International Journal of Orthopaedics Sciences

ISSN: 2395-1958
IJOS 2017; 3(4): 330-335

www.orthopaper.com
Received: 15-08-2017
Accepted: 18-09-2017

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Surgical management of fracture shaft femur in children and adolescents with titanium elastic nailing system

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DOI: https://doi.org/10.22271/ortho.2017.v3.i4e.45

Abstract
Introduction: Treatment of paediatric femoral shaft fractures with titanium elastic nails have gained widespread popularity because of its clinical effectiveness and low risk of complications.
Material and Methods: 30 cases of paediatric femoral shaft fractures of age group 5-16 years were treated with titanium elastic nailing at dr d y patil medical college, pimpri,pune. The outcome was assessed with Flynn's scoring criteria.
Results: Average time of union was 12.1 weeks (8-12 years).Final outcome according to Flynn's criteria was excellent in 27(90%) and satisfactory in 3(10%) cases.
Conclusion: Titanium elastic nails when treated in paediatric femoral shaft fractures gives elastic stability, are biocompatible, promote rapid union and early mobilization, thus less hospital stay.

Keywords: pediatric femoral shaft fractures, titanium elastic nail, intramedullary nailing

1. Introduction
In 1982, Metaizeau and team from Nancy revolutionized the technique of treatment of pediatric femoral shaft fractures with Elastic stable intramedullary nails (ESIN) using titanium nails [1, 2]. Femoral shaft fractures including supracondylar fractures constitute 1.6% bony injuries in children.[3]In younger children less than 4 years of age fall from height is common mode of injury when compared to children above 4 to 12 years where sports injury are a common modality [1].
Femoral shaft fractures are treated with spica casting, traction, external fixators, open reduction internal fixation with plating, Elastic Stable Intramedullary Nailing, and reamed intramedullary rods. In children femoral shaft fractures are primarily stabilized by traction for 3 weeks followed by plaster cast immobilization. Due to plaster cast treatment there will be prolonged bed rest and hamper in routine activities and increased hospital expenditure [4].
In preschool children treated with casting and traction for femur shaft fractures leads to significant complications in comparision to elastic nails like angular deformity and limb length discrepancy [5].
Early weight bearing can be initiated in children treated with reamed rigid intramedullary nails for femoral shaft fractures and there are less chances of rotational malunion and angular deformity. However, there is risk factor associated with avascular necrosis of femoral head when reamed rigid intramedullary nails are introduced through pyriformis fossa. Rigid nails in younger than 13 years have been associated with growth disturbance with femoral neck deformity, including coxa valga, and thinning of femoral neck. There is extensive soft tissue injury and stripping of fracture and skin scarring in femoral shaft fracture treated with compression plating, though they provide excellent stability and maintain length in unstable fractures [6].
Titanium elastic stable intramedullary nailing is clinically effective and has low risk of complications, as there is a closed insertion, fracture hematoma is preserved and physis is spared, hence a popular technique [4, 7, 8].

2. Material and Methods

Our study included 30 cases treated with titanium elastic nailing of which 27 patients were treated with closed reduction and 3 patients needed open reduction for pediatric femoral shaft fractures. The period of study was for 2 years from July 2015 to July 2017. Following are the inclusion and exclusion criteria of cases.

2.1 Inclusion Criteria

2.1.1 5-16 years age group
2.1.2 Simple fractures
2.1.3 Diaphyseal fractures

2.2 Exclusion Criteria

Age <5 years and > 16 years
2.1.4 Pathological fractures
2.1.5 Comminuted fractures
2.2.4 Metaphyseal fractures

2.3 Pre-operative assessment

All patients with pediatric femoral shaft fractures were primarily immobilized with Thomas splint. Pre-operative x rays were taken as follows- X ray full length femur AP view and Lateral view (Figure 1). Anesthesia fitness taken and patient posted for surgery.

Fig 1: Pre-operative x ray

2.4 Procedure

Two prebent flexible nails were inserted across the fracture in a retrograde fashion. Both nails were inserted about 2 cm proximal to distal femoral physis from medial and lateral sides. (Figure 2).

