

Results of Flexible Intramedullary Nailing in the Treatment of Tibial Diaphyseal Fractures in Children

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ABSTRACT

Background: No agreement between the orthopedic surgeons regarding the best treatment for the diaphyseal tibial fracture in children. **Hypothesis:** The flexible intramedullary nailing technique is a valuable procedure with the lower reported incidence of complications for pediatric patients suffering from diaphyseal tibial fractures in the age group that ranges from 6 to 12 years old. **Materials and Methods:** This study was performed prospectively on 16 pediatric patients who underwent flexible intramedullary nailing for the management of the diaphyseal tibial fractures. Results: The final results in 12 patients (75%) were excellent and satisfactory in four patients (25%). The average time of clinical union was 6.75 ± 1.12 weeks, while the average time of radiological union was 9.31 ± 0.79 . **Discussion:** The results of the present study were according to other authors raising our hypothesis that flexible intramedullary nailing procedure has many advantages for children suffering from diaphyseal tibial fractures for the age group between 6 and 12 years old when compared to other methods of fixation. **Conclusions:** We prefer the flexible intramedullary nailing procedure as the first choice to treat the unstable diaphyseal tibial fractures in the pediatric age group between 6 and 12 years old, because it is, less invasive, low chance of infection, refracture, and implant failure. Level of evidence: IV.

Key words: Children, diaphyseal, flexible, fractures, intramedullary, nailing, tibial

INTRODUCTION

The traditional treatment of uncomplicated pediatric tibial and fibular shaft fractures is by manipulation and cast application. However, recently there was an increased interest in surgical stabilization, especially for the unstable closed tibial shaft fractures also open fractures and those with associated soft tissue injuries.^[1,2]

Open fractures were included in the indications of the operative treatment, also some fractures with an associated compartment syndrome, some fractures in children with spasticity (head injury or cerebral palsy), and fractures in which open treatment facilitates nursing care as in multiple

long bone fractures, floating knee injuries, many system injuries, and unstable fractures in which adequate alignment cannot be either maintained or attained.^[1-3]

The treatment methods available for those were external fixation and plating. Complications happening with these techniques include infection, overgrowth, and refracture.^[2] Elastic stable intramedullary nailing (ESIN) of long bone fractures in the skeletally immature has gained widespread acceptance due to its clinical effectiveness and lower incidence of complications, preservation of the fracture hematoma, and a physeal-sparing entry point.^[3-5]

The current study hypothesis is that the flexible intramedullary nailing is an effective treatment with lower morbidity rate in selected pediatric patients in the age group from 6 to

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12 years old. Hence, in the current series we try to answer the following questions such as what are the advantages of the flexible intramedullary nailing procedure over the other methods of treatment used for tibial shaft fractures and what is the impact of factors such as age, sex, time lapse, side affected, and mechanism of trauma with our results.

The purpose of the current series is to analyze and evaluate the results of 16 children who did suffer from diaphyseal tibial fractures and treated by flexible intramedullary nailing at our hospital.

PATIENTS AND METHODS

During April 2014–March 2018, this prospective study was conducted on 16 consecutive children with diaphyseal tibial fractures who had undergone for treatment by flexible intramedullary nailing at our institute. The inclusion criteria were all patients who failed to achieve a satisfactory closed reduction, open fracture Gustilo type I or II, aged from 6 to 12 years old, and polytrauma patients. While the exclusion criteria were, patients with infection, above 12 years and patients with Gustillo type III fractures. Informed consent was obtained from the parents of all children were included in the present study.

They were 12 boys and 4 girls; the right side was affected in 9 patients, and the left side was in 7 patients. The mechanism

of trauma was road traffic accidents (RTA) in 12 patients and sports injuries in 4 patients. 14 patients had closed fractures while the other two patients had open fractures. 9 patients had fractures in the middle third of the tibial shaft, 2 patients had fractures in the upper third of the tibial shaft, and 5 patients had fractures in the lower third of the tibial shaft. 7 patients had oblique fractures, 5 patients had transverse fractures, and 4 patients had comminuted fractures.

