ORIGINAL ARTICLE

# Assessment Of Outcome Of Pediatric Diaphyseal Femur Fractures Treated With Elastic Stable Intramedullary Nails In Gandaki Medical College

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## Abstract

**Introduction:** Various techniques described for managing pediatric femur fractures include closed reduction and internal fixation (CRIF) with elastic nails, open reduction and internal fixation (ORIF) with compression plates, external fixators, and skeletal traction with spica casting. Although flexible intramedullary nailing has emerged as an accepted procedure for pediatric femur diaphyseal fractures, it is not free from complications, including pin site irritation, limb length discrepancy, superficial infection, and synovitis. This study aims to assess the complications and outcomes following the treatment of femoral shaft fractures using titanium elastic nails.

**Methods:** A prospective observational study was conducted with 25 children aged 5 to 15 years, admitted with diaphyseal femur fractures at Gandaki Medical College and Teaching Hospital, Pokhara. All patients were treated with fracture reduction and internal fixation using titanium elastic nails and followed up until fracture union (ranging from 3 to 6 months). The functional outcomes were assessed using the Flynn Scoring System.

**Results:** This study included 25 patients admitted with diaphyseal femur fractures and treated with titanium elastic nails. Radiological union was achieved at an average of 8.8 weeks. Of the total 25 patients, 21 (84%) had an excellent outcome, while 4 (16%) had a satisfactory outcome.

**Conclusion:** We concluded that the Elastic Stable Intramedullary Nail (ESIN) system, when used for the fixation of pediatric femoral shaft fractures, provides a successful outcome with a low complication rate.

**Keywords:** elastic stable intramedullary nail, femoral shaft fracture, pediatric long bone fractures

## Introduction

The femur is the human body's longest, strongest, and heaviest tubular bone. It serves as one of the main load-bearing bones in the lower extremities.[1,2] The word orthopedics translates to "straight child," highlighting the significance of childhood trauma and malformations in the development of this field. Historically, the majority of pediatric fractures were treated conservatively using splinting methods, often resulting in burdensome disability.[3]

Blunt trauma is the primary cause of femoral shaft fractures, which are among the most frequently treated injuries by pediatric orthopedic surgeons. Approximately 70% of femur fractures involve the shaft.[2] Among all pediatric fractures, femoral shaft fractures make up about 1.6%. Accidental trauma is the leading cause of most femoral shaft fractures. However, child abuse accounts for up to 30% of these fractures in children under four years old.[4] Pathologic fractures, stress fractures, and osteogenesis imperfecta can also occur.[5] Conditions such as simple or aneurysmal bone cysts, eosinophilic granuloma, or non-ossifying fibroma may also lead to pathologic fractures in children.[6]

Similar to adults, the femur in children can fracture at the hip, knee, or along the shaft. Whatever the causes, ideal treatment methods, outcomes, and complications differ. A thorough understanding of these differences is essential to appropriately manage individual patients. Various treatment methods exist,

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and there are ongoing debates about which is preferable in specific situations.[7]

The majority of femoral shaft fractures in children aged five and under can be treated with early closed reduction and the use of a spica cast. For adolescents with skeletal maturity, the insertion of anterograde solid intramedullary rods is the recommended method. However, the ideal treatment for children aged 5 to 16 years remains debated. Conservative measures in this intermediate age group carry a higher risk of shortening and malunion than in younger children.[3,8,9, 10]

These fractures can be surgically treated using methods such as strong antegrade intramedullary nails, external fixation, plates, and screws. However, these methods have associated complications, such as pin tract infection, refracture with external fixators, and osteonecrosis with rigid nails.[11,12,14] Plate osteosynthesis remains widely used but is associated with extensive exposure, prolonged immobilization, a higher risk of delayed union, infection, and significant dissection for plate removal.[13] External fixation offers good stability and allows early mobilization but is linked with a higher risk of infection and longer weight-bearing restrictions.[13]

