

**RESEARCH ARTICLE**

# Elastic Stable Intramedullary Nailing of Femoral Shaft Fracture-Experience in 48 Children

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## Abstract

**Background:** Femoral shaft fractures are an incapacitating pediatric injury accounting for 1.6% of all pediatric bony injuries. Management of these fractures is largely directed by age, fracture pattern, associated injuries, built of the child and socioeconomic status of the family. We retrospectively evaluated the use of elastic stable intramedullary nail (ESIN) in surgical management of femoral shaft fractures in children and its complications.

**Methods:** Fifty two children were treated with titanium elastic nails (TEN) from June 2009 to June 2014 at our institution. At the end of the study there were 48 children. Fractures were classified according to Winquest and Hansen's as Grade I (n=32), Grade II (n=10), Grade III (n=6) and compound fractures by Gustilo and Anderson's classification, Grade I (n=5), Grade II (n=3). There were 36 mid-shaft fractures, 7 proximal third shaft fractures, 5 distal third shaft fractures. The final results were clinically evaluated by using Flynn's criteria and radiologically by Anthony et al's criteria.

**Results:** The mean duration of follow-up was 20 months (range 12 – 40 months). All fractures healed radiologically with grade III callus formation at 9 – 12 weeks (mean 9.7 weeks). The results were analyzed using Flynn's criteria and were excellent in 40 children (83%) and satisfactory in 8 children (17%). The soft tissue discomfort near the knee produced by nail ends was the most common problem in our study (25%). Other complications include limb shortening (n=5), Varus malunion (n=4), Nail protruding site infection (n=4) and nail migration (n=2). There was no delayed union, non-union or refractures.

**Conclusion:** TEN is minimally invasive, safe, relatively easy to use and an effective treatment for fracture shaft of femur in properly selected children.

**Level of evidence:** III

**Keywords:** Bone nailing, Femur, Intramedullary fracture fixation, Malunited fracture

## Introduction

Femoral shaft fractures are the most common pediatric injuries treated by orthopedic surgeons resulting in high direct and indirect medical costs (1). The incidence of femoral fractures is 20 – 25 per lakh children per year (2). The treatment of such fractures range from closed reduction with hip Spica, Bryant's traction and surgical stabilization with devices like plate

and screws, nails, ESIN and external fixators (1). Each method has its own set of advantages and disadvantages.

Most pediatric fractures are treated conservatively, as nonsurgical management has been the standard care of treatment for most young children historically, because of rapid healing and spontaneous correction of angulation. The results were usually satisfactory in the long term

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(1). The cost of care is low and the outcome is generally good. In older children, conservative treatment results in loss of reduction, malunion, psychological intolerance to both the child as well as the family and complications associated with plaster, hence, in the last two decades there has been a growing tendency towards a more operative approach in children over six years of age.

Ideally in children between 6-16 years, the fracture needs an internal splint that shares load, maintains reduction and does not endanger the growth areas or blood supply of the femoral head and minimizes morbidity as well as complications<sup>3</sup>.

Plating offers rigid fixation and it needs a larger exposure with increased blood loss, resurgery for implant removal and scarring. It is a load bearing device and refracture is a risk (4). Antegrade nailing is used in children near skeletal maturity (5). External fixators are mainly used in open fractures (6).

ESIN was introduced for femoral fractures by Nancy group in 1979 (3). Titanium implants are increasingly used for ESIN as titanium has an excellent biocompatibility and its elasticity limits the amount that the nail is permanently deformed during insertion and also promotes callus formation by limiting stress shielding. TEN acts as an internal splint, maintains length and alignment that allows rapid mobilization while permitting enough fracture site motion for callus formation and potentially has low risk of osteonecrosis, physical injury and refracture (7). Due to its favorable results and lack of serious complications it remains the ideal treatment of choice for stabilization of pediatric femoral fractures. We did a retrospective analysis of our results using TEN in femoral shaft fractures at our institute.

### Materials and Methods

On a retrospective search of hospital records, we found 52 children between the age group of 6-16 years were treated at our institution from June 2009 to June 2014 among which 48 were available for follow-up. Data collected included details of the patient (age, gender), description of the fracture (type, location, pattern), surgery (open/closed), presence of fracture angulation or rotational malalignment, details of fracture union with initial X-ray to final follow-up X-ray and rehabilitation milestones (non-weight bearing, partial and full weight bearing, return to school) along with presence of any complications. There were 30 boys and 18 girls in our study with an average age of 9.5 years (range 6 - 16) at the time of injury.

