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Original Article

Treatment of paediatric subtrochanteric femoral fractures using titanium elastic nails: a single-center experience

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Abstract: Background: Subtrochanteric femoral fractures in children are uncommon but challenging to manage due to high mechanical stresses and their proximity to the growth plate. While the Titanium Elastic Nailing System (TENS) has proven effective for paediatric diaphyseal fractures, its role in subtrochanteric fractures is less well established. Aim: The aim of this study was to evaluate the clinical and radiological outcomes of paediatric subtrochanteric femoral fractures treated with TENS, specifically assessing union rates, complications, and functional outcomes using Flynn's criteria. Methods: We conducted a prospective observational study of 18 children aged 5-11 years with radiologicaly confirmed subtrochanteric femoral fractures treated using TENS at a tertiary care centre. Patient demographics, fracture patterns, associated injuries, time to surgery, postoperative immobilization, time to weight bearing, fracture union, complications, and outcomes were recorded and analysed. Results: The mean age of patients was 7.7 years, with a male predominance (61%). The most common fracture patterns were oblique and spiral. Associated injuries were seen in 4 patients, and the average time to surgery was 2.1 days. Partial weight bearing was initiated by 4-5 weeks, and radiological union was achieved in all patients, with a mean union time of 9.5 weeks. Complications included limb length discrepancy (1 case), nail irritation (2 cases), and delayed union or malalignment (2 cases). According to Flynn's criteria, 72% had excellent, 22% good, and 6% satisfactory outcomes. Conclusion: TENS is a safe, minimally invasive, and effective treatment for paediatric subtrochanteric femoral fractures in children aged 5-11 years. When applied with proper technique and patient selection, it results in reliable union, early mobilization, and favourable functional outcomes with minimal complications.

Keywords: Paediatric subtrochanteric femur fracture, titanium elastic nailing (TENS), intramedullary fixation in children, fracture union, Flynn's criteria

Introduction

Subtrochanteric femoral fractures in children are rare injuries, accounting for less than 10% of all paediatric femoral shaft fractures [4, 7, 10]. These fractures occur in the proximal femoral shaft just below the lesser trochanter and are biomechanically challenging to manage due to the powerful muscle forces acting around the proximal femur. The major causes of subtrochanteric fractures in children include high-energy trauma such as road traffic accidents and falls from height. In younger children, low-energy trauma such as falls during play may also lead to fractures, particularly in the presence of underlying bone pathology like osteogenesis imperfecta, metabolic bone disease, or malignancy [5, 6, 23]. Due to the anatomical location, these fractures are subject to significant deforming forces from the iliopsoas, gluteal, and adductor muscle groups, which pull the proximal and distal fragments in different directions, often leading to varus, flexion, and external rotation deformities [7, 8, 10]. As a result, achieving and maintaining reduction is more difficult in subtrochanteric fractures compared to diaphyseal femur fractures.

Traditionally, non-operative treatment options such as skeletal traction followed by hip spica casting have been employed, especially in children less than 5 years of age. Although cost-effective, these methods require prolonged immobilisation, lead to increased hospital stays, and carry a higher risk of complications such as malunion, limb length discrepancy, and

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Figure 1. 7-year female presented with injury to right thigh. X-ray showed subtrochanteric fracture right femur.

delayed rehabilitation [13, 14, 25]. With advancements in paediatric orthopaedic trauma care, operative management has gained preference, particularly for children older than 5 years. Current surgical options include Titanium Elastic Nailing System (TENS), locking compression plate fixation, and external fixation. Among these, TENS has become a widely accepted method for paediatric femoral fractures in the 5-11 year age group. It offers several advantages: it is minimally invasive, allows early mobilisation, preserves the periosteal blood supply, and promotes healing through controlled micromotion at the fracture site [1-3]. While TENS is extensively studied and established in the treatment of midshaft femoral fractures, its role in subtrochanteric fractures remains less well defined. Concerns include difficulty in achieving adequate stability in the proximal femur, particularly in comminuted or unstable fracture patterns [6, 16]. However, several studies have reported promising outcomes with TENS in selected subtrochanteric fractures, suggesting that with proper case selection and surgical technique, it can yield satisfactory results [7, 15, 17]. This study aims to evaluate the functional and radiological outcomes of paediatric subtrochanteric femoral fractures treated with Titanium Elastic Nailing System (TENS) in children aged 5 to 11 years, with a focus on union time, complication rates, and final outcomes using Flynn's criteria.

