Evaluation of treatment of open diaphyseal fracture of tibia in children by elastic stable intramedullary nailing

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Background
In children, the guidelines for treatment of tibial open fractures are not clear. The options of treatment include debridement and casting, which may be isolated or with pins incorporated in the plaster with the possibility of loss of reduction and difficulties in wound care. External fixators, which may be circular or monoplanar, and intramedullary fixations, which provide axial stability and a good access to wound care for reconstructive soft tissue procedures, have been used.
Patients and methods
In the period between February 2012 to February 2014, 25 cases of open diaphyseal fractures of the tibia in children underwent debridement and fixation by elastic stable intramedullary nails. The age ranged between 5 and 12 years. There were 16 boys and nine girls. Right side was affected in 15 cases and left side was affected in 10 cases. The fractures were categorized using Gustilo–Anderson classification: type I, 10 cases; type II, nine cases; and type III, six cases, with two cases from type IIIa and four cases from type IIIb, and no cases of type IIIc. The time from injury to surgery varied from 3 to 9 h. Coverage procedures were done to six cases from Gustilo type III.
All patients underwent clinical, radiographic, and by Flynn's scoring criteria for proper evaluation.
Results
According to Flynn's scoring criteria, 23 cases had excellent and satisfactory results (17 cases were excellent and six cases were satisfactory); however, two cases were poor.
Conclusion
Intramedullary fixation of open diaphyseal fractures of tibia in children by elastic nails is a valuable method of treatment of displaced open fractures of the tibia in skeletally immature patients, which allows a good access for wound care and provides axial stability and early motion.

Keywords:
diaphysis of tibia, elastic nails, open fractures in children

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Introduction

The treatment of closed fractures of the tibia in adults and children has been extensively studied with clear guidelines [1]. The open fractures of tibia in adults have clear consensual principles of management as debridement, fixation of the fracture, and wound closure, which may be primary or secondary, or skin reconstruction, which may be primary or secondary.

However, in children, the guidelines are not clear [2,3]. Closed fractures of the tibia in children heal rapidly with minimal complications; it mostly occurs owing to low-energy trauma. However, open fractures in children are usually caused by a high-energy insult, with extensive soft tissue injury, associated fibular fracture, and expected more complications [4].

The options of treatment of open tibial fracture in children include debridement and casting which may be isolated or with pins incorporated in the plaster. Plates and screws are rarely used and may be considered contraindicated. External fixators, which may be circular or monoplanar, and intramedullary fixation have been used [5–8].

The expected complications after open fractures of the tibia in children include infection, delayed union, malunion, angular or rotational deformities, and amputation, which may occur in severely affected cases. Soft tissue injuries may heal primary or secondary or may need grafts for soft tissue reconstruction [9,10].

Patients and methods

In the period between February 2012 and February 2014, 25 cases of open diaphyseal fractures of the tibia in children underwent debridement and intramedullary fixation by elastic stable intramedullary nails at Misr University for Science and Technology Teaching Hospital. The study was approved by the institutional ethics committee in the Orthopedic department, Faculty of medicine, Misr University for science and technology and a consent for each patient was signed by one of the parents.

The inclusion criteria were as follows:

(1) Age between 5 and 12 years.
(2) Open fractures of the tibia with no prior management provided in another hospital.

