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Original Article

Outcomes of Elastic Stable Intramedullary Nailing for Pediatric Femoral Shaft Fractures: A Retrospective Study of 25 Cases

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Abstract: Background: Elastic stable intramedullary nailing (ESIN) is widely used for pediatric femoral shaft fractures because it allows minimally invasive fixation and early mobilization. Objective: To evaluate the outcomes of ESIN for pediatric femoral shaft fractures. Methods: A retrospective case series was performed on 25 children aged 4–15 years with closed femoral shaft fractures treated using ESIN between January 2023 and January 2024. Clinical and radiographic outcomes were assessed with a minimum follow-up of 6 months. Results: The mean age was 11.7 ± 2.3 years, and 68% of patients were male. Midshaft fractures accounted for 60% of cases. Radiographic union was achieved in all patients. One patient developed superficial wound infection. According to Flynn's criteria, 80% of patients had excellent outcomes and 20% had satisfactory outcomes. Conclusions: ESIN is a safe and effective treatment option for pediatric femoral shaft fractures, providing high union rates, favorable functional outcomes, and low complication rates.

Keyword: Pediatric femoral fracture; ESIN; Metaizeau nail; Femoral shaft fracture.

1. Introduction

Femoral shaft fractures account for approximately 4% of all long bone fractures in children and are among the most common injuries requiring hospitalization in pediatric orthopedic trauma patients [1]. Treatment options vary according to patient age, fracture pattern, and associated injuries.

In younger children, conservative treatment with traction or hip spica casting is still commonly used. However, prolonged

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immobilization may delay rehabilitation and increase the risk of joint stiffness, muscle atrophy, and prolonged absence from school and daily activities [2].

Elastic stable intramedullary nailing (ESIN), also known as the Metaizeau technique, has become an increasingly popular surgical option for pediatric femoral shaft fractures. The technique provides stable fixation through a minimally invasive approach while preserving the biological environment of fracture healing [3].

Compared with conservative treatment, ESIN facilitates early postoperative mobilization and functional recovery, as reported in previous studies. Intraoperative fluoroscopic guidance also improves reduction accuracy and facilitates optimal nail placement with minimal soft tissue injury [3].

Several studies have reported favorable outcomes of ESIN in children, with high union rates, low complication rates, and satisfactory functional recovery [1, 4, 5]. However, prospective data regarding short-term outcomes of ESIN in routine clinical practice remain limited in developing countries.Therefore, this study was conducted to evaluate the outcomes of pediatric femoral shaft fractures treated with closed reduction and elastic stable intramedullary nailing under fluoroscopic guidance.

2. Materials and Methods

2.1. Study Design and Patients

A retrospective case series study was conducted using medical records of pediatric patients who underwent ESIN for femoral shaft fractures between January 2023 and January 2024. Twenty-five pediatric patients aged 4 – 15 years with closed femoral shaft fractures were treated with elastic stable intramedullary nailing (ESIN) under fluoroscopic guidance.

2.2. Inclusion Criteria

Patients were included if they:

- Were aged between 4 and 15 years;
- Had closed femoral shaft fractures;
- Underwent surgical treatment using ESIN;
- Had a minimum follow-up period of 6 months.

2.3. Exclusion Criteria

Patients with open fractures, pathological fractures, associated neuromuscular disorders, or incomplete follow-up data were excluded from the study.

Closed reduction and elastic intramedullary nailing (Metaizeau technique).

All procedures were performed under general anesthesia with the patient in the supine position on a radiolucent operating table. Closed reduction was achieved under fluoroscopic guidance. Two titanium elastic nails were inserted retrogradely through medial and lateral entry points at the distal femur. Nail diameter was selected according to the width of the medullary canal (approximately 40% of the narrowest diameter of the medullary canal). The nails were advanced across the fracture site to obtain stable fixation (Figure 1-5). Fracture alignment and nail position were confirmed intraoperatively using fluoroscopy. This technique causes minimal soft tissue damage, reduces blood loss, and preserves the periosteum. Fluoroscopy during surgery helps ensure accurate nail placement, improves surgical precision, and shortens operating time [3].

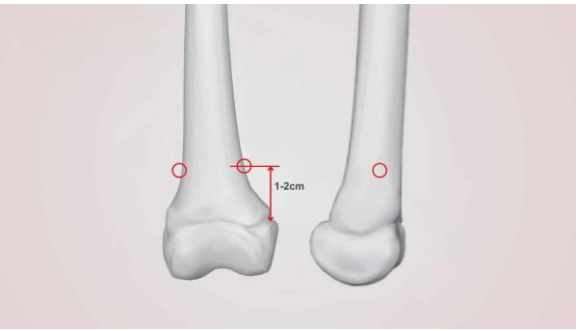

Figure 1. Determination of the entry points.

The entry points are located 1-2 cm proximal to the distal femoral physis to avoid growth plate injury.