Operative techniques

General anesthesia was used in all cases using a tourniquet and complete aseptic conditions. The patient was positioned in a supine position on a radiolucent table. In all 16 patients, we used two flexible nails the size varying from 2.5 to 4.5 cm in C configuration through bilateral anteromedial and anterolateral through 3–4 cm incisions, starting point is 2 cm from the upper tibial physeal plate and inserted to 1 cm from the lower tibial physeal plate Figure 1a-c.

Post-operative care

After surgery, we placed all the patients in a short-leg cast and mobilized, with non-weight-bearing for 4–6 weeks. When sufficient good callus was visible at the fracture site, weight bearing in the walking cast was permitted. When tri-cortical callus was visible on the radiological examination, and there was no tenderness at the fracture site on clinical examination, the fractures were considered to be united.

The final outcome was graded as excellent, satisfactory, or poor based on criteria described by Flynn *et al.*,^[3] Table 1.

Statistical analysis was done using SPSS v.20 software (SSPS Inc., Chicago, IL, USA). According to data qualitative represent as number and percentage, quantitative continues group represented by the mean ± standard deviation (SD), the following tests were used to test differences for significance, difference, and association of qualitative variable by Chi-square test (χ^2). Differences between quantitative independent groups were evaluated by *t*-test and correlation by Pearson's correlation test. *P* value was set at <0.05 for significant results and <0.001 for a high significant result.

RESULTS

The patients were followed up for 2 years up to –3 years (average 2.5 years). There were 12 boys (75%) and four

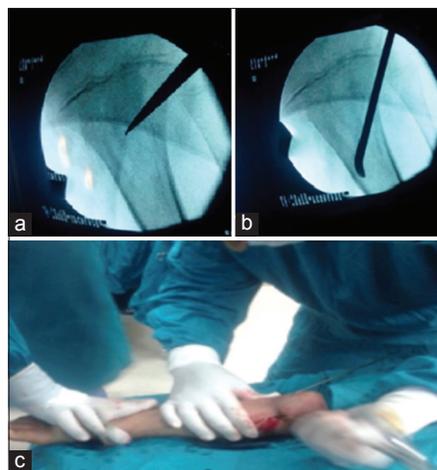


Figure 1: Technique of tibial flexible nail (a) Awel insertion, (b) nail insertion, and (c) closed reduction, manipulation, and nail insertion

Table 1: Flynn *et al.* classification

Category	Excellent results	Satisfactory results	Poor results
Limb-length inequality	<1.0 cm	1.0–2.0 cm	>2.0 cm
Malalignment	5°	5–10°	>10°
Pain	None	None	Present
Complications	None	Minor and resolved	Major and lasting morbidity

girls (25%) with tibial fractures managed with ESIN during the study period. The average age of the 16 children was 9.93 years (SD = 1.84). 12 patients (75%) had tibial fractures following RTA, sports injuries in four patients (25%). In nine patients (56.3%) the right tibia was affected and in seven patients (43.8%) the left tibia was affected. 14 patients (87.5%) had closed fracture while two patients (12.5%) had open fractures.

Nine patients (56.3%) had fractures in the middle third of the tibial shaft, two patients (12.5%) had fractures in the upper third of the tibial shaft, and five patients (31.3%) had fractures in the lower third of the tibial shaft. Seven patients (43.8%) had oblique fractures, five patients (31.3%) had transverse fractures, and four patients (25%) had comminuted fractures. Five patients had (31.2%) associated injuries and 11 patients (68.8%) had isolated tibial fracture only. The average time lapse of the sixteen children was 3.16 years (SD = 1.34).

The post-operative score was excellent in 12 patients (75%) and satisfactory in four patients (25%). The average time of clinical union was 6.75 (SD = 1.12) while the average time of radiological union was 9.31 (SD = 0.79). Two patient (12.5%)

had angulations, one patient only had varus malalignment (<10°) while the other patient had 10 anterior angulation.

The analysis of these fractures showed improper contouring of the nails which resulted in; the apex of curvature was distal to the fracture site. In both patients, the angulations were corrected by remodeling after 6 months. Two patients (12.5%) had lengthening (range from 1 to 2 cm). One patient at the fracture side had a distraction and one had a comminuted middle third fracture.