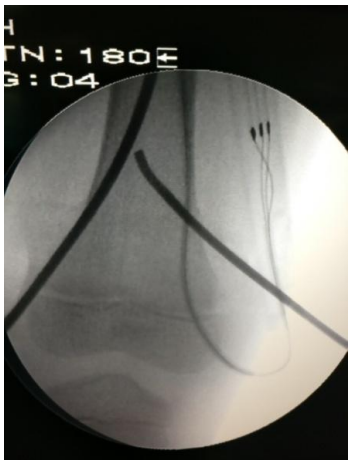

Fig 2: Entry point made with bone awl and prebent nail passed through

Lateral nail was directed till it was within 2 cm of proximal femoral capital physis whereas medial nail was inserted till it was about 1 cm from greater trochantric physis. The size of flexible nail should be approximately 40% of the diameter of the femoral canal at its most narrow point. Diameter of individual nail was selected as per Flynn *et al*' s formula(Diameter of nail= Width of the narrowest point of medullary canal on Antero posterior and Lateral view x 0.4mm).All titanium nails were bent at insertion site and cut close to bone leaving 1.5-2cm of nail protruding for later easy removal. Average operative time for this procedure was 1hour.Post-operative X ray femur full length taken in AP and Lateral view. (Figure 3)

Fig 3: Immediate post-operative x ray

2.5 Post-operative care

All patients were immobilized for 6 weeks in Thomas splint. Intravenous antibiotics and analgesics given. Static quadriceps and Static hamstrings exercises started from 2nd post-operative day. After 6 weeks Thomas splint was removed and active and passive hip, knee and ankle range of movements were started and non-weight bearing started with the help of walker. Serial radiographs taken at 6 weeks,12 weeks,24 weeks (Figure 4,Figure 5). Full weight bearing was allowed once radiographic and clinical union achieved. The functional outcome was assessed using Flynn's scoring criteria.

Fig 4: 6 weeks post operative x ray

Fig 5: Union x ray at 12 weeks

Table : Flynn's scoring criteria

	Excellent	Satisfactory	Poor
Limb length Discrepancy	<1.0 cm	<2.0 cm	>2.0 cm
Mal-alignment	5^0	10^0	$>10^0$
Pain	Absent	Absent	Present
Complication	Absent	Mild	Major complication and / or extended period for resolvable morbidity

3. Results

Our study included 30 cases treated with titanium elastic nailing of which 27 patients were treated with closed reduction and 3 patients needed open reduction for pediatric femoral shaft fractures. All cases were treated with two titanium elastic nail. Follow up of all cases done at regular interval of 6 th week, 12 week and 24 weeks. Clinical and Radiological evaluation was done on each follow up using TENS Outcome score by Flynn's criteria

3.1 Age Distribution

Table 1: Age Distribution

Age in years	No.of cases	Percentage
5 – 8	12	40
9 – 12	15	50
13 – 16	3	10

Majority of the patients i.e. 15 (50%) were in the age group of 9-12 years, followed by 12 (40%) patients in 5-8 years.
The youngest patient was 6 years and oldest patient was 15 years. The mean age in our study was 9.7 years.

3.2 Sex Distribution

Table 2: Sex Distribution

Sex	No. of cases	Percentage
Male	15	50
Female	15	50

There was a bimodal equal distribution of 50%

3.3 Mode of Injury

Table 3: Mode of Injury

Nature of trauma	No. of cases	Percentage
RTA	18	60
Fall from height	9	30
Fall while playing	3	10

RTA was the major cause of fracture in our study 18 (60%) patients and fall from height in 9 (30%) patients.

3.4 Side Affected

Table 4: Side affected

Side affected	No.of cases	Percentage
Left	15	50
Right	15	50

Right femur was involved in 15 (50%) patients and left femur in 15(50%) patients.

3.5 Pattern of Fracture

Table 5: Pattern of Fracture

Pattern of fracture	No.of cases	Percentage
Oblique	12	40
Transverse	12	40
Spiral	6	20

In the present series, 12 (40%) were oblique fractures, 12 (40%) were transverse and 6(20%) were spiral fractures.

3.6 Type of Fracture

Table 6: Type of Fracture

Type of fracture	No. of cases	Percentage
Closed	27	90
Open	3	10

27 (90%) were closed fractures and 3 (10%) was open fractures. Open fracture belonged to Gustilo & Anderson Type I.