Materials and methods

This prospective observational study was conducted at our center between November 2021 and December 2023, after obtaining approval from the institutional (Jawaharlal Nehru Medical College and Hospital) ethics committee. A total of 18 paediatric patients, aged between 5 and 11 years, diagnosed with subtrochanteric femoral fractures were included. Fractures were classified as subtrochanteric if the distance from the lesser trochanter to the fracture line was less than 10% of the total femoral length. The total femoral length was measured on the radiograph of the unaffected limb, defined as the distance from the superior aspect of the femoral head to the medial joint line of the knee. Using preoperative radiographs, the vertical distance from the lesser trochanter to the fracture site was calculated. Only those fractures falling within 10% of the overall femoral length were included in the study. All patients were treated with Titanium Elastic Nailing System (TENS) under standardized protocols [10, 12, 13].

Inclusion and exclusion criteria

The inclusion criterias were: 1) Age between 5 and 11 years; 2) Radiologicaly confirmed isolated or associated subtrochanteric femoral fractures; 3) Closed or Grade I open fractures; 4) Treated operatively using TENS. The Exclusion Criteria were: 1) Age <5 years or >11 years; 2) Pathological fractures; 3) Polytrauma with unstable systemic condition; 4) Open fractures beyond Gustilo-Anderson Grade I; 5) Patients treated with alternative fixation methods.

Preoperative evaluation

Patients were initially stabilized and evaluated clinically and radiologically (**Figure 1**). Preoperative traction or slab was applied in cases with severe pain or soft tissue injury. Fractures were classified based on the radiographic morphology (transverse, oblique, spiral, comminuted) [13, 22].

Surgical technique

All procedures were performed under general or spinal anesthesia on a radiolucent table. Closed reduction was attempted in all patients;

Figure 2. Post-operative X-ray showing fracture stabilized with two TENS nail.

open reduction was done only when closed manipulation failed. Two titanium elastic nails of equal diameter were introduced retrograde through the distal femur and advanced across the fracture site under fluoroscopic guidance to achieve three-point fixation (**Figure 2**) [1, 3, 17]. Nail diameter was selected as per Flynn's formula (approximately 40% of the canal diameter) [1, 25].

Postoperative protocol

Postoperative immobilisation varied based on fracture stability and surgeon preference, including use of hip spica or above-knee slab in selected cases for one to three weeks. Patients were encouraged to begin range-of-motion exercises early. Partial weight bearing was initiated between 3 to 6 weeks postoperatively, depending on clinical and radiological progress (**Figure 3**). Full weight bearing was permitted after confirmed union [12, 17, 25].

Indicators and evaluation criteria

To assess the therapeutic effect of TENS surgery, the clinical indicators recorded and analysed were: 1) Pain relief: Evaluated using patient/parent report and clinical examination, 2) Return to weight-bearing and mobility: Assessed based on the time to initiate partial and full weight bearing, 3) Range of motion (ROM): Serial clinical assessments of hip and knee mobility were performed at follow-up visits, 4) Limb length discrepancy (LLD): Measured clinically with block testing and confirmed radiographically if present, 5) Postoperative complications: Documented events included infection (superficial/deep), nail prominence or irritation, delayed union, malalignment, nonunion, and any reoperations required.

The radiological Indicators recorded and analyzed were: 1) Fracture union: Defined as the presence of bridging callus on at least three cortices in two orthogonal views, along with painless full weight bearing. 2) Malalignment: Angulation >10° in any plane on postoperative or follow-up radiographs was noted as malalignment. 3) Implant position: Regular radiographic checks were done to evaluate nail migration, loss of reduction, or cortical perforation.

Functional outcome assessment

Final outcomes were graded using Flynn's Criteria, which includes the following parameters: 1) Limb length discrepancy (<1 cm: excellent, 1-2 cm: good, >2 cm: poor), 2) Malalignment (<5°: excellent, 5-10°: good, >10°: poor), 3) Pain (none/mild: excellent or good, moderate/severe: poor), 4) Complications (none or minor: excellent/good, major requiring reoperation: poor), 5) Return to normal activity (within expected timeframe = better outcome). Each patient was assigned an outcome category (Excellent, Good, Satisfactory, or Poor) based on the cumulative Flynn score, providing an objective measure of therapeutic success.

Statistical analysis

Continuous variables were shown as mean ± SD, whereas categorical variables were presented as numbers and percentages. The student t-test was used to compare quantitative variables. Statistical significance was attained when the *p*-value was less than 0.05. The analytical process involved entering the data into an MS Excel spread-sheet and utilising the Statistical Package for Social Sciences (SPSS) version 20.0.