In children between 5-15 years with femur fractures, the use of flexible interlocking nails has increased over the past seven years.[12] Elastic Stable Intramedullary Nailing (ESIN) is a simple, efficient, and minimally invasive surgical technique that offers secure fixation, rotational stability, rapid healing, and a prompt return to normal activities.[13,15,16]

Due to its clinical effectiveness and minimal risk of complications, ESIN for long bone fractures in skeletally immature children has gained widespread popularity. Many studies advocate this approach because of its advantages, including closed insertion, preservation of fracture hematoma, and a physeal-sparing entry point.[15 17 18]

This study aims to assess the outcomes of treating femoral shaft fractures using ESIN.

## Methods

This was a hospital-based descriptive observational study conducted at Gandaki Medical College (GMC), Pokhara, from April 2024 to July 2024.

The total sample size for the study was n = 25 using Cochran's formula;

$n=z^2p(1-p)/d^2$

where z is a standard normal variate (at 5% type 1 error($p<0.05$) it is 1.96. P is the expected proportion in the population based on previous studies, which comes to be 0.016, and d is the absolute error or precision =5%.

The sampling technique used was non-randomized purposive sampling. That means 25 children between 5-15 years with a fracture shaft of the femur who visited our center were purposively selected for our study after taking consent from their parents.

Children between 5-15 years with unilateral femur shaft fracture (Winquist grade 0,1, and 2) and open fractures (Gustilo-Anderson Type 1) were included in the study. Whereas comminuted (Winquist grade 3 or 4), segmented, open (Gustilo-Anderson Type 2 and 3), pathological, and associated ipsilateral tibia or contralateral tibia or femur were excluded.

Ethical approval was obtained from the Institutional Ethics Review Committee of GMC (IRC ref: 91/080/081-f). Data were collected from patients attending the orthopedic outpatient department and emergency department at GMCTH. Informed consent was obtained from the patient's guardian or family using a consent form after the study details and procedure were explained. Relevant patient history and clinical examinations were documented using a printed case report form.

All patients underwent preoperative and postoperative X-ray imaging. Postoperative follow-ups were conducted at 2 weeks, 6 weeks, 8 weeks, 3 months, and 6 months. If radiological union was not observed at the 8-week follow-up, follow-ups were conducted biweekly for 3 months and then monthly until fracture union was achieved.

Regular follow-ups and physiotherapy were conducted to evaluate the functional outcomes. Patients were assessed for pain, limb length discrepancy, varus/valgus malalignment, surgical wound complications, nail prominence, and range of motion at the knee joint. Functional outcomes were evaluated using the ESIN scoring system proposed by Flynn et al.[13] at the 6-month follow-up. Statistical analysis was carried out using a computer-based statistical analysis program, Microsoft Excel, and statistical packages, SPSS (Statistical Programme for Social Sciences).

**Table 1:** Criteria for Functional Outcomes[18] (Flynn et al.)

| Outcome | Excellent | Satisfactory | Poor |
|---|---|---|---|
| Limb Length Discrepancy (LLD) | <1 cm | <2 cm | >2 cm |
| Malalignment | Up to 5° | 5°–10° | >10° |
| Pain | None | None | Present |
| Complications | None | Minor | Major |

Radiological union was graded using the criteria proposed by Anthony et al.[24]

**Table 2:** Grading for radiological union[24] (Anthony et al.)

| Grade | Description |
|---|---|
| 0 | No identifiable fracture healing. |
| 1 | Primary bone healing with little or no periosteal new bone formation. |
| 2 | Periosteal new bone formation on two sides of the femur. |
| 3 | Periosteal new bone formation on three to four sides of the femur. |

## Results

In the present study, the mean age of the patients was 9.12 years, with the minimum age being 5 years and the maximum 13 years. 72% of the patients were boys, with a boy-to-girl ratio of 2.5:1. Nineteen (76%) patients reported a mechanism of injury due to road traffic accidents, while a history of falling from a standing height was noted in two (8%) patients, and four

(16%) cases were attributed to falls from a height.

