Surgical Science, 2010, 1, 15-19
doi:10.4236/ss.2010.11003 Published Online July 2010 (http://www.SciRP.org/journal/ss)

Titanium Elastic Nails for Pediatric Femur Fractures: Clinical and Radiological Study

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Received May 16, 2010; *accepted July* 14, 2010

Abstract

Background: Management of femoral diaphyseal fractures in the age group 6-16 years is controversial. There has been a resurgence worldwide for operative fixation. **Material and methods:** Twenty children (15 boys, 5 girls) aged 6-16 years with femoral diaphyseal fractures (20 fractures, one in each) were stabilized with Titanium Elastic Nail (TEN). Patients underwent surgery within ten days of their injury. The results were evaluated using Flynn's Scoring Criteria.Two nails were used in each fracture. **Results:** All 20 patients were available for evaluation and follow up for a mean duration of 24 months (15-32 months). Radiological union in all cases was achieved in a mean time of 8 weeks. Full weight bearing was possible in a mean time of 10 weeks (8-12 weeks). The results were excellent in 14 patients (70%) and successful in 6 patients (30%). Few complications that occurred were infection (in 2 cases), knee joint stiffness(in 4 cases), angulation less than 10 degrees(in 4 cases), shortening less than 10 mm(in 4 cases). **Conclusion:** Intramedullary fixation by TEN is an effective treatment of fracture of femur in properly selected patients of the 6-16 years age group.

Keywords: Children, Intramedullary Fixation, Titanium Elastic Nail, Femoral Fracture, Diaphysis

1. Introduction

Femoral shaft fracture is an incapacitating injury in children [1,2]. The treatment has traditionally been age related, influenced by the type of injury, associated injuries and the location and type of fracture.

The aim of fracture treatment is not only anatomical realignment, but also restoration of muscle and joint function as close as possible to the normal. Psychological recovery is accelerated by early resumption of functional activity, which encourages healing of fracture, maintenance of normal circulation, preservation of tone of the muscles and restoration of the movements of the joints. The aim therefore is early mobilization by early use of the injured part without movement at the fracture site.

Because of rapid healing and spontaneous correction of angulations most of femoral shaft fractures in children younger than six years of age can be treated conservatively. Above six years of age all such fractures when treated non-operatively could have loss of reduction, malunion, intolerance and complication associated with plaster. Near the end of skeletal maturity accurate reduction is necessary as angular deformity is no longer correctable by growth. In skeletally mature adolescents, use of an antegrade solid locked intramedullary nail has become the standard of treatment.

In patients between 6-16 years of age there has been a tendency towards operative approach. Titanium Elastic Nailing (TEN) which is variously known as elastic stable intramedullary nailing (ESIN), has become the choice of stabilization in pediatric long bone fractures, particularly the femoral shaft fracture. The present study is aimed at the evaluation of intramedullay fixation with TEN in children with femoral fractures. Until recently skeletal traction and application of a cast was the preferred method of treatment of diaphyseal femoral fractures in children and young adolescent. The device would exploit a child's dense metaphyseal bone, rapid healing and ability to remodel without risking damage to the epiphysis or the blood supply to the capital femoral epiphysis.

2. Material and Methods

Twenty children (15 boys and 5 girls) in the age group of 6-16 years (average 10.8 years) with femoral shaft fracture were stabilized with TEN from April 2007 to October 2009. The predominant mode of injury was due to fall from height (50%). Right-sided involvement was seen in 13 cases (65%) and left side in 7 cases (35%). Mid-diaphyseal fracture of femur was found in 70 % of

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cases and subtrochanteric fracture in 30% cases. About 50% of the patients underwent surgery within 10 days of their injury. The surgery had been carried out in the Department of Orthopaedics, Darbhanga Medical College & Hospital, Laheriasarai, Darbhanga, Bihar, India.

Nail comes in five diameters from 2.5 mm to 4.5 mm in a fixed length. The nails are colour coded for identification. The nails (**Figure 1**) are straight except for a bent tip. Special instruments include radiolucent reduction tool, nail holder, nail bender, Insertion device, nail extractor, wice grip and a nail impactor were used.

All the patients treated with TENs had skin/skeletal traction for approximately 1 week. As is the policy of our institution the traction pin (4.76 mm threaded Steinmann Pin) was inserted in the operating room under local anaesthesia. The Pin was inserted in the region of tibial tuberosity anterolateral to posteromedial plane. Some patients were stabilised with sk in traction. Compound fractures were primarily thoroughly debrided and upper tibial skeletal traction applied. The injured limb was put on a Bohler's-Brawn splint and adequate weight applied. This is essential to minimize pain, muscle spasm and shortening. Appropriate tetanus prophylaxis, antibiotics and analgesics were instituted. In the period of rest and resuscitation, the patient was properly investigated and examined. As soon as the patient became fit for anaesthesia and surgery he/she was posted for fixation of femoral shaft fractures with TEN. Good preoperative X-ray (**Figure 2**) of the injured femur was used to estimate the nail diameter and to develop an approach to supplement fixation and plan the incision.

