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Outcome of titanium elastic nailing in pediatric subtrochanteric femur fractures: A case series

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Abstract
Introduction: Subtrochanteric femur fractures are difficult injuries to treat in children. Although elastic stable intramedullary nails are commonly used for pediatric femur shaft fractures, there is little information on their effectiveness for managing pediatric subtrochanteric femur fractures. We are not aware of any published study that defines outcome of titanium elastic nail in treatment of pediatric subtrochanteric femur fractures. We, in this study, evaluated radiographic union rates, fracture alignment, and complications after titanium elastic nailing of pediatric subtrochanteric femur fractures.
Materials and Methods: A total of 10 cases of pediatric subtrochanteric femur fractures were admitted in our department between November 2016 and April 2018. This prospective study included 8 males and 2 females, with a mean age of 7.9 years (5-11 years). All patients were treated with elastic stable intramedullary nails and had complete follow up until clinical and radiographic union.
Results: All patients had clinical healing with full weight-bearing and the functional outcome scores were satisfactory. No cases of infection were reported at the time of the last follow-up visit. Complications included malunion (n = 1), irritation (n = 1) at nail insertion site, and limb length discrepancy (n = 1). Despite these complications, there were 7 (70%) excellent, 3 (30%) satisfactory, and none with poor outcomes.
Conclusions: Titanium elastic nailing is an important option for treating subtrochanteric femur fractures in children with low complication rates.

Keywords: Children, subtrochanteric fractures, pediatric, titanium elastic nail, TEN

Introduction
Elastic stable intramedullary nailing is mostly used for the treatment of pediatric femoral shaft fractures. The ideal patient for flexible intramedullary nailing is the child between the ages of 5 and 11 years old with a length-stable femur fracture, in the mid-80% of the diaphysis who has a bodyweight less than 50 kg [1-7] Unstable fracture patterns can also be treated with flexible nailing, but the risk of shortening and angular malunion is greater [1, 2, 6-8].
Subtrochanteric femur fractures are uncommon injuries in children, representing only 4% to 10% of pediatric femur fractures [16, 17] Strong deforming muscle forces in this region deforms the proximal fragment into a flexed, abducted, and externally rotated position causing difficulty in maintaining fracture reduction. Varied fracture patterns, such as long oblique and spiral fractures that are unstable make treatment selection more important in obtaining a successful outcome. These fractures are difficult subset of fractures with loss of reduction and nonunion as significant complications [23].
A pitfall in this fracture is thinking the proximal fragment is too short to use flexible IM nails on the AP radiograph because the proximal fragment is pulled into flexion by the unopposed psoas muscle. Pombo and Shilt reported a series of 13 children, averaging of 8 years old with subtrochanteric fractures, treated with flexible nailing. Results were excellent or satisfactory in all cases. Submuscular plating and open plating are other options for the management of these fractures where infection, blood loss, long operative period, post-operative pain, longer hospital stay, and large scar marks are significant drawbacks [18].
Achievement of provisional reduction by manipulation under fluoroscopy and with proper implant technique these fractures can be effectively treated with flexible Titanium Elastic Nailing (TEN).

There is limited literature available in the management of pediatric subtrochanteric femur fractures with Titanium Elastic Nailing (TEN). The purpose of this study is to evaluate the demography of pediatric subtrochanteric fractures, clinical assessment of entry point, post-operative protocol, radiological union functional outcome and complications of this technique and comparison with other available literature regarding various fixation methods in management of pediatric Subtrochanteric femur fractures in children between 5 to 11 years of age.

Materials and Methods

This is a prospective Hospital based study conducted in the Department of Orthopaedics, Assam Medical College & Hospital for a period of two years (2016-2018) after clearance from the Institutional Ethics Committee (Human).

The fractures within 10% of the total femur length below the lesser trochanter were defined as a subtrochanteric fracture [18] The total length of femur is determined by x-ray of the normal side, which is defined as the distance between top of the femoral head to the medial knee joint line and then distance from lesser trochanter to the fracture line is calculated on pre-operative x-ray. If the distance is less than 10% of total length of femur then these cases are included in the study [23].

Inclusion criteria included Post-traumatic subtrochanteric fractures in age group of 5 to 11 years, less than 50 kg of body weight. Exclusion criteria included Pathological fractures, open fractures, associated injuries in the same limb or any other systemic condition which is contraindication for operative intervention. Length stable fractures are transverse and oblique fractures while comminuted fractures or fractures where length of obliquity is twice the diameter of femur are considered length unstable [7].