Sixty-four percent of the patients had fractures of the right femur, and 36% had fractures of the left femur. An oblique fracture pattern was observed in 44% of cases, while transverse and spiral patterns were noted in 20% and 36%, respectively. Fractures of the middle third of the femur were seen in 60% of the patients, proximal third fractures in 32%, and lower third fractures in 8%. Closed fractures accounted for 88% of cases, while 12% were open fractures.

Regarding the diameter of the nails used, 60% of patients received 3-mm nails, 28% received 2.5-mm nails, and 12% received 3.5-mm nails. Eighty-four percent of the patients were discharged within 5–7 days, while two (8%) patients stayed in the hospital for 7–10 days, and another two (8%) stayed for more than 12 days.

At the two-week follow-up, pain was reported in 25% of the patients, but no incidences of infection were observed. Most patients returned to school within 41–60 days (18 patients), while four patients returned earlier (30–40 days), and the remaining three patients returned within 61–80 days.

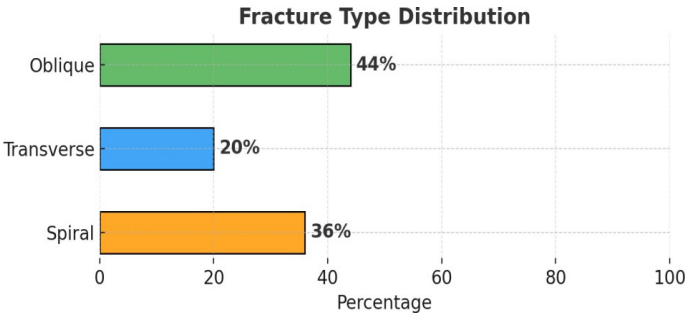
The average time for full weight-bearing without support and radiological union was 8.8 weeks. At the three-month follow-up, fracture union was noted in all 25 patients, although skin irritation was observed in three cases.

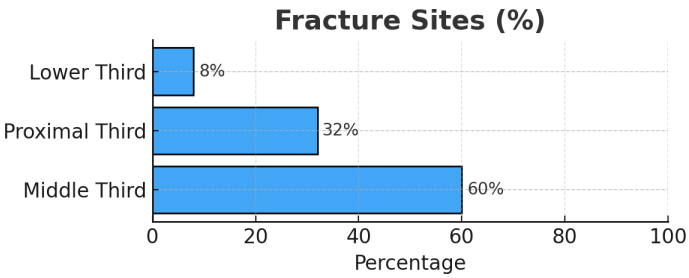
Excellent outcomes were seen in 84% of children, with satisfactory outcomes in 16%. No children experienced poor outcomes.

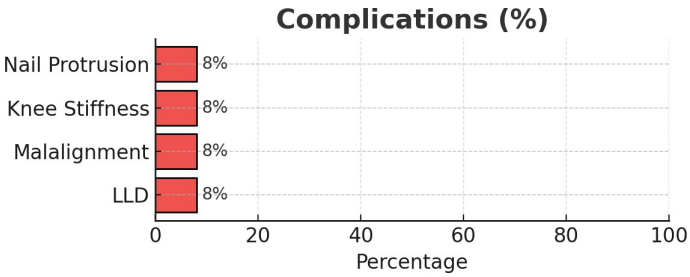
Complications at the six-month follow-up included limb length discrepancy in 8% of patients, malalignment in 8%, knee stiffness in 8%, and nail protrusion in 8%.