The patients did not describe the limb length discrepancy as a complaint by the patients or their relatives. There was no statistically significant relationship between the age, sex, affected side, time lapse before the operation, and nail diameter that was used, intraoperative image intensifier time, mechanism of trauma, type/level/shape of fracture, presence of associated injuries, and final score in this study, Figures 2-5 and Tables 2 and 3.

DISCUSSION

Fractures tibia in skeletally immature patients has been treated successfully traditionally by conservative methods and casting. However, few of these fractures require surgical stabilization, such as open fractures, fractures associated with neurovascular injuries, fractures in the multiply injured patients, and fractures with soft tissue injury, burns, skin



Figure 2: (a) A 7-year-old boy, admitted after a road traffic accident. He had a middle third fracture of the right tibia. Surgery was performed 1 day after trauma, trial of closed reduction was done, but was unsatisfactory, closed reduction and fixation using two flexible titanium nails. (b) At 12 weeks follow-up, X-rays showed solid fracture healing (c) he was admitted for removal of the nails at 6 months

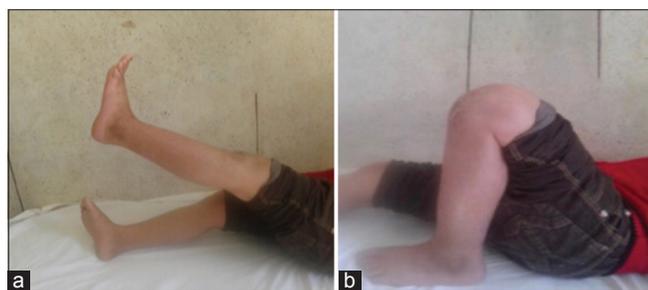


Figure 3: (a and b) The same patient with excellent functional outcome and full range knee motion



Figure 4: (a) A 20-year-old boy, admitted after a road traffic accident. He had a distal fracture of the left tibia. Surgery was performed the same day after trauma. (b) At 12 weeks follow-up, X-rays showed solid fracture healing (c) he was admitted for removal of the nails at 6 months



Figure 5: (a and b) The same patient with excellent functional outcome and full range knee motion

Table 2: Summarized data of the patients

Category	Post-operative score		Total	χ^2	P
	Excellent	Satisfactory			
Side affected					
LT					
n (%)	5 (41.7)	2 (50.0)	7 (43.8)	0.085	0.77
RT					
n (%)	7 (58.3)	2 (50.0)	9 (56.2)		
Method of trauma					
RTA					
n (%)	8 (66.7)	4 (100.0)	12 (75.0)	1.77	0.18
Sport injection					
n (%)	4 (33.3)	0 (0.0)	4 (25.0)		
Type of fracture					
Closed					
n (%)	11 (91.7)	3 (75.0)	14 (87.5)	0.76	0.38
Open					
n (%)	1 (8.3)	1 (25.0)	2 (12.5)		
Level of fracture					
Lower					
n (%)	4 (33.3)	1 (25.0)	5 (31.2)	0.77	0.68
Middle					
n (%)	7 (58.3)	2 (50.0)	9 (56.2)		
Upper					
n (%)	1 (8.3)	1 (25.0)	2 (12.5)		
Shape					
Comm.					
n (%)	2 (16.7)	2 (50.0)	4 (25.0)	4.26	0.11
Oblique					
n (%)	7 (58.3)	0 (0.0)	7 (43.8)		
Trans.					
n (%)	3 (25.0)	2 (50.0)	5 (31.2)		
Total					
n (%)	12 (100.0)	4 (100.0)	16 (100.0)		

RTA: Road traffic accidents

loss, and compartment syndrome.^[6] There are few options for treatment of these difficult fractures.

