Treatment of tibial fractures in children by flexible intramedullary nails

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Abstract

Background
Closed reduction with cast immobilization is the main treatment of diaphyseal tibial shaft fractures in children and adolescents. The indications for treating pediatric tibia fractures surgically are unstable fracture patterns, unacceptable closed reduction, open fractures and unacceptable secondary displacements. Elastic intramedullary nailing of long-bone fractures in children up to 15 years old is an excellent treatment option it is associated with relatively minor complications. It is considered to be a physiological method of treatment because of early weight-bearing, rapid healing and minimal disturbance of bone growth.
Patients & Methods
This study includes 20 children with tibial shaft fractures treated with flexible intramedullary nails. Age of the children ranged from 4 to 14 years old, the final follow-up period was 6 months from the date of the initial injury.
Results
Functional results were assessed according to modified Hindley, The excellent and good results occurred in 19 (95%) patients and were considered satisfactory while the unsatisfactory results were the fair results in 1(5%) patient. The fair result was in a patient who had 10 degrees varus angulation.
Conclusions
Elastic intramedullary nailing is used for treatment of certain pediatric tibial shaft fracture, these include minimally invasive technique, offers smaller incisions, minimal surgical trauma to the fracture zone ,allows more rapid rehabilitation and is associated with relatively minor complications.

Key words
Tibial shaft fractures,chidren ,intramedullary nail, flexible nail.

Introduction

Tibial shaft fractures are among the most common pediatric injuries managed by orthopedic surgeons. They account for approximately 15% of long bone fractures in that age group. Only femur and forearm fractures are more common (1). Tibial fractures are caused by minor falls or twisting injuries in young children and sports related trauma or motor vehicle accidents in older children and adolescents.[2] The average age at injury is 8years [1],and this injury occurs more frequently in boys than in girls.Most tibial fractures in children are short oblique or transverse fractures of the middle or distal third of the shaft.Thirty seven percent of tibial fractures are comminuted [1]. Both tibial and fibular fractures are commonly caused by high energy trauma.Valgus angulation of the distal fragment and shortening are caused by over pull of anterior and lateral compartment muscle groups [3, 4]. Tibial fractures with an intact fibula occur in about 70% of affected children and usually are the result of torsional forces. Although isolated tibial fractures are often minimally displaced at presentation,varus angulation without shortening often occurs in the first few weeks after injury as a result of posterior compartment muscular forces on the distal fragment [4].

Treatment is based on the patient's age, concomitant injuries, fracture pattern, associated soft tissue and neurovascular injury and surgeon's experience,closed reduction and casting is the main treatment for diaphyseal tibial fractures[5]. Carefulclinical and radiographic follow up with remanipulation as necessary is effective for most patients.

The indications for treating pediatric tibia fractures surgically are unstable fracture patterns, unacceptable closed reduction, open fractures and unacceptable secondary displacements [6]. Surgical management options include external fixation, locked intra medullary nail fixation in the older adolescents with closed physis, Kirschner wire fixation, plating and elastic intramedullary nailing. Plating is an excellent option but compared to elastic intramedullary nailing the latter is less invasive, offers smaller incisions, minimal surgical trauma to the fracture zone and allows more rapid rehabilitation. The external fixation is much more bulky and may limit the child in his rehabilitation [6].

Elastic intramedullary nailing (E.I.N) isused for treating tibial shaft fractures in children before skeletal maturity.It allows rapid limb mobilization with few complications mainly leg length discrepancy and secondary deformity[7].

Elastic intramedullary nailing

Elastic intramedullary rod fixation is gaining the popularity for management of unstable tibial fractures in children and growing adolescents. Elastic titanium nails, commonly used in the forearm and femur, also an provide stable fixation for unstable tibial shaft fractures [27]. The elastic nails are introduced through small drill holes in the proximal or distal tibial metaphysis.Access to the soft tissues of the leg for examination, debridement, or reconstruction thus is unimpeded. For fractures that are rotationally unstable, a period of splint or cast immobilization is required when using constructs that do not impart rotational control. Such immobilization also functions as added protection for fractures in young or noncompliant children. Range of motion of the knee and ankle joints may be initiated immediately after fixation and protected weight bearing on the involved limb is progressed within 2 to 3 weeks postoperatively. The flexible nails are removed in the operating room, usually within 4 to 6 months of injury [5].