Results

Demographics and fracture characteristics

A total of 18 paediatric patients with subtrochanteric femoral fractures were included in

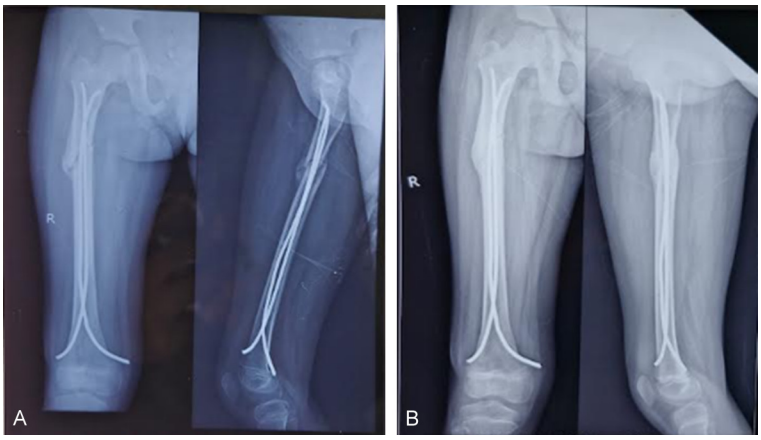

Figure 3. Follow-up x-rays at 6 weeks and 12 weeks revealed callus at the fracture site (A, B).

the study (**Table 1**). The mean age of the patients was 7.7 years (range: 5-11 years), with a male predominance (11 males, 61%). The left femur was involved in 10 cases, while the right femur was affected in 8 cases. The fracture patterns were oblique: 6 cases, spiral: 5 cases, transverse: 5 cases and comminuted: 2 cases. Associated injuries were identified in 4 patients, including mild head injury, ipsilateral radius fracture, soft tissue injury, pelvic contusion and ipsilateral femoral shaft fracture. Preoperative stabilization with traction or slab was performed in 7 patients prior to definitive surgery.

Surgical and postoperative parameters

The average time from injury to surgery was 2.1 days (range: 1-4 days). Postoperative immobilisation was applied in 11 patients (Hip spica in 6 cases and above-knee slab in 5 cases). The duration of immobilisation ranged from 1 to 3 weeks, depending on fracture stability and surgeon preference.

Weight bearing and fracture union

Partial weight bearing was initiated at a mean of 4.5 weeks (range: 3-6 weeks). The mean time to radiological union was 9.5 weeks (range: 7-12 weeks). Implant removal was carried out at a mean duration of 9.7 months postoperatively (**Figure 4**).

Complications

A total of 6 patients (33.3%) experienced complications including limb length discrepancy- 1 case (approx. 1 cm, did not require intervention), nail prominence or irritation- 2 cases, malalignment- 1 case, superficial infection- 1 case, delayed union- 1 case. There were no cases of deep infection, implant failure, or non-union.

Functional outcomes

Functional outcomes were assessed using Flynn's criteria (**Figure 5**). Thirteen patients (72%) had excellent outcomes, four (22%) had good outcomes, and one patient (6%) had a satisfactory result. No patient had a poor outcome. These results indicate that the majority of patients achieved favorable functional and radiological outcomes with minimal complications following TENS fixation.

Discussion

This prospective study evaluated the clinical and radiological outcomes of paediatric subtrochanteric femoral fractures treated with the Titanium Elastic Nailing System (TENS) in children aged 5 to 11 years. Our findings suggest that TENS is a safe, minimally invasive, and effective modality for managing this challenging fracture type, with 100% union rate, low complication profile, and excellent-to-good outcomes in 94% of cases based on Flynn's criteria.

The mean time to radiological union in our series was 9.5 weeks, which aligns closely with prior studies on TENS in femoral shaft fractures [11, 18]. Flynn et al and Narayanan et al reported union times of approximately 8-10 weeks in diaphyseal femur fractures treated with TENS [1, 2]. Although the majority of their cases involved midshaft fractures, our findings demonstrate that similar healing timelines can be achieved even in the biomechanically demanding subtrochanteric region, provided the fracture is well stabilized. One of the key challenges with subtrochanteric fractures is the high deforming force exerted by surrounding muscles, which predisposes to malalignment and delayed healing if not appropriately managed [7, 10]. In our study, malalignment was observed in only one patient, and

Table 1. TENS treatment for pediatric subtrochanteric femoral fractures (Age 5-11)