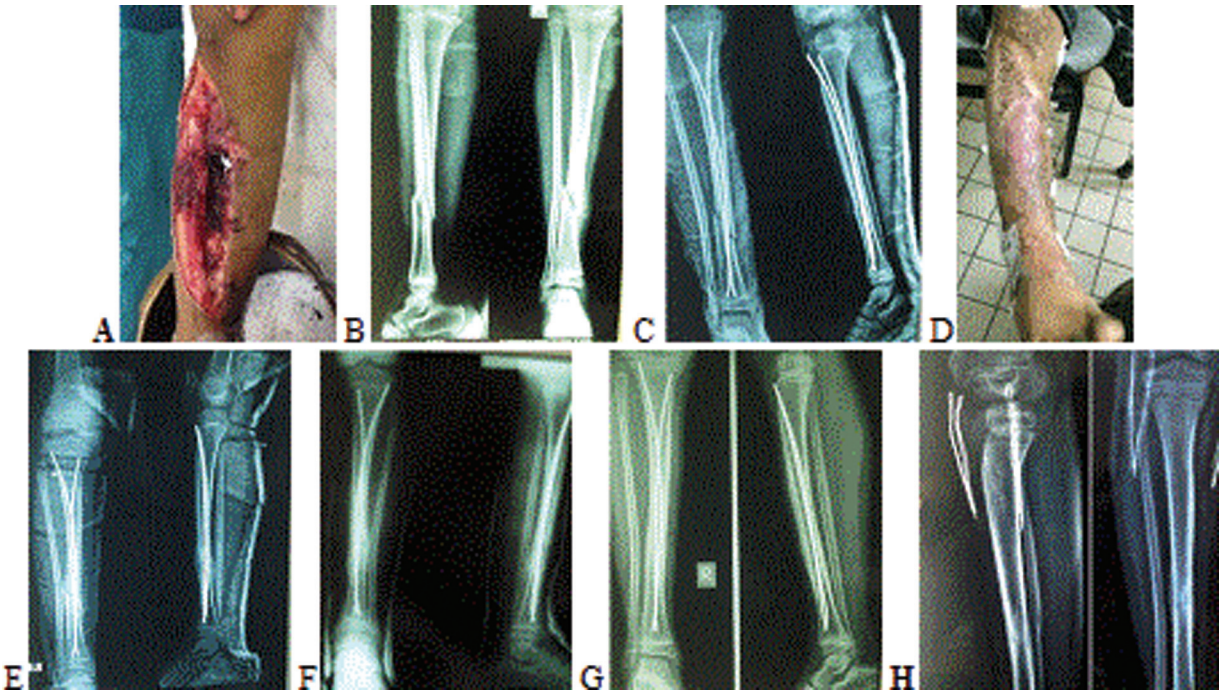
Patients with multiple fractures or polytraumatized were excluded.

All cases were subjected to careful assessment, both general and local, and categorized using Gustilo–Anderson classification for open fractures [11].

Operative technique

(1) All operations were performed under general anesthesia.
(2) Image intensifier was used in all cases.
(3) Debridement was done in all cases by exploration of the wound, excision of the devitalized tissues, removal of all foreign bodies, and thorough wash by saline solutions and the addition of garamycin antibiotic in the last stages of wash.
(4) Two intramedullary elastic stable nails were applied.
(5) Two small incisions were made approximately 1.5 cm in the metaphyseal area of the upper tibia below the physeal plate medially and laterally.
(6) The nail size is determined by image intensifier. It should be approximately 40% of the diameter of the medulla.
(7) The nail is bent gently before insertion.
(8) The site of entry of the nail is detected under image control, and it should be in the metaphyseal area below the physeal plate and in the middle of the anteroposterior borders of the tibia. The cortex is breached by a small awl and the medulla is entered.
(9) Both nails were advanced to the proximal fragment sequentially and stopped before the fracture site.
(10) Then fracture reduction and advancement of both nails to the distal fragment was performed.
(11) All nails are cut, and approximately 2 cm of the nail was left protruded from the cortex to allow removal after complete healing and embedded under the subcutaneous tissue and skin.
(12) The skin wound is left open in small wounds of Gustilo type I, and wounds of gustillo type II were left open for frequent dressing followed by secondary sutures or closed by very wide sutures just for approximation, whereas wounds of Gustilo type III were left for secondary sutures after frequent dressings or partial-thickness skin grafts from the contralateral thigh after the presence of viable granulation tissue and the wound become clean.
(13) A splint was applied in all cases for 4 weeks postoperatively.
(14) Postoperative antibiotics were applied to all patients in the form of intravenous injections of third-generation cephalosporin with the dose 50 mg/kg for 3 days to be continued by an oral form for 7 days. Dosage/duration may be modified according to the condition of the wound.
(15) All cases were checked postoperatively by radiograph for alignment, reduction, and position of nails.
(16) The time from injury to surgery varied from 3 to 9 h.
(17) The age ranged from 5 to 12 years.
(18) The right side was affected in 15 patients, whereas the left side was affected in 10 patients.
(19) Sixteen cases were boys and nine were girls.
(20) The mode of injury was 11 cases of road traffic accidents, nine cases were injured during athletic activities, two cases during bicycling, and three cases owing to falls during stair climbing.
(21) The follow-up period ranged between 6 and 18 months.
(22) Open tibial fractures were categorized using Gustilo classification.
    (a) Type I: 10 cases.
    (b) Type II: nine cases.
    (c) Type III: six cases.
        (i) Two cases IIIa.
        (ii) Four cases IIIb.
    (d) The soft tissue injuries were dealt with as follows:
        (i) Ten cases of Gustilo type I were left for healing.
        (ii) Nine cases of Gustilo type II four cases were closed by very wide sutures just for approximation and five cases were subjected to delayed secondary sutures after the confirmation of clean wound in a period ranged between 5 and 7 days.
        (iii) Six cases of Gustilo III were subjected to repeated dressings till the appearance of healthy granulation tissue and then partial-thickness skin grafts were used usually after 10–15 days.