The most common mechanism of injury was road traffic accident (n=34, 70%) followed by fall from height (n=14, 30%). 36 fractures were in the middle third followed by, seven proximal one-third and five distal-third fractures in which 28 right sided fractures (58%) and 20 left sided fractures (42%) were noted. Fracture patterns according to AO classification included 32 - A3 (n=24), 32 - A2 (n=12), 32 - A1 (n=6) and 32 - B3 (n=6) types. Fractures were classified according to Winquest and Hansen's classification as Grade I (n=32), Grade II (n=10) and Grade III (n=6). Associated injuries were present in 7 patients, 3 had minor head injury and 4 had associated upper limb

fractures, two had fracture both bone forearm right side, one had type I epiphyseal injury distal radius right side and last one had type I monteggia fracture left side. We had five grade I open fractures and three grade II open fracture. All cases after complete pre-op evaluation were taken up for surgery within 10 days (mean 3.6 days). We had inclusion and exclusion criteria for our study.

### Inclusion criteria

Children between 6-16 years with closed fractures and grade I and II open fractures.

### Exclusion criteria

Children <6 and >16 years, grade III open fractures, pathological fractures, metabolic bone disease, non-ambulatory children, children with neuromuscular disorders, segmental and severely comminuted fractures grade IV.

### Technique

Under regional anesthesia after prophylactic antibiotic, the child was placed supine on fracture table with adduction of the affected limb by 100. Closed reduction was performed by manual traction and gentle rotation along with use of F-tool (a radiolucent device), the arms of the F-tool were re-adjusted depending upon the fracture configuration and bulk of thigh, alignment was confirmed in both planes by an image intensifier and was used to make an entry for the placement of skin incision and dividing the fascia-lata in most cases. We used antegrade entry only in cases where the fracture was in distal third or the cortex distally found comminuted to hold the distal nail entry site. No nail caps were implemented during the surgery.

We used 2 nails of same diameter, which was calculated by pre-operative radiograph by:

1. Flynn et al's formula, diameter of nail=width of narrowest point of the medullary canal on AP and LATERAL view X 0.4 mm (8).

2. Kasser and Beatty formula, nail size=internal diameter/2-0.5 mm (9).

Nails come in five diameters from 2.5mm to 4.5mm in fixed length. The nails are color coded for identification. The drill was inclined at an angle of 10 degree, the nail tip was also bent to facilitate placement and to allow the nail to bounce of the opposite cortex at the time of insertion.

Two nails were introduced up to the fracture site and both nails should pass the fracture site nearly simultaneous to prevent angulation at the fracture site. In ten cases we did minimal open reduction. The nails were put in double 'C' construct to ensure three point fixation and for proper rotational stability nails were further advanced into the proximal fragment to diverge laterally towards the greater trochanter and medially within the femoral neck so that early mobilization was possible (7). Care was taken to see the nails did not cross the growth plate proximally and distally. The nail was cut at the entry site so that 1 cm of nail protrudes outside of the cortex. Too much bending was avoided to prevent impingement and bursa problems. There was cock screwing of nails in two cases (4%), we revised it intraoperatively.

**Table 1. Flynn's Criteria**

Variables	Excellent result (n= 40, 83%)	Satisfactory result (n= 8, 17%)	Poor result (n= 0, 0%)
Length discrepancy	<1 cm	<2cm	>2cm
Mal-alignment	5 degrees	5 to 10 degrees	>10 degrees
Pain	No	No	Yes
Complications	None	Minor and solved	Major and/or residual morbidity

**Table 2. Anthony Radiological Criteria**

<b>Grade 0</b>	No identifiable fracture healing
<b>Grade 1 ( Average callus formation at 3.6 weeks)</b>	Primary bone healing with little or no periosteal new bone formation
<b>Grade 2</b>	Periosteal new bone formation on two sides of the femur
<b>Grade 3 (n= 48, Average callus formation at 9.7 weeks)</b>	Periosteal new bone formation on three or four sides of the femur.

Post operatively IV antibiotics continued for three days. Suture removal was done at tenth day. No postoperative external immobilization was used and gradual mobilization was started. The children were followed up at 1,2,3,6 month's interval until fracture union. At each visit, progression of union at fracture site was assessed radiologically, tenderness at the fracture site was determined by clinical examination along with limb alignment, rotation, length discrepancy, range of motion of hip and knee and any other complications. Full weight bearing was started when radiograph revealed soft callus at the fracture site. The children were evaluated clinically by Flynn's criteria [Table 1] and radiologically by Anthony et al criteria [Table 2] at the end of six months and at the end of one year (8, 10).

### Results

The median duration of surgery was 65 minutes (range 40-90 minutes). The mean hospital stay was 7.3 days (5 - 15 days), the hospital stay was longer in children with head injury and associated other injuries, there was no post-operative infection in our study even in open fractures. The mean age was 9 years (range 6 -16 years) and median body weight was 27.5kg (range 14 – 65) as well as average BMI was 27.2 (range 24.4 to 31.0). Minimum nail size used was 2.5mm while maximum

nail size used was 4mm according to Flynn's and Beaty's formula.