Biological aspects of elastic intramedullary nailing Bone healing

The development of the (E.I.N.) technique is based on the aim of achieving rapid bone healing. In children, osteoblasts in the inner cellular layer of the thick periosteum are able to build new bone more rapidly. Later in life, as the periosteum becomes thinner, the bone healing process is prolonged in line with the patient's age. This method thus preserves the periosteum allowing a rapid bone healing in children [8,9]

Double frame

The double frame model illustrates the principle of the EIN technique. The inner frame consists of the medullary canal containing the elastic flexible nails and the bone, where as the muscles on the anterior/posterior, medial/lateral sides form the outer frame. Both frames have to be functional in order to provide sufficient stability for reducing and maintaining fracture reduction [8,9]

Exceptions:
In the tibia, the application of the principle of EIN is more demanding because of the missing outer frame, and muscle coverage on the medial and lateral sides.

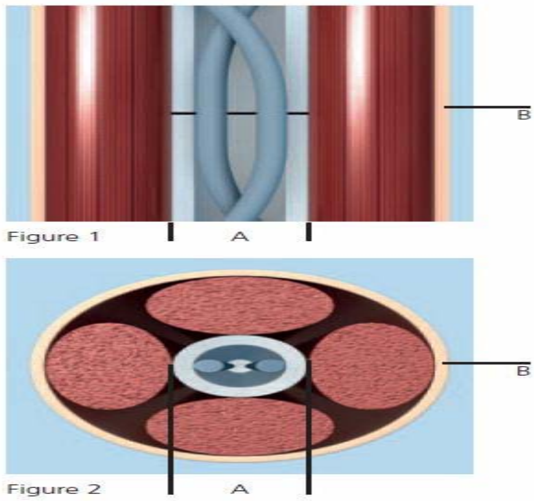

Figure (1): the double frame model [9]

Biomechanical Principle of Elastic Intramedullary Nailing(E.I.N)

The elastic flexible nails are bent and inserted into the medullary canal. This elastic deformation within the medullary canal creates a bending moment within the long bone that is not rigid (fig.2), but that is stable enough to reduce and fix the fracture [8, 9].

Patients & Method

This study includes 20 children with tibial shaft fractures. Age of the children ranged from 7 to 14 years old. Duration of the follow up was 6 months.four patients (20 %) had associated injuries, two of them had fracture femur and another one with bilateral fracture femur and last one with ipsilateral fracture femur, distal femur physis type 4 and fracture left ulna. There were 14 males and 6 females patients. The right side was affected in 10 patients and the left side in 10 patients, 8 cases were due to minor falls or twisting injuries, 9 cases were due to motor vehicle accidents and road traffic accidents and 3 cases were subjected to a direct fall of a heavy object on the leg , 14 patients were closed while the remaining 6 were open . 12 cases had fractures of the middle third,7 had fractures of the lower third and 1 had fracture of the upper third of the tibia , The fracture line was transverse in 6 patients, oblique in 13 patients and spiral in 1 patient. Close reduction was in 18 cases and open reduction was in 2 cases.

