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Flexible intramedullary nail fixation for paediatric tibial diaphysis fractures

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Abstract

Background and objectives: Paediatric tibial diaphysis fractures were usually treated by conservative treatment without surgery. Nowadays, flexible intramedullary nails are frequently used in these fractures. The aim of this study was to assess the outcome of this technique and to evaluate the results regarding the union rate and postoperative complications. **Methods:** This study included 48 patients aged between 5 and 15 years. Forty-six cases had unilateral tibial diaphysis fractures and 2 cases had bilateral fractures. All the patients were treated with closed flexible intramedullary nailing. The study was done prospectively over a period of 2.5 years in West Erbil Emergency Hospital with a minimum follow up of 6 months. **Results:** In our study, the mean age was 8.8 years. The participants consisted of 36 patients (72%) males and 14 (28%) females. Fractures of the distal third of the tibial diaphysis were the most common and accounted for 31 cases (62%), those with middle third fracture were 19 cases (38%) and the upper third were 4 cases (8%). All patients got union with an average of 11 weeks. Nail protrusion and skin irritation were the most common complications, found in 10 patients (20%), and reoperation was done in three of them by cutting tip of the nail.

Conclusion: Flexible intramedullary nails are effective and minimally invasive method for treatment of paediatric tibial diaphysis fractures; they control the length, angulations and rotation, as they provide stability through three points of fixations for each nail.

Key words: Flexible intramedullary nail,Paediatric,Tibial diaphysis fracture.

Introduction

Tibial fracture is common across all age groups and is considered the third most common long bone injury in children and adolescents. It is more common in males and occurs due to various mechanisms[1]. The average age of occurrence is 8 years, and its frequency does not change significantly with age.

Most of paediatric tibial fractures (70%) are isolated injuries, and 30% of these fractures are associated with ipsilateral fibular fractures. Tibial fractures occur in the distal third in 50% to 70% of the cases, while 19% to 39% occurs in the middle third. The least commonly affected is the proximal third. Types of paediatric tibial fractures are oblique in 35%, comminuted in 32%, transverse in 20%, and spiral in 13% of the cases[2].

Previously, surgical treatment has rarely been indicated in tibial fractures in children3. Excellent results can be achieved with conservative treatment, with reported union rates of more than 90%, and 100% full functional recovery4. In the last years, management of paediatric tibial fractures has changed more towards surgical intervention because of quicker recovery, shorter rehabilitation period, less immobilization, lack of stiffness of adjoining joints, and less psychological impact to the children[3]. In some cases, reduction cannot be kept due to significant shortening, angulation, or malrotation at the fracture site, making surgical intervention necessary.

In other cases, operative treatment is needed because of polytrauma, open fracture, or compartment syndrome[4]. Rigid intramedullary nails are generally contraindicated in paediatric age groups, because of skeletal immaturity and risk of physeal injury with avascular necrosis. Furthermore, external fixation is associated with high complication rates such as loosening and pin tract site infection. As a result, flexible intramedullary nailing is being used with increasing frequency because of its effectiveness and low complication rate[5,6]. These flexible nails have good biomechanical stability from their “C” configuration, which produce three points of fixation and act as an internal splint[7]. The biomechanical principle of flexible nails is depending

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on the symmetrical bracing of two elastic nails inserted into the metaphysis, each supporting the inner cortical contact. This creates the following four biomechanical properties which are all essential to achieving the best results[8]: flexural stability, axial stability, translational and rotational stability.

The aim of this study was to assess the outcome of flexible intramedullary nails in the treatment of tibial diaphysis fractures in children and to evaluate the results regarding the union rate and postoperative complications.

Patients and methods

This is a prospective descriptive case control study, which includes 50 fractures (48 cases), with 46 unilateral and 2 bilateral tibial diaphysis fractures, collected over two and a half years between 1/5/2016 and 1/12/2018 with a minimum follow up period of 6 months.

All patients were admitted and underwent closed elastic nailing at West Erbil Emergency Hospital. A written consent was obtained from the parents of the patients who were enrolled in this study.

All patients aged between 5 and 15 years had sustained trauma either due to road traffic accidents or fall from height, and had suffered closed tibial diaphysis fracture, open tibial diaphysis fracture (Gustilo grade 1 and 2) or multiple injuries.

Exclusion criteria involved obese children more than 40 kg, those with open tibial diaphysis fracture (Gustilo grade 3), proximal or distal fractures near the growth plate or patients with compartment syndrome of the leg.

All data were analysed in a prospective manner from the preoperative period till the postoperative period. Outcome of the surgery regarding the union rate and complications were recorded.