Demographic information, mechanism of injury, fracture type, associated injuries, Intra-operative problems, postoperative immobilization, time to radiographic union, time of assisted and unassisted weight-bearing, time of nail removal, complications and total duration of follow-up were recorded in the selected patients after informed consent from the parents.

Two retrograde TEN were used in all cases. All of the surgeries were performed on a radiolucent table. Using preoperative radiographs, the smallest diameter of the femoral canal was measured. The equation described by Beaty and Kasser [24] was used to select the appropriately sized nails. One millimeter was subtracted from the smallest femoral canal diameter measured on anterior-posterior and lateral radiographs, and the result was divided by 2. This measurement correlated with the size of the nails used.

Patients were placed supine on the operating table. Closed reduction of the fracture was done under fluoroscopy. An incision was made on the lateral aspect of the distal thigh at the level of proposed nail insertion 2.5 to 3 cm proximal to the distal femoral physis. The subcutaneous tissues were dissected in line with the skin incision, exposing the lateral aspect of the distal femoral metaphysis.

An awl was used to initiate a start hole manually. Distal end of the nail was slightly bent to facilitate the passage of the nail beyond the far cortex and to facilitate fracture reduction. The appropriately sized nail was placed in the starting hole, and the intramedullary position was verified using fluoroscopy. The lateral nail was advanced across the fracture site and placed just distal to the greater trochanteric apophysis.

Next, a medial incision was made, and an equal-sized nail was inserted at same or just proximal level of the lateral nail. The medial nail was advanced into the femoral neck, directed toward the femoral head just short of the proximal femoral physis. To minimize soft-tissue irritation, both nails were trimmed, allowing nearly 1 cm to protrude from the distal starting hole. The stability of the fracture was checked intraoperatively under direct fluoroscopic guidance, Patients were advised against weight-bearing activities until clinical and radiographic healing was confirmed. Radiographic union was defined as bridging callus over at least 3 out of 4 cortices on AP and lateral radiographs [6].

We used Flynn's Titanium Elastic Nails Outcome Scoring system [1] to classify the outcomes of fractures and classified results as excellent, satisfactory, or poor based on residual leg-length inequality, fracture malalignment, pain, complications. A patient's overall outcome was determined by the category with the worst result.

Table 1: Flynn's Titanium Elastic Nails Outcome Scoring system

	Excellent	Satisfactory	Poor
Malalignment (deg.)	<5	6-10	>10
Leg-length inequality (cm)	<1	1-2	>2
Pain	None	None	Present
Complications	None	Minor/ Resolved	Major complication/ Lasting morbidity

Fracture malalignment was determined based on the radiographs obtained at the final follow-up. Malalignment was measured in the coronal and sagittal planes on AP and lateral x-rays respectively, and the greatest malalignment was recorded. Leg-length inequality was determined based on the clinical exam as compared to the contralateral limb. The presence or absence of pain was recorded based on the final follow-up visit depending on the patient's complaint. Any complication that led to revision surgery was considered a major complication. Complications that resolved with nonoperative management or did not require any treatment were considered minor.

Results

A total of 10 patients (8 boys and 2 girls) met the inclusion criteria for the present study admitted in our department from November 2016 to April 2018. The average age of the patients in this study was 7.9 years and the average weight was 25 kg (range, 18 to 40 kg). There were 7 length stable fractures and 3 length unstable fractures. The average length of hospitalization was 14 days. Patients were advanced to full weight-bearing at an average of 6 weeks. The average time to radiographic union was 10 weeks. The implants were not removed in our study. The average length of follow-up was 6 months.

Table 2: Demographic data

Age	7.9 years
Male	8
Female	2
Weight	25kg
Length stable fractures	7
Length unstable fracture	3

Results were evaluated using Flynn titanium elastic nail scoring system. Excellent results were demonstrated in 70%, satisfactory results in 30% and none of the patients showed poor results. Major complications were seen in 2 (20%) patients and minor complications in 3 (30%) patients (Table

3). Fracture malalignment was seen in 1 patient at the time of radiographic union. Leg length inequality was seen in 1 patient. Superficial infection at insertion point in 2 patients and irritation at the insertion site in 1 patient were other complications.