Half an hour before operation 1 ampoule of atropine was given intramuscularly. Intravenous line was setup. Prophylactic antibiotic 1 gm ceftriaxone was given intravenously. 1 ampule perinorm was given intramuscularly. General/spinal (above 14 years) anaesthesia was given with full aseptic and antiseptic precautions on an image intensifier (IITV) compatible operation table.

As soon as anaesthesia was effective, the patient was placed supine and upper tibial skeletal traction pin was removed with aseptic and antiseptic precaution. The patient was placed on radiolucent fracture table. The limb was prepared and draped to give access to the entire femur and knee joint and to permit manual manipulation of

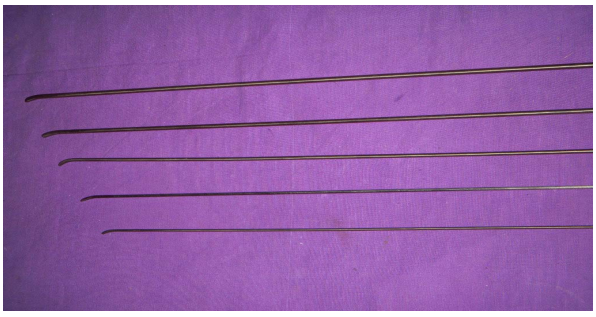

Figure 1. TEN with different length and diameter.

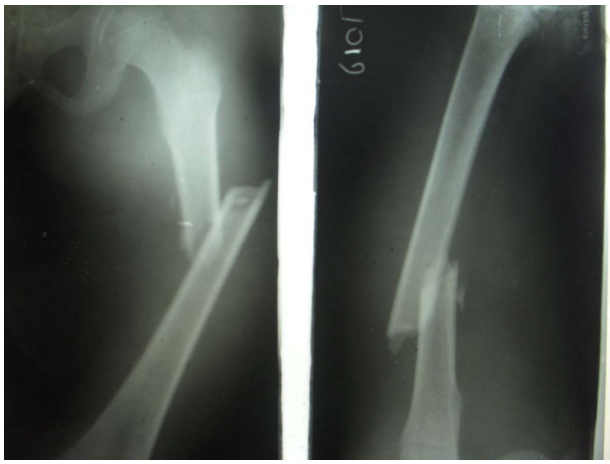

Figure 2. Preoperative x-ray of femur (AP and Lat view).

the thigh. The image intensifier was placed so that one could get antero-posterior and lateral view of the femoral shaft. The monitor was placed in such a way that surgeon could have clear vision when inserting the nail and reducing the fracture.

The selection of the insertion point for the nails was medial and lateral at the top of the flare of the medial and lateral condyles so that after insertion they would tend to bind against the flare of the condyles. If the nails are inserted too low, they will tend to backout, which is a troublesome complication. In addition, the insertion should be posterior to mid line of the shaft so that if the nails backout, they will be less likely to enter the synovial pouch.

A 5mm incision was made on the lateral side of the leg extending about two finger breadth above the superior pole of the Patella. (The superior pole of the patella lies slightly above the level of the physis). A guide wire for 6.5 mm cannulated screw was passed at 45 degrees angulation at the level of the superior pole of the patella. Over this a drill hole was made with the cannulated drill bit. Using a curved bone awl, the hole is extended cephalad to elongate the hole and avoid cracking of the cortex when the rod is inserted. The medial entry hole was similarly elongated using a curved bone awl in cephalad direction. The diameter of nail should be 2/5 of the internal diameter of the medullary canal (Nail diameter = 0.4 x Canal diameter).

Ideally, the lateral nail should extend to the level of the greater trochanter and the medial nail into the femoral neck. The amount of prebending should be equal for both the nails. (The amount of bending should be three times the inner diameter of the shaft).Both the nails were inserted through the entry holes one after another and were driven up to the fracture site. The reduction was helped by the use of F-tool which is a radiolucent device. The arms of the F-tool were readjusted depending on the fracture configuration and bulk of thigh viewing with the image intensifier. This nail was advanced about 2 cm and

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then rotated. At this point, it was advanced further by rotating this nail. Further reduction of the fracture was accomplished and then the second nail was advanced.

The traction was released and both nails were advanced to their full length. Rotational and angular malreductions were checked and if present the same was corrected by partially with drawing the nails, correcting the deformity and reinserting the nails. When the nail was at its final position, it was marked with a pen or clamp about 10 to 20 mm from the insertion hole. The nails were cut at the marked level and advanced so that they lay against the supracondylar flare of the femur in order to avoid complications at the insertion site.