In general, the choice between conservative and surgical treatment was according to the acceptable alignment criteria cited by Heinrich and Mooney[9], which are detailed in Table1:

Table (1): Acceptable alignment of a paediatric diaphyseal tibial fracture described by Heinrich and Monney

Patient Age	< 8 Years	≥ 8 Years
Valgus	5 degrees	5 degrees
Varus	10 degrees	5 degrees
Angulation anterior	10 degrees	5 degrees
Angulation posterior	5 degrees	0 degrees
Shortening	10 mm	5mm

After admission, all patients were assessed and resuscitated properly. All of them were operated on within 1 day after doing all necessary preoperative preparations. In the theatre, we used the following techniques of flexible intramedullary nailing: Put the patient in supine position on the radiolucent table. After induction of general anaesthesia and under fluoroscopy, we made marks on the skin at the tibial tubercle and the starting points for nail entry. The starting point for nail entry is 1-2 cm distal to the physis and 2 cm posterior to the tibial tubercle, as shown in Figure 1 (A). We chose two appropriately sized nails, 2.3 mm or 4mm in diameter, depending on the width of medullary canal. We used the largest diameter available that fit the medullary canal according to Flynn formula, which states that the nail diameter should be 40% of the narrowest part of medullary canal. The width of the medullary canal was measured from true size x-ray. Titanium nails were used. The nails had bevelled blunt tips; the tips of the nails are usually designed to be bent by about 45 degrees in order not to penetrate the opposite cortex. We made two longitudinal incisions, about 1-2 cm, on both the medial and lateral side of the proximal tibial metaphysis. After making the skin incision, we used either awl or drill bit to make the hole by holding the awl or the drill bit first perpendicular (90 degrees) to the bone then bending it to 60 degrees after penetrating the cortex, Figure 1 (A). Prebent nails were inserted, as shown in Figure 1 (B). We placed the selected nail on the T-handle and inserted it in an antigrade fashion. Under fluoroscopy, we slid the nail along the opposite cortex until the fracture was reached, Figure 1 (B). We reduced the fracture by holding the knee in flexed position then traction of the ankle joint with counter traction from above. After reduction, we advanced the nail across the fracture. We placed the second nail from the other side in a similar fashion, as shown in Figure 1 (B). We bent the proximal nail ends and cut them 1 cm from the cortical surface so that the nail ends sit deep to the compartment fascia, Figure 1 (C).

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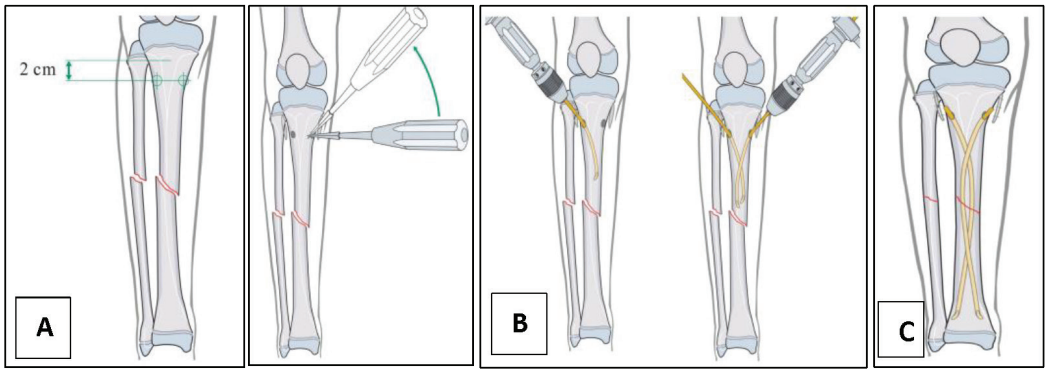

Figure (1): A: Proper starting point for nail insertion., B: Insertion of elastic nail, C: Cutting of the nails8.

In the postoperative period we did the followings: Leg elevation for 24 - 48 hours. Above knee back slab was applied in 15 degrees in flexion position for 2 to 3 weeks. The patients were discharged on the 2nd postoperative day providing that there were no associated injuries. All patients continued on oral antibiotics for 1 week, except those with open fractures, who received IV antibiotics and then changed to oral antibiotics. On 14th day sutures were removed, and active hip and knee exercises started. Full weight bearing was promoted when there was complete union and evidence of bridging callus. Fractures were considered to be united when tricortical callus was visible on the radiographs and consolidation at the fracture site was present on clinical examination. All patients were reassessed clinically and radiologically many times, with a minimum of 6 months follow up period. In general, the final results were assessed according to Flynn criteria, as shown in Table 2.