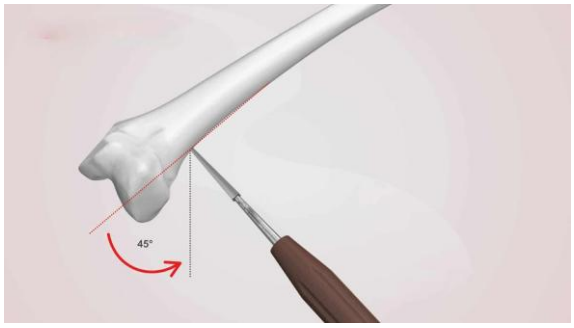

Figure 2. Initial insertion technique.

The bone cortex is opened using an awl or drill bit, positioned at an angle of 45◦ to the long axis of the femoral shaft.

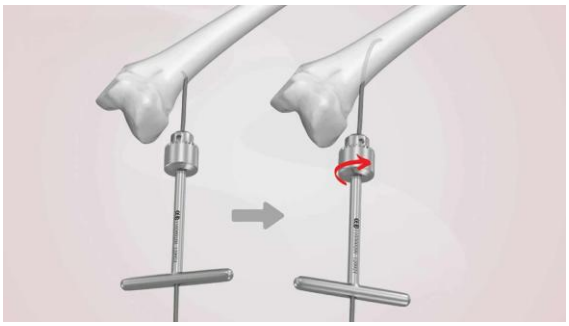

Figure 3. Advancement and rotation of the elastic nail.

The titanium elastic nail is introduced and rotated using a T-handle to navigate through the medullary canal.

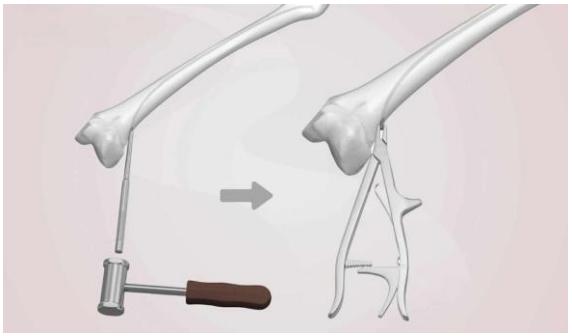

Figure 4. Driving the nail across the fracture site.

A mallet is used to gently advance the nail while ensuring the curved tip remains oriented correctly to facilitate fracture reduction.

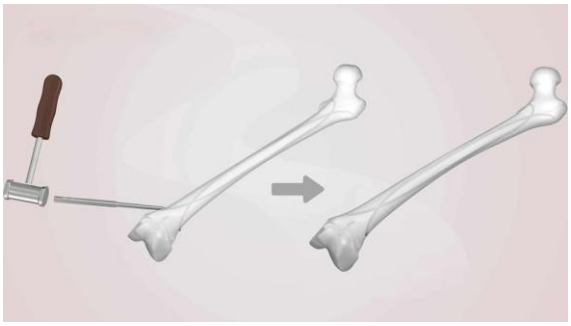

Figure 5. Final positioning and stability check.

The nails are advanced into the proximal metaphysis to achieve three-point fixation, ensuring optimal mechanical stability of the femoral shaft fracture

2.4. Postoperative Management

Passive and active range-of-motion exercises were initiated on the second postoperative day. Partial weight-bearing was permitted according to pain tolerance and radiographic evidence of healing. Patients were followed clinically and radiographically at regular intervals.

2.5. Outcome Assessment

Clinical evaluation included wound healing, postoperative complications, and functional recovery. Radiographic assessment was performed to evaluate fracture union and alignment. Functional outcomes were assessed according to Flynn's criteria and classified as excellent, satisfactory, or poor.

2.6. Statistical Analysis

Data were analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages.

2.7. Ethical Approval

This study was approved by the Institutional Ethics Committee of E Hospital (Approval No.

50/2025/BVE-HDDD, dated August 19, 2025). All procedures were performed in accordance with the ethical standards of the institutional research committee and the Declaration of Helsinki. Written informed consent was obtained from the patients' parents or legal guardians prior to participation in the study

3. Results

3.1. General Characteristics

Table 1. Age Characteristics

Age	Quantity (n)	Percentage (%)
4-6	4	16
7-10	10	40
11-15	11	44
Total	25	100
Mean ± SD (min – max)	11.7 ± 2.3 (4 – 15)	

The average age was 11.7 years (Table 1). The youngest patient was 4 years old, and the oldest was 15 years old. The age group from 11 to 15 years accounted for the highest proportion, representing 44% of the total cases.

In our study, there were 17 male patients, accounting for 68%, and 8 female patients, accounting for 32%.

Table 2. Classification by Cause of Fracture

Cause of Injury	Number of Patients (n)	Percentage (%)
Traffic accidents	5	20
Domestic accidents	13	52
Sports injuries	7	28
Total	25	100

Domestic accidents were the most common cause, accounting for 52%. Traffic accidents ranked second with 5 patients, representing 20%. Sports injuries were the cause in 7 patients, making up 28% of the cases (Table 2).