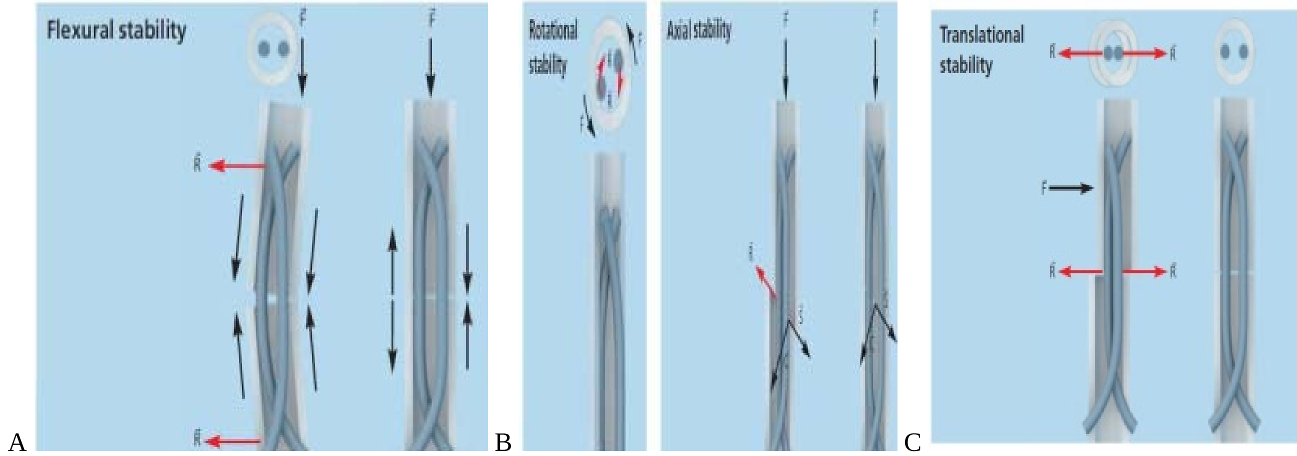

Figure (2): stability of (E.I.N)[9]. A: the flexural stability of (E.I.N) B: the rotational and axial stability of (E.I.N) C: the translational stability of (E.I.N)

Methods

Implants and Instruments:

Titanium elastic nails are available in six diameters:1.5 mm, 2.0 mm, 2.5 mm,3.0 mm, 3.5 mm and 4.0 mm. The nails are color-coded for easy identification.(fig.3).[3]

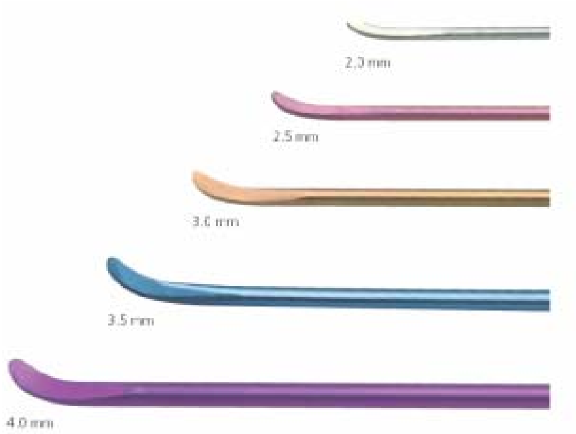

Figure 3: Nail color

The proper nail diameter is no more than forty percent of the width of thecanal, selection of two nails of the same diameter so the opposing bending forces are equal, avoiding misalignment.

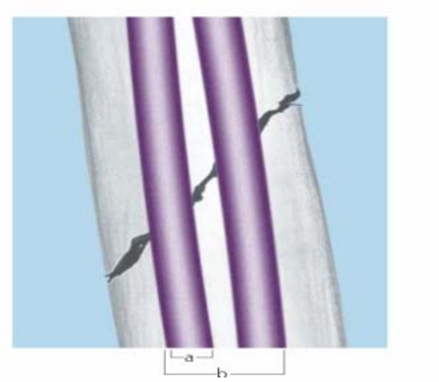

Figure (4): Nail diameter (a) should beno more than 40% of the width ofthe medullary canal at the narrowestpoint (b) [8,9]

*Blunt ended titanium nails were used. For tibial nailing, nail size is normally between 2.5 and 4.0 mm depending on the patient's age and bone size.Special attention was directed to prepare the nails prior to their introduction. The nail is angled about 45 degree about 2 cm from one end to facilitate penetration of the medullary canal regarding the biomechanical properties, a good contact of the nail with the inner side of the cortex is essential especially for long oblique and spiral fractures where a danger of shortening exists. Pre-bending in this case is therefore highly recommended [8,9]. By introducing the two nails and aligning the curves opposite to each other, a three point pressure system is created which converts shear stress into compression. Because of the relative stability, micro movements are allowed, promoting callus formation and healing [6].

Surgical technique:

Standard tibia descending technique

* The site of entrance of the nails was first checked by fluoroscopy. The entry points are situated anteriorly on the proximal medial and proximal lateral metaphyseal cortices, 2 cm distal to the proximal physis, next to the tibial tuberosity (fig.5).[9]

Fgure :5 The entry points

* Then small symmetrical skin incisions were made on the same level on the medial and lateral sides of the tibial tuberosity. These are 2 –3 cm in length proximal to the planned entry points.The fascia was divided over a sufficient length, a small hole was made in the lateral cortex using small drill pit 2.7 mm or 3.2mm (fig.6). The opening was slightly larger than the selected nail diameter.