Table (2): Flynn criteria10

Variables	Excellent	Satisfactory	Poor
Shortening	< 1cm	< 2cm	> 2cm
Angulation	5 degrees	10 degrees	> 10 degrees
Pain	None	None	Present
Other complications	None	Minor & resolved	Major & lasting

Case No. 1: A 13 year old male child with spiral fracture of distal tibial diaphysis treated with titanium elastic nailing.

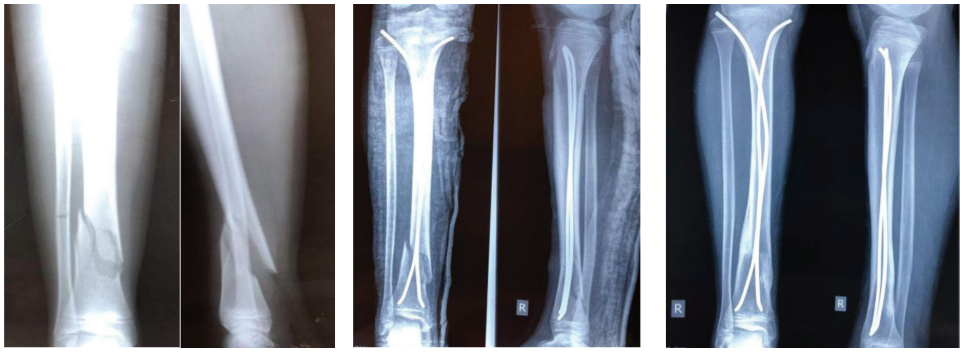

Figure (2): Preoperative (a) and postoperative AP and lateral radiographs.

Case No. 2: A 10 year-old child with multiple fractures (tibia and bilateral femur) treated with titanium elastic nailing.

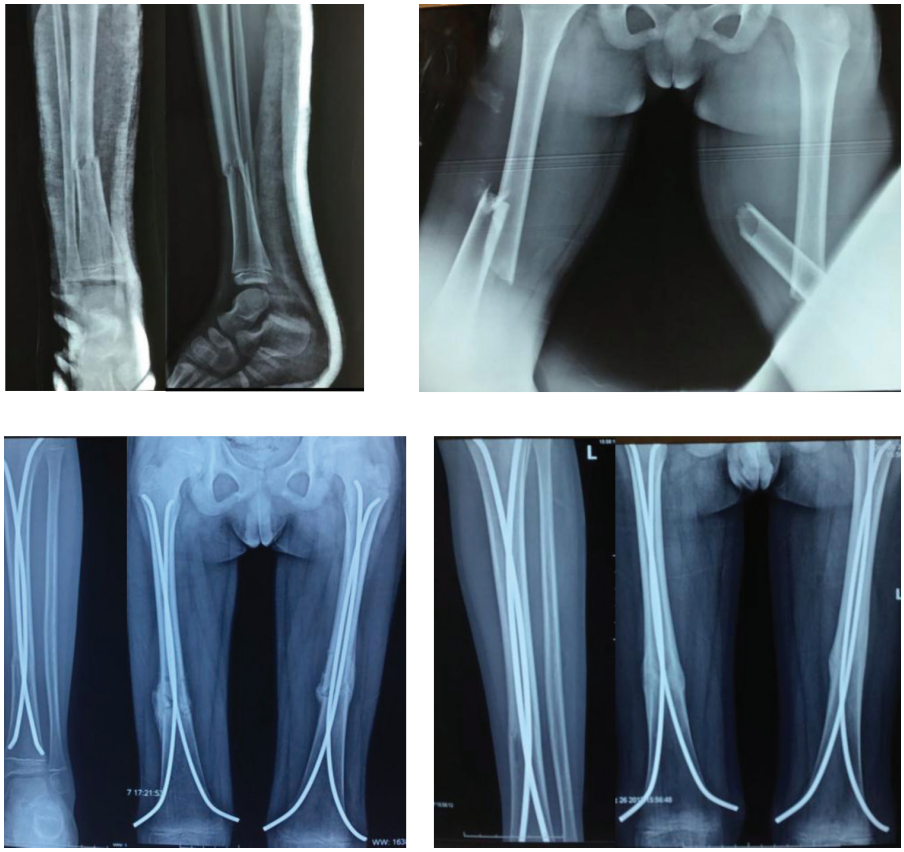

Figure (3): Preoperative (a) and postoperative AP and lateral radiographs.