The majority of fractures were classified as Grade 1 and Grade 2 according to the Winquist-Hansen classification, accounting for 36% and 44% of cases, respectively (Table 3).

Table 3. Fracture Classification According to Winquist-Hansen

Grade	Number of Cases (n)	Percentage (%)
Grade 0	2	8
Grade 1	9	36
Grade 2	11	44
Grade 3	3	12
Grade 4	0	0
Total	25	100

Table 4. Fracture Location

Fracture Site	Number of Patients (n)	Percentage (%)
Upper third	6	24
Middle third	15	60
Lower third	4	16
Total	25	100

Fractures in the middle third of the femur were the most common, with 15 patients (60%). Upper third fractures accounted for 6 patients (24%), and lower third fractures occurred in 4 patients (16%) (Table 4).

3.2. Treatment Results

Table 5. Surgical Wound Condition

Wound Condition	Number of Patients	Percentage (%)
Healed primarily	24	96
Superficial infection	1	4
Total	25	100

Primary wound healing was observed in 24 patients (96%). One patient (4%) developed a superficial infection, which required wound separation and daily dressing changes; the scar eventually healed well (Table 5).

Soft and flat scars were seen in 21 patients (84%). Hypertrophic scarring occurred in 3 patients (12%). One case (4%) presented with local irritation at the scar site (Table 6).

Table 6. Scar Outcome

Scar Condition	Number of Patients	Percentage (%)
Soft, flat scar	21	84
Hypertrophic scar	3	12
Local irritation/inflamed	1	4
Total	25	100

Table 7. Bone Healing Status

Bone Healing Status	Number of Patients	Percentage (%)
Healed without displacement	25	100
Healed with slight displacement	0	0
Healed with major displacement	0	0
Nonunion	0	0
Total	25	100

All patients in our study showed radiographic evidence of complete bone healing at their most recent follow-up. A total of 25 patients (100%) achieved healing without any residual displacement (Table 7).

We evaluate overall results based on the Flynn score (Table 8).

Table 8. Overall Treatment Outcome (Flynn's Criteria)

Outcome Level	Number of Patients	Percentage (%)
Excellent	20	80
Satisfactory	5	20
Poor	0	0
Total	25	100

A total of 20 patients (80%) achieved excellent results. Five patients (20%) had satisfactory outcomes, and there were no poor results.

No patient required early nail removal because of soft tissue irritation, and no clinically significant angular deformity was observed on follow-up radiographs.

4. Discussion

In the present study, elastic stable intramedullary nailing (ESIN) provided favorable clinical and radiographic outcomes in pediatric femoral shaft fractures, with a high union rate, low complication rate, and satisfactory functional recovery.

Male patients accounted for 68% of cases, with a male-to-female ratio of 2.1:1. This finding is consistent with previous studies reporting a higher incidence of femoral shaft fractures in boys because of greater physical activity and trauma exposure [4]. The average age in our study was 11.7 ± 2.3 years, with most patients aged 11–15 years. Surgical stabilization in this age group is beneficial because it allows earlier mobilization and faster return to daily activities compared with prolonged conservative treatment [5].

Radiographic union was achieved in all patients, with no cases of nonunion or major malalignment. Similar union rates have been reported in previous studies [3, 5, 6]. The favorable healing outcomes may be explained by the minimally invasive nature of ESIN, which preserves the periosteum and fracture hematoma while providing adequate elastic stability for callus formation.

Primary wound healing occurred in 96% of patients, and only one patient developed superficial wound infection. Local irritation at the nail entry site was uncommon and resolved after implant removal, similar to previous reports by Lohiya et al., [5].

According to Flynn's criteria, 80% of patients achieved excellent outcomes and 20% achieved satisfactory outcomes, which are comparable with the results reported by Lohiya et al., Lu et al., and Govindasamy et al., [5, 7, 8].

Domestic accidents were the most common cause of injury in our study, followed by sports injuries and traffic accidents. Similar findings have been reported by Pogorelić et al., [4]. Midshaft fractures were the most frequent fracture location, which is consistent with previous reports by Mani et al. and Barlas et al.,

[9, 10]. Most fractures were classified as Winquist–Hansen grade I or II, which are considered suitable indications for ESIN [11].

Previous studies have reported that ESIN may facilitate early postoperative rehabilitation and return to function. In our study, mobilization exercises were initiated from the second postoperative day.

This study has several limitations, including the relatively small sample size, single-center design, absence of a comparative control group, and short follow-up duration. However, our findings suggest that ESIN is a safe, effective, and minimally invasive treatment option for pediatric femoral shaft fractures with favorable short-term outcomes.

5. ConclusionBottom of Form

Elastic stable intramedullary nailing under fluoroscopic guidance is a safe and effective treatment method for pediatric femoral shaft fractures. The technique provides stable fixation, high union rates, favorable functional outcomes, and low complication rates while allowing early postoperative mobilization and rehabilitation. ESIN should be considered a reliable minimally invasive option for the management of femoral shaft fractures in school-aged children.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

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