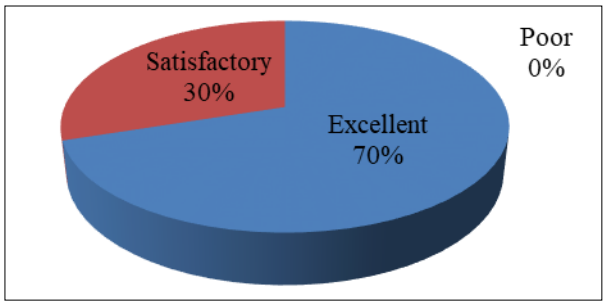

Fig 1: Functional outcome

Table 3: Complications

Superficial infection	2
Deep infection	0
Skin irritation	2
Insertion site persistent pain	1
Malunion	1
Limb length discrepancy	1
Knee stiffness	0
Nerve injury	0

No patient treated with titanium elastic nail required surgery for major complications.

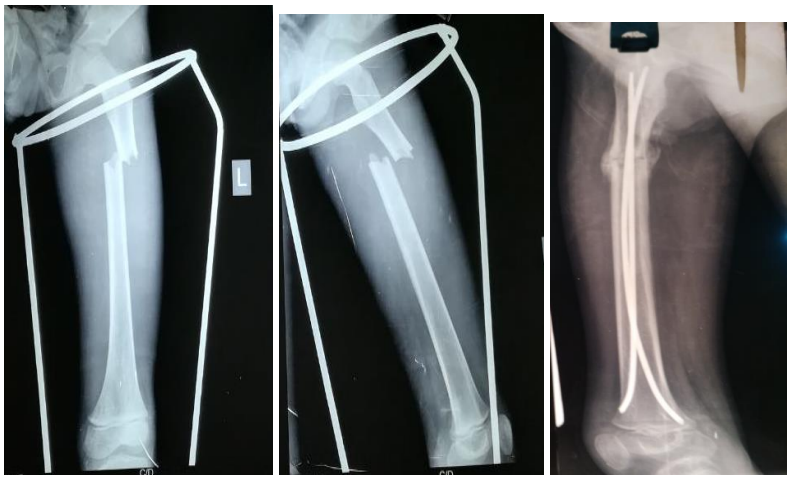

Fig 2: A length stable fracture showing radiological union at 6 weeks

Fig 3: A length unstable fracture showing radiological union at 10 weeks of follow up

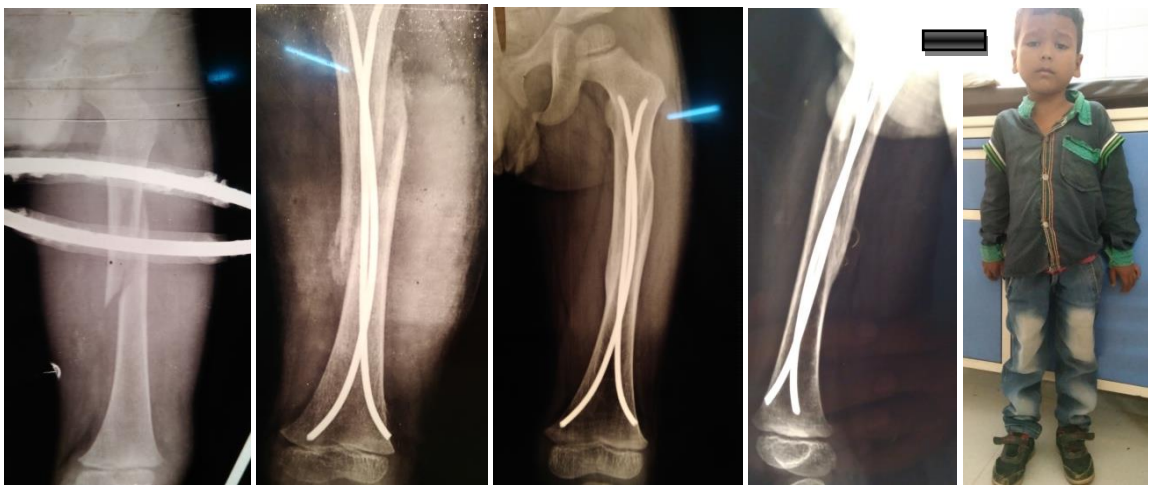

Fig 4: varus malunion with satisfactory functional outcome in a length unstable fracture

Discussion

Most of the literature on femoral shaft fractures treated with titanium elastic nails is on mid-shaft fractures. There is no consensus in the literature on the definition of a pediatric subtrochanteric femur fracture. [17, 18, 21] Pombo and Shilt recently defined a pediatric subtrochanteric femur fracture as a fracture that is located within 10% of the total femur length below the lesser trochanter.