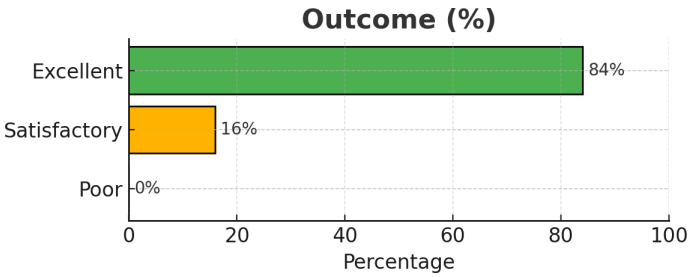
The fracture pattern showed no significant relationship with the union time ($p > 0.05$). Similarly, the fracture site was not significantly related to the union time ($p > 0.05$).

However, the weight of the child was positively correlated with the union time




## Discussion

Femoral shaft fractures are common and temporarily disabling injuries in children. Recent advances in adult orthopedic traumatology have led to a more aggressive approach toward managing these fractures in children. Multiple treatment modalities are available. Controversy persists regarding which method is superior in specific scenarios. Surgical intervention for treating femoral fractures, especially those involving compound injuries, associated ipsilateral tibia fractures, head injuries, neurovascular injuries, and polytrauma, is widely accepted in the pediatric age group of 5–15 years. For isolated femoral fractures, numerous studies suggest that operative procedures provide better outcomes than conservative treatments by reducing complications.

The shift toward surgical treatment is driven by its ability to avoid undesirable outcomes such as nonunion, malunion, wound complications, and prolonged immobilization. Intramedullary nailing has emerged as one of the most effective methods for treating children. In pediatric patients, intervention with elastic nails is technically easier than using conventional nails, such as Ender nails, which are more rigid and challenging to insert due to the smaller bone diameters in children.

Studies have shown that pediatric femur fractures treated with intramedullary titanium elastic nails (TENS) achieve successful outcomes in children aged 5–15 years. Pediatric femoral shaft fractures are more common in males, with an approximate male-to-female ratio of 2.5:1[19]. In the present study, the ratio was consistent at 72% boys and 28% girls.

Previous studies have reported a bimodal age distribution for

children with femoral shaft fractures, with peaks in children younger than 5 years and mid-teenage groups. In this study, the age range was 5–15 years with a mean age of 9.2 years and a median age of 10 years. The mean age in this study was slightly lower than that reported by Ligier JN et al[17] (10.2 years; range: 5–16 years) study by Khazzam et al.[20] reported a mean age of 9.7 years (range: 2–17 years).

In this study, the outcome was evaluated using Flynn et al.'s criteria.[21] Excellent outcomes were seen in 84% of children and satisfactory outcomes in 16%. No children experienced poor outcomes. These findings are comparable to a study by Kumar N et al.[22] from India, where 70% of patients achieved excellent outcomes, and 30% had satisfactory results. Flynn JM et al.[23] reported excellent results in 65% of patients, with satisfactory and poor results in 25% and 10%, respectively. Similarly, Sankar WN et al.[24] reported excellent results in 63.15% of patients, with satisfactory and poor outcomes in 31.57% and 5.26%, respectively.

Fracture union time in this study ranged between 8 to 12 weeks, with a mean of 8.8 weeks. The mean time to full weight-bearing was 10.05 weeks. Statistical analysis showed a significant relationship between patient weight and union time ($p < 0.05$), indicating that union time increased with weight. Oh et al.[26] observed unions within 12 weeks (mean: 10.5 weeks) in all 31 fractures in their study. Buechsenchuetz et al.[27] reported that fractures in 42 patients with elastic stable intramedullary nailing healed at a mean of 88 days. Houshian et al.[28] reported a median union time of 7 weeks (range: 5–9). KC Saikia et al.10 noted a mean union time of 8.7 weeks (range: 6–12 weeks) and weight-bearing time of 8.8 weeks (range: 6–12 weeks). AtulBhaskar reported a mean union time of 10 weeks (range: 6–16 weeks). External fixator stabilization technique typically results in a union time of 3–4 months.[29]