Out of 48 children available for evaluation, within a mean follow-up of 20 months (range 12 – 40 months) callus was first noted on follow-up radiograph at mean of 3.6 weeks (range 3.2-6.4 weeks). All fractures in our study united with grade III callus in average of 9.7 weeks (9-12 weeks) and full weight bearing was started at the same time and was initiated to attend school as well [Table 3]. Functional range of movement of knee was achieved in an average of 8.6 weeks (6 – 14 weeks). Clinical evaluation revealed full range of motion of hip, knee and ankle in all patients at final follow-up.

Radiological evaluation was done by Anthony et al criteria. All children had grade III callus at the end of 12 weeks. Two children with head injury had large sized and very early callus formation which decreased with passage of time and the final result was excellent. There was no nonunion or delayed union in our study. Clinical evaluation was done using Flynn's criteria. The results were excellent in 40 children (83%) [Case 1- Figures 1-4] and satisfactory in eight children (17%) [Case 2-Figures 5-10]. No child had poor result.

The most common problem encountered in our present study was skin irritation and impingement due to the distal nail ends in 12 cases (25%) [Table 4]. We

**Table 3. Fracture specifications and follow-up findings**

Type of Fracture (Winquest and Hansen's classification)	Number of cases (n=)	Average follow-up period ( in months)	Clinical results by Flynn's criteria (in %)	Mean radiological union (in weeks)
I	32	24	56	9.2
II	10	18	33	9.3
III	6	18	11	10.6
IV	-	-	-	-
Total/Average	48	20	100	9.7

**CASE 1:**

**Figure 1: Pre operative x-ray showing middle third shaft of femur fracture**



**Figure 3. Three Months Old Post-Operative X-Ray Showing Grade 3 Callus Formation.**

had asymptomatic nail migration in two cases (4%) [Case 3- Figures 11-14]. All these problems settled upon nail removal. Out of 48 cases, 5 cases (10%) had limb length shortening, out of which, four children had shortening of less than 5 mm which was insignificant. In one child, with comminuted fracture, who weighed 65 kg at age 14 had shortening of 15 mm. Angular mal



**Figure 2. Immediate post op X-ray.**



**Figure 4. Post op clinical picture showing excellent results according to Flynn's criteria.**

alignment was defined as an angulation of  $> 100$  in the coronal plane or  $> 150$  in sagittal plane (11). In our study we had Varus malunion of  $> 5$  degree in coronal plane in four children (8%). Rotational malalignment was termed as "excessive" if it was more than 10 degree (12). We did not have any children with rotational malalignment. Four children (8%) had nail protruding site infection which settled with regular dressing and oral antibiotics.

Nails were routinely removed (Not mandatory) at the end of one year after good fracture union. In two cases we had had asymptomatic proximal migration of the nail which penetrated the proximal cortex. So we removed the nail from the other side. No complications

CASE 2:



Figure 5. Right sided long oblique fracture in AP view.



Figure 6. In Lateral view.



Figure 7. Immediate post op x-ray.



Figure 8. Six months follow-up x-ray with fracture united well.



Figure 9. Patient had a varus angulation of 5°.



Figure 10. Satisfactory results achieved as per Flynn's criteria.

Table 4. complications

Intra-operative	Postoperative	Leg-length discrepancy
Difficulty/loss of reduction(10) Rods exchanged/improper size selection (2) Penetration of proximal cortex(0) Cock screw phenomenon(2) Blood loss (0)	Nonunion/delayed union(0) Re-fracture(0) Nail tip irritation(12) Malalignment(4) Asymptomatic nail migration(2) Pin site infection(4)	Shortening (5) <1 cm(4) <2 cm(1) >2cm(0) Lengthening (0)
Total-14	Total -22	Total -5

## CASE 3:



Figure 11. Proximal third shaft of femur fracture.



Figure 12. Two months post op X-ray with grade II callus formation with minimal varus angulation.



Figure 13. Three months old post-op X-ray with grade III callus formation.



Figure 14. Patient had a proximal migration removed through proximal entry.

were associated with the nail removal procedure and no refractures was observed after nail removal till date.

### Discussion

The ideal choice in treatment of femoral shaft fractures has remained a constant challenge to the orthopedics fraternity. Non-operative management results in complication such as malunion, joint stiffness and delay in functional recovery in older children and also results in prolonged hospitalization causing financial loss to the family as well as increased hospital bed occupancy ratio has led to the emergence of operative fixation for these kind of fractures (13, 14).

TEN is elastic stable intra-medullary nail which works on the principle of symmetric bracing action of

two nails with same modulus of elasticity which gives three point fixation, rotational, axial, transitional and bending stability by counteracting the distraction and compression forces working at the fracture site (15, 16).