3.7 Time interval between trauma and surgery

Table 7: Time interval between trauma and surgery

Reduction	No. of cases	Percentage
>24 hours	0	0
2-4 days	21	70
5-7 days	9	30
➢ 7 days	0	0

21 (70%) patients were operated between 2 to 4 days and 9 (30%) patients were operated between 5-7 days. The commonest time interval between trauma, and surgery was 2-4 days.

3.8 Type of Reduction

Table 8: Type of Reduction

Reduction	No. of cases	Percentage
Closed	27	90
Open	3	10

In 3 patients, fracture pattern was spiral and in proximal 1/3rd. Closed reduction was attempted, but was not possible. Open reduction was done and fracture was fixed with flexible nails.

3.9 Size of nail

Table 9: Size of nail

Size of nail	No. of cases	Percentage
2 mm	6	20
2.5 mm	9	30
3 mm	12	40
3.5 mm	3	10

Nail diameter is calculated by Flynn *et al*' formula.
In 6(20%) patients 2mm nails was chosen. In 9(30%) patients

were treated with 2.5mm nails.
12(40%) patients were treated with 3 mm nails. 3(10%) patients were treated with 3.5 mm nails.

3.10 Stay in Hospital

Table 10: Stay in Hospital

Hospital stay in days	No.of cases	Percentage
6 – 9	15	50
10 -12	9	30
>12	6	20

15(50%) patients stayed about 6-9 days.9(30%) patients stayed for 10-12 days.6(20%) patients stayed for more than 12 days in hospital.

3.11 Time for union

Table 11: Time for union.

Time for union	No. of cases	Percentage
8 weeks	3	10
10 weeks	6	20
12 weeks	21	70

In our series, time to union ranged from 8 to 12 weeks average being 12.1 weeks

3.12 Complications

Table 12: Complications

Complications	No. of cases	Percentage
Limb lengthening		
> 5mm	-	-
< 5mm	-	-
Limb shortening		
> 5mm	-	-
< 5mm	-	-
Infection	3	10
Delayed union and non-union	-	-
Nail impingement at entry point	3	10
Mal alignment		
a. Varus angulation	-	-
b. Valgus angulation	-	-
c. Anterior angulation	-	-
d. Posterior angulation	-	-
e. Rotational malalignment	-	-
Knee Stiffness	-	-

Superficial infection was seen in 3(10%) patients which were controlled by antibiotics.
Nail impingement was seen in 3(10%) patients treated with analgesics and early removal of nail.

3.13 Functional outcome

Table 13: According to Flynn score criteria

Clinical outcome	No of patients	Percentage
Excellent	27	90.00%
Satisfactory	3	10.00%
Poor	0	0%
Total	30	100%

According to Flynn's criteria, result was excellent in 27 (90%) cases and Satisfactory in 3 (10%) cases.

3.14 Statistical tests like Chi-square tests and t tests were applied and compared with variables and outcome as follows.

Time of fracture union

Table 14: Time of Fracture Union

Functional outcome	MEAN ± S.D	p VALUE
Excellent	9.33 ± 1.35	0.105
Satisfactory	8.00 ± 0.00	

t-test applied, p value 0.105,not significant.

4. Discussion

Accidents are the most common cause of fracture in children. Diaphyseal pediatric femoral shaft fractures constitute 70% amongst femoral fractures in children as stated by Blount. In the past 20 years different modalities of treatment has been tried by paediatric orthopedists to treat lower limb fractures to avoid prolonged immobilization and complications. Spica cast immobilization and casting resulted in limb length discrepancy, angulation, rotational deformity, psychological and economical complications [9, 10, 11]. Solid antegrade intramedullary nailing had resulted in avascular necrosis of the femoral head, trochantric epiphysiodesis and coxa valga [12, 13, 14].

TENS nailing limit the amount of permanent deformation, as they are elastic, biocompatible and promote healing by limiting stress shielding and no metal sensitivity reactions are observed [7, 9, 15, 16, 17, 18].
Literature suggests there is excellent union rates in TENS nailing of paediatric femoral shaft fractures [18].

4.1 Age distribution

In our study majority of the patients, i.e. 15 (50%) were in the age group of 9-12 years, followed by 12 (40%) patients in 5-8 years. The mean age in our study was 9.7 years.
J.N. Ligier *et al* [18] treated femoral shaft fractures in age ranging from 6 to 16 years with the mean age of 10.2 years.
Fabiano Prata Nascimento *et al* [19] treated femoral shaft fractures in age range 5 to 14 yrs with average age being 9.6 yrs.