Figure 1



(a) Photograph showing the area of skin loss. (b) Lateral and anteroposterior views showing fractures of the tibial diaphysis. (c) Postoperative radiograph anteroposterior and lateral views after fixation by intramedullary stable elastic nails (d) Photograph showing the leg after partial-thickens skin graft. (e) Postoperative radiograph anteroposterior and lateral after 1 month. (f) Postoperative radiograph lateral and anteroposterior after 2 months. (g) Radiograph anteroposterior and lateral complete healing after 3 months. (h) Postoperative anteroposterior and lateral radiographs after removal of the nails after 10 months.

Table 1 Comparison between Gustilo types regarding time to union

Gustilo type	*N*	Mean	SD	*F*	*P* value
I	10	9.40	2.319	13.018	<0.0001
II	9	12.22	2.728		
III	6	15.33	1.033		
Total	25	11.84	3.210		

P value less than 0.0001, significant.

Postoperatively, all cases were observed for any sign of infection and discharged after stabilization of the wound.

The hospital stay varied between 3 and 16 days in cases subjected to repeated dressings and partial-thickness skin grafts.

All patients were evaluated daily for the condition of the wounds during the hospital stay and then weekly till healing of the wound, and then every 2 weeks till fracture healing (Fig. 1).

Statistical analysis

Descriptive statistics was done using number and percentage for categorical variables, whereas for quantitative variables, mean±SD and range (minimum–maximum) were used.

Comparison of quantitative variables between more than two groups was done using analysis of variance test, whereas of quantitative variables between two groups was done using Student's t test. Comparison of categorical variables between groups was done using χ^2 test.

Results

All cases were evaluated clinically and radiologically for wound healing, rotational or angular deformities, bone union limb shortening or lengthening, and according to Flynn's scoring criteria [12]. All cases united in a period ranging between 8 and 16 weeks.

The cases that united in 16 weeks were all from Gustilo type III cases. The statistical analysis revealed that fractures of Gustilo I healed faster than type II, and fractures type II united faster than type III ($P<0.0001$) (Table 1).

There is no difference in statistical values between males and females regarding the time to union ($P=0.492$) (Table 2).

Statistical analysis shows that the younger the age the faster the healing time ($P<0.0001$) (Table 3).

Statistical analysis revealed that there is no relation between Gustilo type and sex ($P=0.179$) (Table 4).

Table 2 Comparison between males and females regarding time to union

	Sex	*N*	Mean	SD	*t*	*P*
Time to union	Male	16	11.50	3.055	0.698	0.492
	Female	9	12.44	3.575		

P value equal to 0.492, not significant.