In the present series, all fractures were united within 12 weeks of fixation with no non-union or delayed union. Children who had transverse fracture pattern had a shorter union time and was found to be heavier when compared to others. Male children had earlier union rate when compared to females. Oh et al observed that all 31 fractures in his series healed within 12 weeks without delayed union (17). Buechsenchuetz et al reported that in 42 patients treated with ESIN all fractures healed at a mean of 88 days from injury (18).

Hospitalization time has been considerably decreased

with TEN. In present series it was 7.3 days on average and return to school was initiated on 9.7 weeks on average causing less disturbance in the continuation of the studies in children. The partial and complete weight bearing in the series averaged 4.5 and 9.7 weeks respectively. In children with comminuted fracture, head injury and associated other injuries affected the mobility of the patients in turn delaying the weight bearing. Oh et al used ender nails and observed walking without assistive devices at an average of 9.7 weeks (17). Flynn et al and Mazda et al observed walking without assistive devices at an average of 8.5 and 9.5 weeks respectively in patients using TENs (1, 19).

The indication of TEN is expanding, as their advantages are realized and complications are very less compared to other methods of fixation. The main advantages are: they are readily available in different diameters and inexpensive.

Similar functional outcomes are noted in cases of both open and closed femoral shaft fractures as we included only children with intact periosteum in our series and TENS don't disturb the fracture hematoma when done as closed procedure, so chance of infection is very less. When applied in retrograde manner there is little chance of avascular necrosis of femoral head (20, 21).

Through thorough nail size evaluation using the formula implemented, our results were outlined to be excellent as compared to other studies. In Narayanan et al series, smaller and mis-matched nail diameter used in three cases was associated with increased incidence of varus or valgus angulation and mal-rotation.

Fracture geometry and the location is an important determinant for surgical outcome. In our study, TEN gave excellent results in transverse, short oblique fractures. Transverse, short oblique and minimally comminuted fractures are suitable for TEN as stated by Flynn et al and Narayanan et al (1, 22).

The chance of entry site irritation was the most common problem (25%) encountered in our study as compared to other studies. Ligier et al observed 13 cases of skin ulceration or local inflammatory reaction due to nail protrusion out of 123 cases (23). In our series, it could have been avoided with proper selection of insertion site and proper advancement of the nail to lie against the supracondylar flare. We had two cases of nail migration in the present series that probably was caused due to the poor technique. Two cases of proximal migration were observed by Karaoglu et al in the series of 31 femoral fractures stabilized with ender nails (24).

As we used two nails of same thickness after proper pre-bending we had Varus angulation in only four cases which would have been avoided with adequate bracing. This enlightens us that a cautious approach is always needed in treating unstable fracture patterns and fractures in obese children (25-27). So this mal-alignment can be overcome by additional plaster stabilization or by traction or a brief period of bed rest or use of femoral brace. Limb length discrepancy

was seen in five cases in which three had angulation at the fracture site. Few more years of follow up will be required before precise difference in lower limb extremities can be determined.

In our study, there was superficial infection at nail protruding site in four cases which would have been accounted due to the poor hygienic activities. We had per-operative technical difficulties in 10 cases where we had to open the fracture site due to failure of closed reduction due to soft tissue interposition. This might be due to improper traction or splint or due to delayed surgery by associated injuries. In two cases we had cork screw phenomenon which was deducted by image intensifier and replaced in correct manner.

We evaluated our clinical results using Flynn's criteria in our study. We had excellent results in 40 children (83%) and satisfactory results in 8 children (17%). we did not have any poor results. Our results were comparable to other studies which were done in similar manner viz, Flynn et al, Narayanan et al (1, 22). In our study nails were removed at end of one year as an outpatient procedure under anesthesia, without any complication during or after the procedure.

This study had certain limitations as it was single centered, so the results should be generalized with caution. We didn't compare other modalities of fixation with TEN. Long term results of the treatment were not analyzed.

TEN is minimally invasive, safe, physical protective, relatively easy to use and an effective treatment for fracture femur in properly selected children with minimal complications. Most of the complications are in fact due to improper technique which can be eliminated by strictly adhering to the basic principles and technical aspects. TENS used in children at 6 - 16 years of age for femoral shaft fractures hastens fracture union, reduced amount of shortening and mal-union as well as allows earlier rehabilitation along with return to school life with successive functional outcome. We recommend TEN for pediatric femoral shaft fractures in children.

RG and JJM wrote the paper. RG, RG, SK reviewed the literature. RG1 and SK were the main operating surgeons in the whole series and critically reviewed the paper. JJM and SI maintained all records of the patients and followed them. All authors read and approved the final manuscript.

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