature and ability to meet many of these requirements [4]. However, the technique is not without its limitations, as complications such as nail irritation and alignment issues may arise [5]. These factors underscore the importance of selecting and applying TENS judiciously to optimize outcomes in pediatric patients.

II. Methodology

This study was conducted at Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh (BSMMU) from July 2011 to June 2012. A total of 56 patients with femoral shaft fractures aged 7 to 14 years were included. The inclusion criteria were patients with closed fractures or grade I and grade II open fractures, no additional lower limb fractures, and fixation performed within five days of injury. Polytrauma patients were also included. Exclusion criteria included children younger than 7 or older than 14 years, femoral metaphyseal fractures, grade III open fractures, fractures associated with neuromuscular disorders, and pathological or metabolic bone disorders. **Preoperative Planning and Nail Selection:** Titanium Elastic Nailing System (TENS) nails were used, following the technique described by Ligier et al. (1988). The femoral diaphyseal internal diameter was measured on anteroposterior and lateral radiographs. The nail diameter was calculated by dividing the internal diameter by two and subtracting 0.5 mm, as per Kasser and Beaty's guidelines. Nail sizes ranged from 2.00 mm to 4.00 mm, with a standard length of 440 mm. **Surgical Procedure:** Under fluoroscopic guidance, a 1–2 cm incision was made on the lateral aspect of the distal femur, approximately 2 cm proximal to the distal femoral growth plate. The distal femoral metaphysis was exposed, and an entry point was created 2.5 cm proximal to the growth plate using an awl. Two flexible nails of equal diameter were inserted in a retrograde manner through medial and lateral incisions. They were advanced proximally, one toward the calcar region of the femoral neck and the other distal to the trochanteric physis. To ensure stability, a double "C" construct was formed, allowing three-point fixation. This technique, described by Heinrich et al. (1994), ensures adequate alignment and early mobilization [6]. The distal ends of the nails were trimmed, leaving 1 cm of nail outside the cortex to minimize soft tissue irritation and prevent bursa formation. All procedures were confirmed using intraoperative fluoroscopy. **Postoperative Care:** Postoperatively, the patients were placed in a supine position with the operated limb elevated on a pillow. Partial weight-bearing began at three weeks, progressing to full weight-bearing by six to eight weeks, based on the fracture pattern and callus formation. Outcomes were evaluated using the Flynn criteria [5].

III. Result

Table 1 displays with 62.5% of the cases, the right side experienced the most fractures, whereas the left side experienced 37.5%. This suggests that femur fractures on the right side are more common, which may be related to things like handedness or typical pediatric injury-causing activities.

Table 1: Distribution of Injury by Side

Side	Frequency	Percentage (%)
Right	35	62.5
Left	21	37.5
Total	56	100

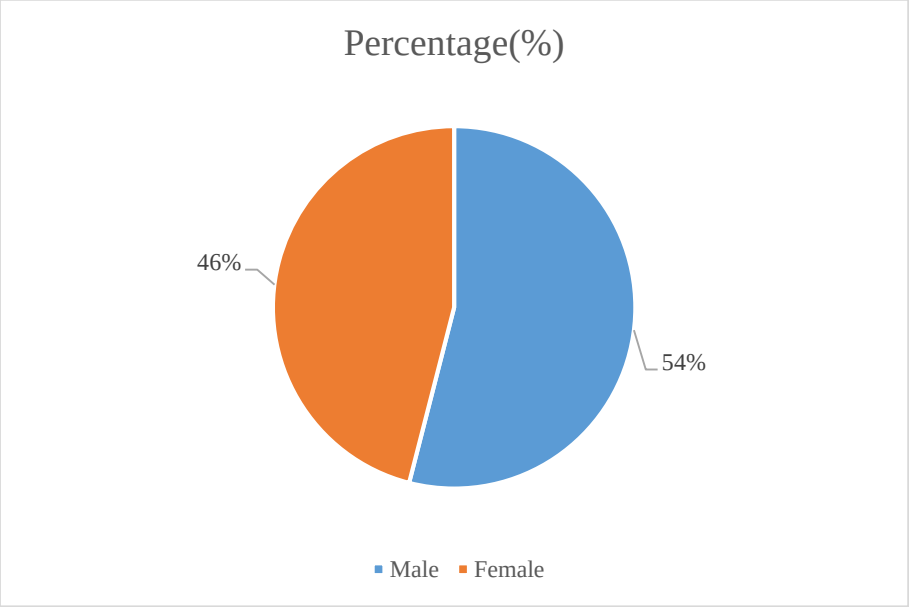

Figure 1: Gender Distribution

The 56 patients' gender distribution is shown in Figure 1 as 46.4% female and 53.6% male. Due to their increased participation in high-risk physical activities, male children have a slightly higher incidence of femur fractures than female children.

According to table 2, falls accounted for 39.3% of injuries, while road traffic accidents (RTAs) accounted for 60.7% of cases. This shows that RTAs are a major contributor to children's femur fractures, underscoring the necessity of more robust safety protocols in high-traffic areas.