Table 3 Correlation between age and time to union

	Time to union
Age	
Pearson correlation	0.820**
Significance (two-tailed)	<0.0001
N	25

P value is significant. **Significance (two-tailed).

Table 4 Relation between Gustilo type and sex

	Sex		χ^2	*P*
	Male	Female		
Gustilo				
G1				
Count	5	5	3.802	0.179
% within sex	31.3	55.6		
G2				
Count	8	1		
% within sex	50.0	11.1		
G3				
Count	3	3		
% within sex	18.8	33.3		
Total				
Count	16	9		
% within sex	100.0	100.0		

P value equal to 0.179, not significant.

According to Flynn's scoring criteria, 23 cases had excellent and satisfactory results (17 cases were excellent and six cases were satisfactory) whereas two cases were poor. Of the two cases with poor result, one developed shortening of more than 2 cm and angular deformity more than 10° and the other developed infection and skin sloughing after partial-thickness skin graft and the two cases have painful legs.

Discussion

Patients with open fractures of the tibia who are skeletally immature represent a great challenge to the orthopedic surgeon.

Options of treatment include debridement, closed methods of reduction, and application of a cast, which were used widely to provide an easy method of treatment, but the difficulty in wound care and the possible loss of reduction are the problems with the use of this technique, and also if skin reconstructive procedures were decided. The use of casting with pins incorporated in the cast for better stability makes the daily wound care difficult and affects the results, with possible loss of reduction [2,13].

External fixation after debridement is also widely used. Fixators whether circular or monoplanar are good methods of fixation of open fractures but are not without complications, such as pin tract infections, loosing of the fixators with the possible malunion, and interference with the access for skin and soft tissue reconstructive procedures [14,15].

Internal fixation of open fractures is considered a contraindication by many orthopedic surgeons. All these make the use of stable elastic intramedullary nailing of the tibia in open fractures a very good option [16,17].

It allows a good access for daily dressing and wound care and does not interfere with skin and soft tissue reconstructive surgeries if needed. It is not invasive, as the skin for introduction of the nails is about 1–2 cm in the medial and lateral aspects of the upper tibia below the physical plate, and the incision is only for the debridement of the wound.

In this series, the tip of the nails was bent to facilitate gliding inside the medulla. The point of entry, the curve of the nail when prebent before insertion, and the distal end of the nail with the other nail offer better stability, prevent axial rotation, and allow earlier mobility.

The nail tip of each one at the site of insertion was cut and left approximately 1 or 2 cm from the nail end to be embedded under subcutaneous tissue and skin and to allow easy removal. By this way, skin infection was avoided and not present, as was present in studies where the nails was left protruded from the skin for easy removal [18]. Slongo *et al*. [19] used end caps to decrease the soft tissue irritation and prevent nail migration.

In this study, there were no reported cases of physeal arrest or growth affection owing to the careful entry point which is done under the control of image intensifier, which facilitates avoidance of violation of the physeal plate.

No cases of nonunion were reported in this study.

The infection rate in this study is very low compared with external fixators or casting. One case developed infection and sloughing of the skin after partial-thickness graft. The case was from Gustilo type III.

No cases of nail migration were reported. Nail migration through the skin was reported in four cases causing infection in approximately 20% of cases, reported by Gicquel *et al.* [20].

Shortening greater than 2 cm and angular deformity with residual pain were reported in one case, which is a 12 year-old obese boy from Gustilo type III.

Griffet *et al*. [21] reported no cases of refracture after healing in treatment of closed tibial fractures by stable intramedullary elastic nailing. In this study, there were no reported cases of refracture after healing and also no reported cases of limitation of knee or ankle movement and no physiotherapy was required.

Conclusion

Intramedullary fixation of open diaphyseal fracture of tibia in children by elastic nails is an effective procedure in the treatment of displaced open fractures of the tibia in patients who are skeletally immature provides a good access for wound care. It allows the performance of soft tissue reconstructive procedures and with less hospital study. It also provides early motion and less invasive surgery with early weight bearing, more axial stability, and less rotational and angular deformities.

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Conflicts of interest

There are no conflicts of interest.

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