* With the help of a T-handle and by rotation

movements of the wrist, introduce through the already drilled hole and push it down the medullary canal to the already reduced fracture site, Two nails one lateral and one medial are adequate to stabilize the fracture. Both nails were checked that they are located in the medullary canal (fig.6).

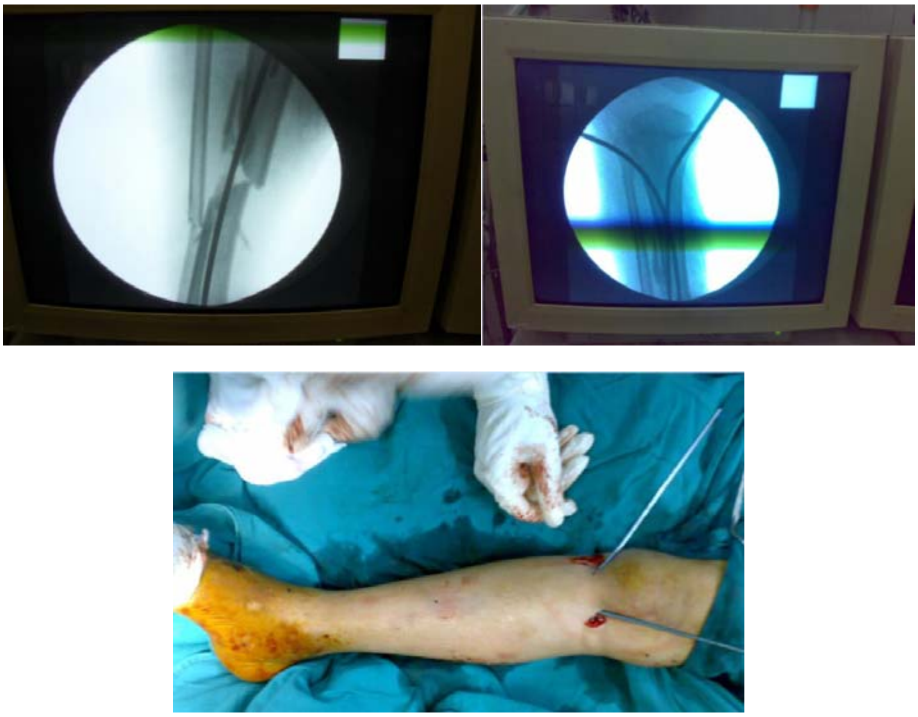

Figure 6: Both nails are located in the medullary canal

* External immobilization of the fracture with below knee splint applied.

X-ray was taken at 3 weeks interval to confirm the union of fracture; the nails are removed electively when bone healing is indicated on the x-ray in the form of bridging callus in three cortices at least.

Evaluation of thesis results

The cases were followed up both clinical and radiological every 3 weeks post operatively. The follow up includes; assessment of union, alignment, shortening, weight bearing, knee and ankle motions and presence of infection.

Assessment of results:

A)Radiological assessment:

*Acceptable parameters of reduction are (5)::

Up to 5° of varus or valgus angulation.

<5°of sagittal angulation

1 cm of shortening.

50% translation is acceptable.

Up to 10° of varus and 10° of sagittal deformity are acceptable in children younger than age 8 years.

B) Functional assessment:

Functional results were assessed according to modified Hindley (1988) [10] .As shown in the table.

Table : The functional assessment of the results [10]

Deformity	Excellent	Good	Fair	Poor
Valgus/varus	None	2-5°	6-10°	>10°
Anteversion/recurvatum	0-5°	6-10°	11-20°	>20°
rotation	0-5°	6-10°	11-20°	>20°
shortening	0-5mm	6-10 mm	11-20 mm	>20mm
Joint function (range of motion)				
knee	Normal	>75%	>50%	<50%
ankle	Normal	>75%	>50%	<50%
Deep infection	Absent	Absent	Absent	Present
Non union	Absent	Absent	Absent	Present

*Excellent and good results were considered satisfactory, while fair and poor results were considered unsatisfactory.