A knee immobilizer or controlled motion brace should be used for additional support. The patients were advised to perform movements at the knee joint and three point touch down exercise the day after surgery under the guidance of a physiotherapist. When early callus formation is observed, weight bearing can be increased. External support can be discontinued when radiographic healing is complete. It is important that the patients bear weight because this provides the motion at the fracture site that leads to early callus formation. In all cases postoperative x-rays antero-posterior and lateral views were taken. In the post-operative period parenteral antibiotics were continued for 5 days and then oral antibiotics were given till stitch removal. Along with antibiotics, haematinics, serratiopeptidase, Calcium, multivitamins were given. Stitches were removed on the 12th post-operative day. After removal of stitch by 13th to 14th day post-operative patients were discharged.

Patients underwent regular follow up in the out patient department for clinical and radiological evaluation in the immediate post-operative period (**Figure 3**), at 4 weeks, 8 weeks (**Figure 4**), 12 weeks (**Figure 5**), 24 weeks, 35 weeks or till the publication of this series, whichever was earlier.

3. Results

The median duration of the surgery was 80 min (60-120 min). All 20 patients were available for evaluation after a mean of 24 months (15-32 months) of follow-up. All patients were encouraged to do hip and knee non weight bearing exercises from first post-operative day. Weight bearing was allowed according to the fracture geography and fixation. At the end of 1st post operative week all patients were made ambulatory on crutches allowing weight bearing according to the quality of fixation. By 8 th week all the patients were bearing weight with only 2 patients with touch-down weight bearing. Out of 20 cases, 2 cases complained of pain and irritation of skin at the entry site, associated with the prominence of the ends of the nails.

Out of 20 cases, 10 mm (1 cm) shortening was observed in 4 cases. These were among the earlier cases of the series and with comminuted fractures. Out of 20 patients, 3 patients showed 10 degree or less angulation in the lateral plane and one patient had an eight degree angulation in the anteroposterior plane. No broken nails were observed in any of the 20 cases. Out of 20 cases, 2 opening the entry site. These patients had to undergo knee physiotherapy again and regained movements at the knee. No re-fracture was observed in the 2 cases that underwent

Figure 3. Immediate postoperative x-ray of femur (AP and Lat view).

Figure 4. 8th week postoperative x-ray of femur (AP and Lat view).

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Figure 5. 12th week postoperative x-ray of femur (AP and Lat view).

nail removal.

4. Discussion

In the present series TEN was used as a mode of fixation in different types of femoral fractures in children between ages 6 to 16 years. 20 cases were treated and evaluated radiologically, clinically and functionally for the efficacy of TEN.In our series results were excellent in all 20 cases. Heinrich *et al*. (1994) reported that 22% of their patients had an extension over 5 mm, and 11% had a shortening under 5 mm. In a study comparing several methods including TEN the maximum shortening was observed in the early casting group followed by external fixator group where as lengthening was observed only in the external fixator group. In our study only 4 cases showed 1 cm shortening which was clinically indiscernible. Herndon *et al*. (1989) reported that malunion developed in seven of 24 patients who were treated with traction while no malunion was observed in 21 children who were treated using TEN.

In a study comparing antegrade versus retrograde TEN by Galpin *et al*. [6] it was reported that 35 out of 37 patients had excellent improvement in terms of angular deformity. We had angulation less than 10 degree towards varus/valgus or antero/posterior only in 4 patients (20%). In our series union progressed satisfactorily in all 20 cases. At the end of 8 weeks, 14 cases showed fair to good callus formation while 6 cases had minimal callus formation. No bone grafting was required in any of the cases. No significant malunion was observed in any of the 20 patients.

Flynn *et al*. (2002) found TEN advantageous over hip-spica in treatment of femoral shaft fractures in children. Buechsenschuetz *et al*. [7] documented TEN to be superior in terms of union, scar formation and overall patient satisfaction when compared to traction and casting. Ligier *et al*. [8] treated 123 femoral shaft fractures with TEN. All fractures united with excellent long term outcome. Similarly Narayanan *et al*. (2004) found TEN to be a very promising modality of fracture management in children. In our series of 20 cases, in 2 cases implants were removed after complete union.

In the present series, by the time stitches were removed all 20 cases could do straight leg raising exercises. At the end of study period 15 patients (75%) could do full range of motion at knee joint.

All patients were encouraged to do hip and knee non-weight bearing exercises from first post-operative day. At the end of 1st postoperative week all patients were made ambulatory on crutches, allowing weight bearing according to the quality of fixation.