Pt. No.	Age	Sex	Side	Fracture Type	Time to Surgery (days)	Associated Injuries	Prior Treatment	Post-op Immobilisation	Time to WB (weeks)	Time to Union (weeks)	Time to Nail Removal (months)	Complications	Flynn's Outcome
1	6	M	Left	Transverse	2	None	Skin traction	None	4	8	9	None	Excellent
2	7	F	Right	Oblique	1	Head injury (mild)	Slab	Hip spica (2 weeks)	5	9	10	LLD 1 cm	Good
3	8	M	Left	Spiral	3	None	None	Above-knee slab (1 week)	4	10	8	None	Excellent
4	9	F	Right	Transverse	2	Ipsilateral radius fx	POP cast	None	3	7	9	Nail prominence	Good
5	10	M	Left	Oblique	1	None	Skin traction	None	4	9	10	None	Excellent
6	5	M	Right	Spiral	2	None	None	Above-knee slab (2 weeks)	6	11	9	None	Excellent
7	11	F	Left	Comminuted	4	Pelvic contusion	Skin traction	Hip spica (3 weeks)	6	12	12	Malalignment	Satisfactory
8	6	M	Right	Transverse	2	None	None	None	4	8	9	None	Excellent
9	7	F	Left	Oblique	1	Soft tissue injury	Slab	None	3	9	9	Superficial infxn	Good
10	8	M	Right	Spiral	3	None	None	Above-knee slab (1 week)	5	10	11	None	Excellent
11	9	F	Left	Comminuted	2	None	Skin traction	Hip spica (2 weeks)	6	11	10	Nail back-out	Good
12	10	M	Right	Oblique	1	None	None	None	3	8	8	None	Excellent
13	5	M	Left	Transverse	2	None	POP cast	Above-knee slab (1 week)	4	9	9	None	Excellent
14	6	F	Right	Spiral	2	None	None	None	5	10	10	Nail irritation	Good
15	11	M	Left	Comminuted	3	Femur shaft fracture	Skin traction	Hip spica (3 weeks)	6	12	12	Delayed union	Satisfactory
16	7	F	Right	Oblique	1	None	None	Above-knee slab (2 weeks)	4	8	8	None	Excellent
17	8	M	Left	Spiral	2	None	None	None	4	9	9	None	Excellent
18	9	F	Right	Transverse	2	None	Skin traction	Above-knee slab (1 week)	5	10	10	None	Excellent

Figure 4. TENS was removed at 10 months after surgery following complete fracture union.

delayed union in one, both of which were managed conservatively. These findings are comparable to those of Ho et al and El Sayed et al, who also observed that TENS can achieve satisfactory reduction and alignment in most subtrochanteric cases, with low rates of malunion when proper technique is used [6, 7]. The complication rate in our study was 27.7%, but most were minor and self-limiting (nail prominence, mild limb length discrepancy, superficial infection). No cases of implant failure, deep infection, or non-union were reported. These results are consistent with the complication profiles reported in prior literature. Wall et al and Narayanan et al noted similar minor complications with TENS, reinforcing its relative safety in the paediatric population [2, 24].

An area of variability in TENS use for subtrochanteric fractures is the need for postoperative immobilisation. In our study, 11 patients (61%) received either hip spica or an above-knee slab based on fracture stability. Although some studies advocate routine immobilisation for subtrochanteric fractures treated with TENS, our results support selective use of immobilisation, as union was achieved in all cases regardless of whether a splint or cast was used. This is in agreement with findings by Shilt and Spiegel et al, who suggested that TENS provides sufficient stability in most cases, and that adjunctive immobilisation may only be necessary in comminuted or unstable patterns [4, 8]. In terms of functional outcomes, 94% of our patients achieved excellent or good results as per Flynn's criteria, with only one patient falling into the satisfactory category due to minor malalignment. These findings are in line with those of Ligier et al and Suggu et al, who reported high satisfaction rates and early return to activity following TENS in paediatric femoral fractures [3, 9]. However, it is important to recognize that TENS is not suitable for all subtrochanteric fractures, particularly those with extensive comminution or poor cortical contact, where rotational control is compromised. In such cases, plating or submuscular bridge plating may be more appropriate, as highlighted in meta-analyses by Li et al and others [5, 6, 19]. Nonetheless, for simple to moderately unstable fractures in the 5-11 year age group, TENS remains a valid and often preferable option due to its minimally invasive nature and favourable biological environment for healing [20, 21]. This study has certain limitations. First, the sample size is relatively small (n=18), which limits statistical power and generalizability. Second, the lack of a control group treated with alternative methods (e.g., plating or conservative management) restricts direct comparison of outcomes. Third, long-term follow-up into skeletal maturity was not performed, so potential late complications such as growth disturbances or femoral overgrowth could not be assessed.

Conclusion

Our study supports the growing body of evidence that TENS is a reliable and effective treatment option for paediatric subtrochanteric femoral fractures in properly selected cases. Its advantages include early mobilisation, high union rates, low complication profile, and good functional recovery. Larger comparative studies with long-term follow-up are needed to further validate these findings and refine treatment algorithms.

Disclosure of conflict of interest

None.

Abbreviations

TENS, Titanium elastic nailing system; ROM, Range of motion; WB, Weight bearing.

Figure 5. Clinical picture showing functional outcome at 6 months of follow-up (A-C).

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