Results

All 48 cases (50 factures) that sustained tibial diaphysis fractures were identified. Demographic data of the patients, fracture pattern, level of fracture, type of fracture and associated injuries are mentioned in Table 3. All patients were skeletally immature; age ranged between 5 and 15 years with an average of 8.8 years. The gender incidences were 36 males (72%) and 14 females (28%). The fractures were on the right side in 31 patients (62%), and on the left side in 19 patients (38%). The most com-

mon mechanism of the injury was road traffic accidents (RTA), which occurred in 35 patients (70%), and fall from height (FFH), which occurred in 15 patients (30%). Fractures that involved the distal third of diaphysis were the most common and accounted for 31 patients (62%), those with facture of the middle third accounted for 15 patients (30%), and those with upper third fracture accounted for 4 patients (8%), as shown in Table 3.

In 29 patients (58%), the fractures were short oblique; in 16 patients (32%), the fractures were transverse; in 5 patients (10%), the fractures were spiral. The fractures were closed in 44 patients (88%), type 1 open fracture in 4 patients (8%), and type 2 open fracture in 2 patients (4%). In the current study, the associated injuries (2 patients with bilateral tibial fractures, 2 patients with head injuries, 1 patient with bilateral femoral fractures, 1 patient with dorsal foot wound, 1 patient with fracture of the 1st metatarsal bone, 1 patient with clavicle fracture, and 1 patient with fracture of the distal radius) were present in 9 patients (18%).

Table (3): Demographic data of the patients, fracture pattern, level of fracture, type of fracture and associated injuries.

Variables	Categories	No.	%
Gender	Male	36	72
	Female	14	28
Site of fracture	Right	31	62
	Left	19	38
Mechanism of injury	RTA*	35	70
	FFH**	15	30
Site of fracture	Upper third	4	8
	Middle third	15	30
	Lower third	31	62
Pattern of fracture	Short oblique	29	58
	Spiral	5	10
	Transverse	16	32
Type of fracture	Open (Gustilo 1)	2	4
	Open (Gustilo 2)	4	8
	Closed	44	88
Associated injuries	Yes	9	18
	No	41	82

* RTA: Road traffic accident. **FFH: Fall from height

For all the patients who underwent operation, the operation time was taken into account. In 7 patients (14%), the duration of the operation was between 20-29 minutes, and in 43 patients (86%), the duration of the operation was 30-60 minutes. The average duration for the surgeries was 38 minutes. All fractures were reduced closely. In this study, all the patients were immobilized with back slab post operation. Twenty-four patients (48%) were immobilized for 2-3 weeks, 17 patients (34%) were immobilized for 4 weeks, and 9 patients (18%) were immobilized for 5-6 weeks. In the current study, 38 patients (76%) were capable of partial weight bearing in a period between 1-4 weeks, while in 12 patients (24%) the partial weight bearing occurred in a period of 5-7 weeks. Unsupported full weight bearing was started in 9-11 weeks in 38 patients (76%) and 12-16 weeks in 12 patients (24%), and no cases delayed more than 16 weeks.

In the present study, complete union was achieved by 9-11weeks in 34 patients (68%), by 12 weeks in 10 patients (20%), and by 13-16 weeks in 6 patients (12%), which was considered delayed union. The average time for complete union was 11 weeks. No case of non-union was recorded as there was no pain at fracture site at 6 months postoperatively, as shown in Figure 2.

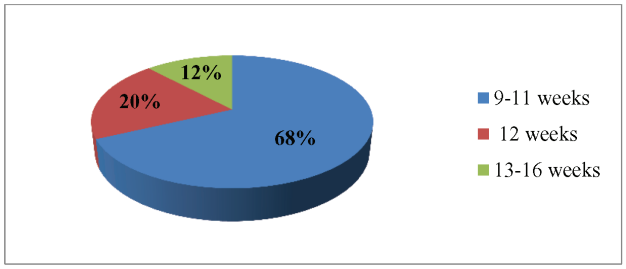

Figure (2): Time of complete union.

The complications that occurred in our study were all minor and treated accordingly. Nail protrusion and skin irritation occurred in 10 patients (20%), out of which 3 patients were treated by cutting the tip of the nails because of severe pain and irritation

No shortening more than 0.5 cm was recorded. Shortening was recorded in 20 patients (40%), in which no intervention was needed.

In 45 patients (90%), the degree of angulations in AP and lateral views were less than 5 degrees, while in 5 patients (10%), the degree of angulations were 5-10 degrees. All patients had less than 5 degrees of rotation, and all these degrees were accepted according to Table 1.