Sink et al.[30] and Agus et al.[31] in their study reported 12 weeks and 12.4 weeks, respectively, as the union time when submuscular plates were used for the management of these fractures. Therefore, the time taken for fracture union by the titanium elastic nailing system is lesser as compared to the other surgical methods for treating paediatric femoral shaft fractures. Titanium elastic nail seems advantageous over other surgical methods, particularly in this age group, as it is a simple, load-sharing internal splint that does not violate open physis, allows early mobilization, and maintains alignment. Micromotion conferred by the elasticity of the fixation promotes faster external bridging callus formation. The periosteum is not disturbed, and being a closed procedure, there is no disturbance of the fracture haematoma, thereby less risk of infection.

The most common complications of titanium elastic nailing include limb length discrepancies, fracture angulation, refractures, and infections. In this study, malalignment was observed in 8% of children during the final follow-up. This included a valgus tilt of 10° in one case and an anteroposterior angulation of 10° in another, both considered satisfactory per Flynn et al.'s criteria.[21]

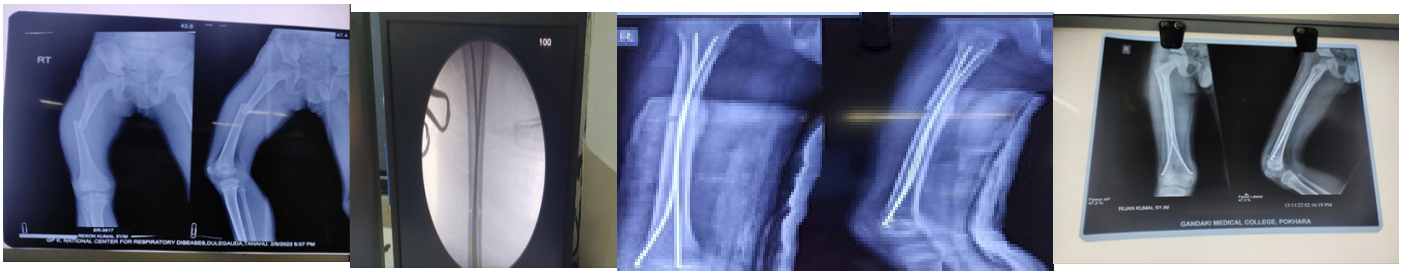
Limb length discrepancy is a problem, especially after femoral fractures. It has been recommended to leave at least 1.5 cm overlap between the fracture ends to prevent overgrowth. With end-to-end alignment with titanium nails, overgrowth remains a potential problem.[33] These patients must be followed up until skeletal maturity.[33] In this study, limb length discrepancy was noted in 8% of the children, that is, in one case shortening of 3mm and 6mm lengthening in another case. However, this finding was within the limits of excellent results according to Flynn et al.'s 21 criteria. KC Saikia et al.[10] reported limb lengthening of <1.5 cm in 13.64% cases, while Bekir YU et al.[34] reported limb length discrepancy in 18.6% cases. Singh et al.[35] recommended that this complication can be avoided by adhering to the principles of flexible intramedullary nailing.

The most common complication of the titanium elastic nail is entry site irritation, infection and pain.[14,36] In our present study, skin irritation was reported in three of the patients at three-month follow-up, which subsided with oral antibiotics subsequently.

## Conclusion

Based on our study, it can be concluded that ESIN, when used for the fixation of pediatric femur fractures in children aged 5–15 years, yields excellent and successful outcomes with a low complication rate. ESIN nails provide stable fixation, allowing for early postoperative mobilization. When patients adhere to postoperative mobilization exercises, a quicker return to normal movement and function can be expected. Proper patient selection and cooperation are crucial to achieving good results with titanium elastic nails. According to our study, the fracture union rates for pediatric femoral shaft fractures after internal fixation with ESIN are excellent.

## Case illustrations



Pre-operative X-ray Intraoperative C-arm image
1-month follow-up 6 months follow-up

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