Results

Functional assessment:

I. Alignment:

A) Shortening: Early post operative measurements showed that no case had shortening and these measurements continued till final follow up peroid.

B) Angulations:

Anterior or posterior:

*immediately postoperative:7 cases had anterior/posterior angulations.

*By end of follow up period: 2 cases who had anterior angulations 5 degrees were corrected and reached zero degree. the net result of cases who had anterior/posterior angulations by end of follow up peroid was 5 cases.all of these 5 cases had anterior/posterior angulations below 10 degrees which is satisfactory according to this protcol.

Medial or lateral:

*immediately postoperative:6 cases had medial/lateral angulations.

* By end of follow up period:.one case who had 5 degrees varus angulation was corrected and reached zero degree.the net result of cases who had medial/lateral angulations by end of follow up period was 5 cases.4 cases had medial/lateral angulations below 5 degrees which is satisfactory according to this protocol.the remaining case had 10 degrees varus angulation which is unsatisfactory (fair) according to this protocol.

C) Rotation:

None were met with internal or external rotation in this series.

2.Fracture union(radiological& clinical):

The mean period of good callus formation was 5.1 weeks.The mean period of full bridging callus formation was 9.05 weeks.The mean period of consolidation was 18.8 weeks. The mean period of full weight bearing was 9.75 weeks.the mean time of union (formation good callus,full bridging and consolidation) was better for patients below 10 years old than those above 10 years old.The mean time of good callus formation was better for fractures of distal third tibia than fractures of middle and upper third.the mean time of full bridging callus formation was better for fractures of distal third than fractures of middle and proximal third.the mean time of consolidation was better for fractures of upper third than fractures of middle and distal third.The mean time of union (formation good callus,full bridging callus and consolidation) was better for oblique fractures than other shapes.the mean time of union (formation good callus,full bridging callus and consolidation) was better for closed fractures than open fractures .

3. knee &ankle motion:

All patients regained full range of motion of the both joints within 2-3 months after union of fracture, except one case (5%) that had knee range of knee motion 60% of normal and reached 80% by physiotherapy this is considered satisfactory according to the thesis protocol.

4. infection:

3 Cases (15%) had superficial infection.All of them had open fractures and they were treated by general and local antibiotics.There is no incidence of deep wound infection in any case.

Overall results:

The excellent and good results occurred in 19 (95%) patients and were considered satisfactory, while the unsatisfactory results were the fair results in one (5%) patient. The fair result was in a patient who had 10 degrees varus angulation.

Discussion

Treatment is individualized based on the patient's age, concomitant injuries, fracture pattern, associated soft-tissue and neurovascular injury and surgeon's experience,closed reduction and casting is the main treatment for diaphyseal tibial fractures.Careful clinical and radiographic follow-up with re-manipulation is necessary for most patients.[5]

The indications for treating pediatric tibia fractures surgically are unstable fracture patterns (spiral, oblique and comminuted shaft fractures are almost always much displaced and unstable), unacceptable closed reduction, open fractures and unacceptable secondary displacements. [6,7]

Kuibak et al (2005) compared the use of titanium flexible nails with external fixation in a mixed group of patients with open and closed tibial fractures, the authors reported a clinically significant decrease in time to union with titanium nails compared to external fixation. [11]

Berger et al (2005) reported that the external fixator is much more bulky and may limit the child in his rehabilitation. [6]

Mashru et al (2005) reported that standard open reduction and plate fixation which requires a large exposure with soft tissue stripping, usually is not indicated in children. [5] This coincides with Berger et al (2005) who reported that plating is an excellent option but compared to (E.I.N.) the latter is less invasive, offers smaller incisions, minimal surgical trauma to the fracture zone and allows more rapid rehabilitation. [6]

Elastic intramedullary nailing of long-bone fractures in children up to 15 years old is an excellent treatment option it is associated with relatively minor complications. [6] It is considered to be a physiological method of treatment because of early weight-bearing, rapid healing and minimal disturbance of bone growth. [7]