4.2 Mode of Injury

In the present study RTA was the major cause of fracture in our study 18 (60%) patients and fall from height in 9 (30%) patients.
JM Flynn [7] *et al* in his multicentric study, the commonest mechanism of injury was RTA 58.1% followed by accidental fall 19.6% and fall from height 28.8%.

4.3 Pattern of Fracture

In the present study, 12 (40%) were oblique fractures, 12 (40%) were transverse and 6(20%) were spiral fractures.
Heinrich SD, *et al* [17], noted 35 (44.87%) transverse fractures and 14 (17.94%) oblique fractures in their study.
J.N. Ligier *et al* [18], out of 123 fractures studied 47(38%) were transverse fractures, communited fractures 25(20.3%), oblique fractures 7(23.3%), spiral fractures 19(15.4%), and 4 (3.2%) were segmental fractures.

4.4 Type of Fracture

In our study 27 (90%) were closed fractures and 3(10%) was open fractures. Open fracture belonged to Gustilo & Anderson Type I in our study.
Fabiano Prata Nascimento *et al* [19] reported 28(93.3%) closed and 2(6.7%) open fractures.

4.5 Time interval between trauma and surgery

In our study 21 (70%) patients were operated between 2 to 4 days and 9 (30%) patients were operated between 5-7 days. The commonest time interval between trauma, and surgery was 2-4 days.

In Cramer KE, *et al* [20] study 3 (15%) patients were operated within 24 hours. 23 (40.35%) patients were operated within 24 hours.

4.6 Type of Reduction

In 3 patients, fracture pattern was spiral. Closed reduction was attempted, but was not possible. Open reduction was done and fracture was fixed with titanium nails.

In Heinrich SD, *et al* [15] study 5 (6.41%) fractures, open reduction was done to facilitate passing the nail across the fracture site.

Fabiano Prata Nascimento *et al* [19]. treated all cases with closed nailing.

4.7 Time for union

In our series, time to union ranged from 8 to 12 weeks average being 12.1 weeks

In the study conducted by Oh C.W *et al* [21] *et al* average healing time was 10.5 weeks.

4.8 Complications

4.8.1 Limb length discrepancy

No patient in our study had limb length discrepancy

Fabiano Prata Nascimento *et al* [19] showed the final shortening on the limb, after a follow-up period of at least 24 months, occurred in 6.7% of the cases (two patients), with 0.25 cm on average.

Cramer KE, *et al* [20] noted average limb lengthening of 7mm (range 119mm) in their study. Clinically significant limb discrepancy (> 2cm) did not occur in any patient in their study.

4.8.2 Infection

In our study Superficial infection was seen in 3 patients which were controlled by antibiotics.

J.M Flynn[7] *et al* reported 4(1.7%) cases of superficial infection at the site of nail insertion out of 234 fractures treated with titanium nails.

4.8.3 Range of Motion

All patients had full range of hip and knee motion in the present study.

Flynn J M [7] *et al* reported 2 cases of knee stiffness out of 234 patients treated with titanium elastic nails which required manipulation under general anaesthesia.

4.8.4 Nail Impingement

In the present series, nail impingement was seen in 3 (10 %) patients. Early implant removal was done.

In the study conducted by Carrey T.P *et al* [4] out of 38 cases nail impingement was noted in one case which necessitated early removal.

4.8.5 Rotational Deformities

In our study no patients had varus/valgus angulation, anterior and posterior angulation and rotational malalignment.

Heinrich SD [15] *et al* reported 5° of varus angulation in one child in their study and 11 % of fractures had an average varus or valgus malalignment of 6°.

4.9 Functional outcome according to Flynn score criteria

According to Flynn's criteria, In our study result was excellent in 27 (90%) cases and Satisfactory in 3 (10%) cases. In J.M. Flynn *et al* [7] study excellent results were achieved in 77.7% patients, satisfactory results were achieved in 14.6%, and poor results were noted in 7.8%, amongst 234 patients treated with titanium elastic nails for paediatric femoral shaft fractures.

5. Conclusion

Titanium elastic nailing fixation is a simple, easy, less operative time, less blood loss, reliable and effective method for management of pediatric femoral fractures between the age of 5-16 years, with reasonable time to bone healing.

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