Flynn *et al*. (2002) used a knee fixating device to control the pain, to support quadriceps and to prevent the end of nail causing any soft tissue irritation in the knee until the callus tissue appears (4-6 weeks). The patients were able to walk on day 9 on an average with the help of equipment and at week 8.5 on average without the equipment. In our series patients were made ambulatory on crutches after 1st postoperative week. Partial weight bearing was allowed at 6 weeks (range 4-8 weeks) and full weight bearing was allowed at 10 weeks (Range 8-12 weeks).

The results of the present series are comparable to those of the other series on management of femoral shaft fracture in children. It has definite advantages over the other conventional implants that have been used in the management of pediatric fractures. Notable advantages of this technique are early union due to repeated micromotion at fracture site, early mobilization, early weight bearing, scar acceptance, easy manipulation involved in implant removal and high patient satisfaction rate. Besides these, unlike other implants TEN does not endanger either the epiphysis or the blood supply to femoral head. The excellent biocompatibility and elasticity of titanium have further enhanced the virtues of TEN. High grade of elasticity of titanium limits the degree and permanence of deformation that the nail undergoes during insertion. More importantly elasticity promotes callus formation by limiting stress shielding.

Table 1 shows important aspects of this study like age and sex of the patients, nature and mode of injury, specifications of nail used, follow up results and duration, surgical complications like intraoperative blood loss and others.

The biomechanical principle of TEN is based on the symmetrical bracing action of two elastic nails inserted into the metaphysis, each of which bears against the inner bone at three points. This biomechanics helps in achie-

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Table 1.

S.No.	Name	Age in years	Sex	Mode of Injury	Type of fracture	Side of fracture	Closed /open Injury	Blood loss	Nail dia.	ROM	Time for union			
											4 Wks.	8 Wks.	12 Wks.	24 Wks.
1	MP	8	M	RTA	MD	R	Closed	100-200	2.5 mm	FR	+	++	+++	+++
2	RS	11	M	HGT	MD	R	Closed	< 100 ml	2.5 mm	FR	+	++	+++	+++
3	NK	13	M	ASLT	MD	L	Closed	100-200	2.5 mm	FR	+	++	+++	+++
4	PK	12	F	RTA	ST	R	Open	100-200	2.5 mm	0-100°	-	+	++	++
5	GH	14	M	HGT	MD	L	Closed	< 100 ml	3 mm	FR	+	++	+++	+++
6	KP	9	M	ASLT	MD	L	Closed	< 100 ml	2.5 mm	FR	+	+	++	+++
7	ST	11	M	HGT	MD	R	Open	200-300	2.5 mm	FR	+	++	+++	+++
8	RD	14	F	ASLT	ST	R	Open	< 100 ml	3 mm	0-120°	+	++	+++	+++
9	AK	12	M	HGT	MD	R	Closed	100-200	2.5 mm	FR	-	+	+	++
10	UP	13	M	HGT	MD	R	Closed	< 100 ml	3 mm	FR	+	++	+++	+++
11	BS	10	F	RTA	ST	L	Closed	100-200	2.5 mm	FR	+	++	+++	+++
12	DNP	11	F	HGT	MD	R	Open	200-300	2.5 mm	0-120°	+	++	++	+++
13	BP	11	M	HGT	MD	R	Closed	< 100 ml	2.5 mm	FR	++	+++	+++	+++
14	NP	15	M	RTA	SY	L	Open	100-200	3 mm	FR	+	++	+++	+++
15	WA	16	M	HGT	MD	R	Closed	< 100 ml	3.5 mm	FR	+	+	++	+++
16	SKG	10	M	HGT	ST	L	Open	100-200	2.5 mm	0-100°	+	++	+++	+++
17	VD	16	M	HGT	MD	L	Closed	< 100 ml	3.5 mm	FR	+	+	++	++
18	SL	15	M	RTA	ST	R	Closed	< 100 ml	3 mm	FR	+	++	+++	+++
19	AP	8	M	ASLT	MD	R	Open	200-300	2.5 mm	0-120°	-	+	++	++
20	GLY	16	F	RTA	MD	R	Closed	100-200	3 mm	FR	++	+++	+++	+++

M = Male; F = Female; RTA = Road Traffic Accident; HGT = Height; ASLT = Assault; MD = Mid diaphyseal; ST = Subtrochanteric; R = Right; L= Left; ROM = Range of Motion; FR = Full Range; + = Little amount callus seen; ++ = Fair amount callus seen; +++ = Good amount of callus seen; - = No visible callus seen.

ving a high grade of stability *i.e.* flexural stability, axial stability, translational stability and rotational stability.

5. Conclusions

The intramedullary fixation by TEN is a method of choice due to its distinct advantages over other conventional modalities. Easy manoeuvering, excellent outcome, lower incidence of complications and easier postoperative maintenance have made TEN the most prudent, practical and successful intervention in the management of femoral shaft fractures of patients between 6 and 16 years of age.

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