Table 2: Cause of Injury

Mechanism	Frequency	Percentage (%)
h/o Fall	22	39.3
h/o RTA	34	60.7
Total	56	100

Table 3 shows that of the 10 open fractures, the majority were Grade I (70%), while 30% were Grade II. No Grade III fractures were reported in the sample. This indicates that most open fractures were of a less severe nature, which is favorable for management and recovery.

Table 3: Grades of Open Fractures

Grade	Frequency	Percentage (%)
Grade-I	7	70
Grade-II	3	30
Total	10	100

Table 4 demonstrates that the majority of clinical outcomes were favorable, with 71.4% of patients attaining excellent outcomes. 10.7% had subpar results, while 17.9% had favorable outcomes. This suggests that only a small proportion of patients had negative outcomes from the treatment, while the majority benefited.

Table 4: Clinical Outcomes

Clinical Outcomes	Frequency	Percentage (%)
Excellent	40	71.4
Successful	10	17.9
Poor	6	10.7
Total	56	100

As indicated in Table 5, Two patients experienced varus angulation (3.6%), one experienced valgus angulation (1.8%), and four experienced entry site irritation (7.1%). Three (5.4%) of the cases had limb length differences of less than 1.5 cm, but these were not clinically major. One patient (1.8%) needed their nails removed because of wound breakdown at the entry site.

Table 5: Complications

Complication	Frequency	Percentage (%)
Varus Angulation	2	3.6
Valgus Angulation	1	1.8
Entry Site Irritation	4	7.1
Limb Length Discrepancy	3	5.4
Nail Removal (Wound Breakdown)	1	1.8
Total	11	100

Figure 2: Radiograph of Closed fracture right femoral shaft

Figure 3: Radiograph of 3 months after surgery

IV. Discussion

According to Anglen and Choi (2005), femoral shaft fractures, subtrochanteric fractures, and supracondylar fractures account for roughly 1.6% of all pediatric bone injuries [1]. The treatment of pediatric femur fractures has changed over the last 20 years, and several surgical options have been investigated. Among these, titanium elastic nailing (TENS) has gained popularity as a treatment for pediatric femur shaft fractures because of its benefits over other techniques like plate fixation and external fixators, which might not be appropriate for the study's target age group.

TENS (titanium elastic nailing) has a number of advantages for young patients. It functions as a straightforward internal splint that shares load and doesn't obstruct the growth plate, enabling early mobilization without compromising alignment. Bridging callus forms more quickly at the fracture site due to the nail's flexibility and the micromotion facilitated by the fixation's elasticity. Furthermore, because TENS is a closed procedure, it minimizes the disruption of fracture hematoma and lowers the risk of infection while also protecting the periosteum [4]. According to Flynn et al. (2001), who discovered that TENS produced better results for pediatric femur fractures, these characteristics make TENS especially beneficial when contrasted with alternative techniques, like hip spica [5].

The effectiveness of TENS, Rush nails, and Ender nails has not been directly compared, but it is important to recognize that all these methods can yield positive results. However, Rush and Ender nails present certain limitations, particularly in terms of rotational stability, and may require multiple nails to achieve adequate fixation. Furthermore, Ender nails are less suitable for pediatric fractures because they lack the flexibility and elasticity provided by TENS [4].

The fracture's location and geometry play a key role in selecting the appropriate surgical implant. TENS is typically suitable for transverse, short oblique, and minimally comminuted fractures, showing positive outcomes in children aged 6–12 years with these types of fractures [2,7]. TENS is appropriate for all femoral diaphyseal fractures in children older than six, provided the fracture is not a severe type III open fracture and the epiphysis is still open [8]. However, for comminuted, long oblique, or spiral fractures, TENS may not provide sufficient stability, and post-operative immobilization could be required.

Complications like angulation, limb length disparity, and entry site irritation were noted in this study; these findings are in line with those of other research [9, 10]. A common side effect of TENS is entry site irritation, which was observed in 4 patients (7.1%). Long and noticeable nail ends (7–2 cm) and a mismatch between nail diameter and canal size were found to be significantly associated with irritation, which may be a contributing factor to the higher incidence of varus and valgus angulations. Furthermore, there were three instances of limb length discrepancy (5.4%), but they were not clinically significant. One patient (1.8%) had their nails removed

because of wound breakdown at the entry site, highlighting the importance of post-operative care and careful surgical technique.

V. Conclusion

With benefits like early mobilization and fracture alignment maintenance, this study shows that titanium elastic nails (TENS) are a successful treatment for pediatric femoral shaft fractures. Although issues like limb length disparities and irritation of the entry site were observed, they were controllable and had little effect on the results. When the fracture is not severe or comminuted, TENS is especially beneficial for children under the age of twelve. All things considered, TENS is still a good choice for treating these fractures, and more comparative research may lead to better results.

VI. Recommendation

TENS is an effective and reliable treatment for pediatric femoral shaft fractures, especially in children aged 6-12 years, and should be preferred over other fixation methods. Surgeons should carefully select the appropriate nail size and ensure proper placement to avoid complications such as entry site irritation and varus/valgus angulations. TENS is most suitable for transverse, short oblique, and minimally comminuted fractures. For more complex fractures, post-operative immobilization may be necessary. Regular follow-up is important to detect and manage any complications like limb length discrepancy or angulation. Further studies comparing TENS with other methods like Rush and Ender nails could provide more insights into their relative effectiveness.

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