Only in 5 patients (10%), limitation of knee movement was recorded, which was mild. In the current study, other than nail removal, there were other operations done in 5 of the patients: 2 patients with type 2 gustilo open fracture were treated with wound debridement at the 7th day, and 3 patients underwent cutting the tip of the nails due to skin irritation after two months of the 1st operation. No case of re-fracture was recorded.

In 15 patients (30%), the results were satisfactory due to skin irritation (in 10 of them) or malalignment (in 5 of them), and in 35 patients (70%) the results were excellent and there were no poor results, as shown in Table 4.

Table (4): Outcome according to Flynn criteria

Variables	Excellent	Satisfactory	Poor
Shortening	50	0	0
Angulation	45	5	0
Pain	50	0	0
Other complications	40	10	0

Discussion

The fractures of tibial diaphysis are common among the paediatric age groups, and it is usually treated by cast immobilization as initial treatment. However, there are certain conditions that necessitate surgical stabilization, for example, open fractures, multiple injuries, unstable fractures, and failure of conservative treatment[3].

In the past, most of tibial diaphysis fractures, even the unstable ones, were treated by manipulation and cast immobilization, which had certain complications including malunion, and limb length discrepancy, or by using traditional fixations such as external fixators, which sometimes lead to pin tract infection and loosening. Nowadays, with the development of elastic nails, most of these complications have been minimized as these nails provide a load sharing biocompatible internal splint, allowing early mobilization and avoiding any growth disturbance by preventing damage to epiphyseal plate and minimalizing risk of infection and soft tissue damage[11].

In our study, the right side (62%) was more common than the left side (38%). Regarding the mechanism of injury, RTA (70%) was more common than FFH (30%). These results are compatible to a study conducted by Anjum, who showed that the right side was more common than the left, 60% and 40%, respectively, and that RTA(80%) was a more common cause than FFH (20%) [12]. Also, the current study showed that the fractures were more common in the distal third of the tibial diaphysis, which occurred in 31 patients (62%), 15 patients (30%) suffered fracture in the middle third, and 4 patients (8%) had fracture in the upper third.

In this study, the average time of complete union was 11 weeks, which is compatible to a study done by Zarad, in which the average time was 10[13] In another study done by Swindells, the average time of complete union was 10 weeks[14], and in a study done by Bhaskar, the average time of complete union was 11 weeks[15], which are all compatible.

In the current study, there was no case of non-union as they were all reduced closely. This is compatible to a study done by Kamran, which also did not have any case of non-union[16]. Moreover, in this study, there were 6 cases of delayed union in which complete healing took more than 12 weeks, which were due to a type of open This is compatible to a study done by Uludaş in which there were complete union of all the 20 cases with 4 cases of delayed

union and no cases of non-union[17]. The complications that occurred in this study were mostly minor, including nail protrusion that happened in 10 patients, which was due to improper cutting of the nails, and angulation 5-10 degrees in 5 patients, which was due to inadequate reduction. This is compatible to a study done by Elseyd in which there were 3 patients of total 20 patients with nail protrusion and skin irritation, and only 2 patients with angulation 5-10 degrees[18].

Regarding limb length discrepancy in the current study, no more than 5 mm discrepancy was recorded. This little discrepancy might be due to overlapping, especially in spiral fractures. Compatible results were recorded in a study done by Jeong, in which no more than 10 mm discrepancy was recorded[19] in 16 patients with tibial diaphysis fracture .In the current study, at 6th month follow up, 45 patients (90%) had full range of knee movements and 5 (10%) patients had mild limitation of knee movements due to bursitis and skin irritation at entry site. A study done by Sharma showed compatible results regarding range of motion, in which all 25 patients regained full range of motion[20].

According to Flynn criteria, our study showed excellent results in 35 patients (70%) and satisfactory results in 15 patients (30%), which were either due to nail protrusion or malalignment with no poor results. A study done by Vaish showed compatible results, excellent results were seen in 73% of the patients and satisfactory results were seen in 27% with no poor results[21]. In another study done by Elsayd, in a total of 20 patients, 15 of them (75%) had excellent results and 5 patients (25%) had satisfactory results, and no poor results were seen[18].

Conclusion

Flexible intramedullary nails are effective way for treatment of paediatric tibial diaphysis fractures; they control the length, angulations and rotation, as they provide stability through three points of fixations for each nail. It is a simple and easy method but with radiation risk. Although elastic nails have complications, they are avoidable and minor, and can be managed with minimal intervention.

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