In this study 14 cases (70%) were males and 6 cases (30%) were females, this coincides with Mashru et al (2005) who reported that this injury is more frequently in boys than in girls. [5] The age of patients in the present study was between 7 and 14 years old years which is comparable with Mashru et al (2005) who reported that the average age of injury is 8 years. (5) This also coincides with Berger et al (2005) who reported the use of (E.I.N) in children up to 15 years old. [6]

In this study 6 fractures (30%) were open and 14 fractures (70%) were closed.Berger et al (2005) reported that in the study on 9 patients, all fractures were diaphyseal and splinted with two nails .two fractures were open (22.2%) and seven was closed (77.8%). (6)Buckley et al (1994) reported that approximately 9% of pediatric tibial fractures are open. [12]

The mean hospital stay was 3-5 days including the removal of the nails.This coincides with Berger et al (2005) who reported that the mean admission time was 2 days for the initial operation and the mean admission time for the second operation was 1 day. [6]

In the present study, the titanium nails were used for fixation of all cases with tibial shaft fractures. Titanium nails of different diameters and length were used according to bone length and medullary canal diameter; these nails are pre-bent and introduced into the metaphysis via stab incisions. This is the same approach advocated by Berger et al (2005). [6]

In the study of Ligier et al (1985) the authors advocated tibial descending technique in pediatrics. [9] On the other hand Mashru et al (2005) advocated that the nails can be introduced through small drill holes in the proximal or the distal tibial metaphysis.[5] In 20 cases(100%) tibia descending technique was used.

In this study, full bridging callus was observed in all of patients at 11 weeks after the initial operation allowing full weight bearing.Berger et al (2005) reported that clinical and radiological consolidation was established within 9 weeks .[6]

In the present study, Below knee splint as external immobilization was used for 4-6 weeks. When early callus formation is observed, patellar tendon bearing cast was done and partial weight bearing was started. Full callus bridging allowing full weight bearing , except the 4 cases associated with fracture femur showed delayed weight bearing. Nectoux et al (2008) reported that in the original description of the (E.I.N.) technique, no additional immobilization was mentioned. [7]

In this study the union rate was (100%) on the other hand Berger et al (2005) reported that there were no complications were noted and the union rate was 100%. [6]

All patients of this series showed satisfactory range of knee and ankle motion, one patient (5%) with ipsilateral femur fracture and distal femur physis type 4 had active knee flexion up to 60% of normal reached 80 % by physiotherapy, this coincides with Nectoux et al (2008) who reported that no physiotherapy was required and all children regained normal joint range of motion on their won. [7] On the other hand in conservative treatment Mashru et al (2005) reported that tibial fractures requiring repeated manipulation or open fractures or fractures that are severely comminuted should be immobilized for longer periods to achieve clinical and radiological healing. [5] NO Shortening was recorded this coincides with Berger et al (2005) who reported that when concerning (E.I.N.) of tibial fractures ,they noted no complications this includes the often reported leg length discrepancy. [6] 5 cases showed angulations in sagittal plane by end of follow up period .range of anterior or posterior angulations was below 10 degree which is satisfactory according to this protocol.5 cases showed angulations in cronal plane by end of follow up period. Range of medial or lateral angulation was below 5 degrees which is satisfactory according to this protocol except one case had 10 degrees varus angulation which is unsatisfactory (fair) according to this protocol.

This coincides with Nectoux et al (2008) who reported that clinical and radiographic malunion is the second most frequent complication encountered and is the result of slight telescoping at the fracture site. [7]

In this series none of the cases developed external or internal rotation, and this was found to be in agreement with Berger et al (2005) who reported that no complications were noted. [6]

In this series none of the cases developed deep infection, 3 cases (15%) had superficial infection and they are treated by general and local antibiotics this coincides with Nectoux et al (2008) who reported that they did not encounter any deep wound infection nor did they need any revision surgery whatsoever after the initial operation. [7]

In this study, the results of treatment by flexible intramedullary nails gave (95%) satisfactory results after an average period of 6 months follow up, this coincides with Berger et al (2005) when concerning (E.I.N.) of tibial fractures, they noted no complications, but this may be influenced by their small study group. [6] Gordon et al (2007) reported that retrospectively reviewed 60 pediatric patients with open or closed tibial shaft fractures managed with flexible nails they found 18% complication rate. [13]

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