There are few previous reports in the literature on the treatment of pediatric subtrochanteric femur fractures with modern instrumentation. Jarvis and colleagues retrospectively reviewed 13 skeletally immature adolescents who had undergone treatment of a subtrochanteric femur fracture with a variety of different techniques. The 3 patients who were managed non-operatively had unsatisfactory radiologic outcomes, including fracture mal-alignment up to 16 degrees and shortening of the affected limb by an average of 2.6 cm. Despite the very small sample size, the authors concluded that internal fixation was more effective than non-operative treatment. [22] With the wide range of fixation options that are currently available for treatment of femur fractures in school-age children and skeletally immature adolescents and the low risk of associated complications, we recommend against non-operative management of subtrochanteric femur fractures in this age group.

Pombo and Shilt examined 13 pediatric patients with subtrochanteric femur fractures treated with titanium elastic nails. Two patients had a residual leg-length inequality, where the affected limb was longer by 1.3 and 1.6 cm, respectively. The leg-length inequality was thought to be secondary to physiological overgrowth. There were no other complications and no poor results. The authors recommended advancing the lateral nail into or just distal to the greater trochanter apophysis and advancing the medial nail into the femoral neck just short of the proximal femoral physis. This slight modification in the technique may decrease the forces at the fracture site, and help control rotation and angulation. (18) We used this technique in our series, still 1 patient developed fracture shortening and increased angulation.

Although titanium elastic nails are currently the most popular treatment option for femoral shaft fractures in children and young adolescents, several studies have demonstrated suboptimal results with fractures in the proximal third of the femur [1, 3] and length-unstable fracture patterns.(1, 3, 6, 8) Frequently described complications include fracture shortening and angulation that lead to painful, prominent, or exposed nails, malunion, and leg-length discrepancy. [1, 3, 6-8] Ho *et al* [3] reported a 22% complication rate with proximal third femur fractures managed with titanium elastic nails. Our study has similar rate of complication 20% when compared to Ho *et al*. In Flynn *et al* [1] series, the only patient with a poor Titanium Elastic Nails Outcome Score was an 11-year-old child with a proximal, oblique comminuted fracture that healed with 15 mm of shortening and 20 degrees of varus angulation. Both Narayanan *et al* [6] and Sink *et al* [7] reported a higher complication rate and risk of unplanned surgery with length-unstable femur fractures treated with titanium elastic nails. Proximal third femur fractures or length unstable fractures treated with titanium elastic nails may benefit from additional postoperative immobilization [1, 4, 6] although Sink *et al* [7] did not find that routine use of a single-leg spica cast decreased the complication rate.

Numerous studies have demonstrated good results with alternative methods of fixation for proximal third femur fractures and length-unstable femoral shaft fractures in children. [6-8, 10-15] Rathjen *et al* [10] reported similar results when length-stable and length-unstable pediatric femoral shaft fractures were treated with stainless steel flexible intramedullary nails. Distal locking of the stainless steel nails may prevent fracture shortening and reduce complications in length-unstable fractures. [9] In our study no fracture was treated with stainless steel elastic nails. Caird and colleagues demonstrated a 10% complication rate in 60 pediatric patients with femoral shaft fractures treated with compression plating. Twenty-five percent of the fractures were in the proximal third of the femur. [12] Kanlic and colleagues found a 4% complication rate in 51 pediatric femoral shaft fractures treated with submuscular plating. Twenty-four percent of the fractures were in the subtrochanteric region and 55% of the fractures were unstable. [14] Sink *et al*. [15] reported excellent results in 27 children with length-unstable femur fractures treated with submuscular plating. Sink *et al* also showed a significant decrease in overall and major complications when unstable fractures were treated with submuscular plating compared with titanium elastic nails. Similarly, we found that the complication rate was higher for length-unstable subtrochanteric femur fractures treated with titanium elastic nails when compared to length stable patterns.

One limitation of this study is a small sample size and short period of follow up. Another limitation is that the subtrochanteric fractures treated with other methods were not compared with titanium elastic nail.

Conclusion

Our results indicate that titanium elastic nail fixation of pediatric subtrochanteric femur fractures is associated with excellent outcome scores and a lower overall complication rate with length stable fracture patterns. Length unstable fractures have higher complication rate when treated with titanium elastic nails. Length unstable fracture fixation with submuscular or open plating needs to be compared with titanium elastic nails in a randomized study to get a conclusive treatment results for these difficult fractures.

The authors have no conflict of interest.

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