External fixation is a common option but got a significant, complicated rate. Flexible intramedullary titanium nails allow immediate stabilization with the fracture in the multiply injured child, facilitate access to compromised soft tissues, and avoid the need for prolonged immobilization.^[7]

The titanium elastic nails (TENs) development fixation method have put an end to the criticism of the surgical

treatment of pediatric long bone fractures, as it obviates any growth disturbance by preserving the epiphyseal growth plate, it avoids bone damage or weakening through the elasticity of the construct, which provides a load sharing, biocompatible internal splint, and finally it entails a minimal risk of bone infection.^[8]

O'Brien *et al.*^[7] reported 16 fractures of the tibia, fixed internally with flexible titanium nails, which gained a very good functional outcome with no significant angulation or leg length discrepancy and no infections. El-Adl *et al.*^[8] treated 25

Table 3: Relationship between age, sex, and post-operative score there was no significant relation between post-operative score and either age or sex

Category	Postopscore		Total	χ^2	P
	Excellent	Satisfactory			
Age					
<10					
n (%)	5 (41.7)	1 (25.0)	6 (37.5)	0.35	0.55
≥10					
n (%)	7 (58.3)	3 (75.0)	10 (62.5)		
Mean±SD	9.97±2.1	10.0±0.81		t=-0.07	0.94
Sex					
Female					
n (%)	2 (16.7)	2 (50.0)	4 (25.0)	1.77	0.18
Male					
n (%)	10 (83.3)	2 (50.0)	12 (75.0)		
Total					
n (%)	12 (100.0)	4 (100.0)	16 (100.0)		

SD: Standard deviation

tibial fractures by ESIN. According to Flynn *et al.*'s^[3] outcome rating system, 75.8% of the results were excellent, 24.2% were satisfactory, and there were no poor results. Vallamshetla *et al.* also reported.^[9] 56 fractures of the tibia, fixed internally with intramedullary elastic nails with excellent outcome in 84% of cases the complications, were residual angulations in two patients, two leg-length discrepancies, two deep infections, one delayed union, and two failures of fixation.

Sankar *et al.*^[10] managed 19 cases with tibial shaft fractures with ESIN, based on Flynn classification, they had 12 (63%) excellent, 6 (31.5%) satisfactory, and one had (5.3%) poor result. Vrsansky *et al.*^[11] reviewed 308 children with fractured long bones fixed with flexible intramedullary nails, in which 36 involved the tibia. They reported the excellent outcome, with all patients mobilizing independently by 3–5 months. In 2005, Kubiak *et al.*^[12] compared between external fixation and ESIN in the treatment of pediatric tibial shaft fractures and found out, the average time to union fractures was 18 weeks in the external fixation group, compared with 7 weeks in the ESIN group and the time to full weight-bearing in the ESIN group was 7 weeks which was 3 weeks less than that in the external fixation group which was 10 weeks.

Kubiak *et al.*^[12] reported increased levels of patient satisfaction in association with ESIN. Till *et al.*^[13] reported a similarly high level of patient satisfaction in 70 patients with long-bone fractures that were treated with ESIN, 14 of which involved the tibia.

In their series 64 patients (91%) described their functional ability as perfect, and 65 patients (93%) reported that their

contentment with the procedure was great. Bar-On *et al.*^[2] reported that all of the 10 children parents who had been treated with elastic stable intramedullary nailing would have their children undergo the same treatment again, whereas the parents of two of eight cases who had been managed with external fixation would prefer non-operative treatment for their children in the future. Cullen *et al.*^[14] reported a mean time to union of 15 weeks in 83 open tibial fractures in children (mean age, 9 years) who had been managed with external fixation. Furthermore, Kubiak *et al.*^[12] reported less complication with superior functional in the group treated with TENs.

Our study's had limitations which are the absence of a comparable controlled group for comparison with other methods of treatment of the tibial shaft fractures in children and limited numbers of open fractures. On the other hand, our results were in accord to other authors raising our hypothesis that the flexible intramedullary nailing has great advantages for treatment of tibial shaft fracture in children with selected age group between 6 and 12 years age group compared to the other methods used.

CONCLUSIONS

Flexible intramedullary nailing is a valuable treatment option in selected cases of diaphyseal tibial fractures from 6 to 12 years old age group. The procedure has low morbidity also good results with short hospitalization. Most of the associated complications can be avoided by strictly adhering to the basic principles and technical aspects.

Ethical approval

All procedures which have been performed in the studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1975 Helsinki Declaration as revised in 2000.

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