Diaphyseal femur fracture in children: Comparative study between treatment using compression plates versus titanium elastic nails (TENs)

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Abstract

Aim of the study
To compare and evaluate the outcome of treatment of diaphyseal femur fracture in children treated with compression plates versus TEN.
Background
Diaphyseal femur fractures in children are the most common musculoskeletal injury in children requiring inpatient treatment. The most common fracture causes include: falls, road traffic accidents and abuse. Different treatment options may be applied based on the patient's age, fracture characteristics and associated musculoskeletal or neurovascular injuries.
Surgical treatment of pediatric femur fractures is indicated in the 6-14 years age group, as the treatment can lead to rapid mobilization and shorter hospital stay.
Treatment with TEN is considered a treatment option as it is minimally invasive and allows for better management of diaphyseal fractures of the middle third. However, this type of treatment does not control the rotation and shortening of the limb.
Another treatment option is fixation with compression plates, which allows for better stability and control of the fracture.
Another treatment options include external fixation, skin traction and hip spica.
Patients and Methods
This study was prospective, clinical study.
We treated a total of 30 patients aged 6-14 years who have a diaphyseal femur fracture,
16 of them with closed reduction and TEN and 14 with open reduction and compression plate.
Every patient was evaluated periodically both radiologically and clinically.
Results
30 patients (16 in the TEN group and 14 in the compression plate group), at 3 months, the compression plate group exhibited better recovery based on the consolidation and knee flexion. Flexible nail operations are safer with fewer complications. In addition, particularly wound complications were relatively higher with compression plate group.
Conclusion
The group of patients treated with compression plate exhibited better radiological recovery and return to their activity earlier. Furthermore, they suffered relatively higher surgical wound complications.

Keywords
Titanium elastic nail, compression plate, femur fracture in children.

Introduction

Diaphyseal femur fractures in children account for 1.4-1.7% of all fractures, and 7.6% of those involving the long bones. The ratio of diaphyseal femur fractures between males and females is 2.6:1 [1,2]. In children between 6 and 9 years of age, these fractures are often caused by being struck by motor vehicles, and can lead to a complex and unstable fractures[3]. A small child can sustain a fracture by a simple fall on level ground while playing, but for the older child a stronger force is required[4]. Most fractures are displaced and factors that should be considered for choice of treatment are age, type of injury, associated injuries, type and location of the fracture, psychological and social situation and the ability of the family to take care of the child.

A variety of methods have been described by different studies and authors for the management of femur diaphyseal fractures of children between the ages of 6 to 14 years. Some of the techniques includes closed reduction and internal fixation(CRIF) with elastic nails, open reduction and internal fixation (ORIF) with compression plates, external fixators and skeletal traction with spica casting[5]. Nowadays there is an

increased tendency towards operative fixation of paediatric femur fractures because of rapid recovery and to avoid prolonged immobilization[6].

The use of elastic intramedullary nails is considered a treatment option for patients between 5 and 11 years old[7]. A minimally invasive approach is performed and allows better managemnet of diaphyseal fractures of the middle third , however, this type of treatment does not control the rotation and shortening of the limb(8).

Another treatment option is fixation with plates, which can be achieved through open reduction and plate fixation or indirect reduction and the application of a bridge plate[9,10]. The advent of locking plates, which has led to the concept of "external fixation internally", allows for better stability and can be applied with minimally invasive techniques[11].

The ideal treatment method should provide adequate stability to permit early mobilization, preserve or optimize fracture biology, minimize scarring, avoid serious complications, and achieve these goals in cost-effective manner.

The purpose of this study was to compare the results and complications of two methods of fixation which are compression plates and Titanium elastic nails (TEN) in children aged between 6 and 14 years.

Patients and methods

We conducted a prospective study of traumatic diaphyseal femoral fractures in a total number of 30 children from six to fourteen years of age. Among them 16 patients were treated with closed reduction and Titanium elastic nails (TEN), and 14 patients were treated with open reduction and internal fixation with compression plates. We had taken written informed consent from the parents of study participants or guardians and obtained base line information.

The inclusion criteria were as follows: patients 6-14 years of age with diaphyseal femur fracture, weight less than 50 kilograms. Patients with head trauma, open fractures, pathologic fractures, fracture line that extend either to the proximal or distal femur, active infections and non-ambulatory patients were excluded.

The fractures were classified according to AO/OTA classification as follows[12]: Type A

(simple, transverse or oblique), type B (middle fragment wedge shaped) or type C) complex with multiple fragments).

All patients were followed radiographically until the fracture healed and knee range of motion, rotational and angular deformities were reviewed clinically .

The procedures were performed under general anesthesia with the patients on a supine position, without the use of a fracture table. Fixation was then done according to the group into which the patient was added, with either CRIF with Titanium elstic nails or ORIF with compression plate and screws.

In the group where patients were treated with CRIF with flexible nails, and under flouroscopic control, two nails of the same diameter were inserted in a retrograde fashion. The diameter of the nail should be 40% of the narrowest diameter of the diaphysis. Two and half cm incisions were made in the medial and lateral thigh 2 cm proximal to distal femur growth plate[8]. These nails were precurved to an angle of 30 degrees. The apex of the curvature of the nails should be at the level of the fracture site to ensure a good equilibrium of reduction and stabilization forces[13]. The nail was placed on a T- handle which used to introduce the nail through the hole drilled in the cortex. Further advancement was achieved by applying oscilatory movement to the T-handle. Under flouroscopic visualization ensure that the nail was advancing in the medullary canal and not stuck against any of the cotices. The first nail was advanced up the distal fragment in a retrograde manner until just before the fracture site. The other nail was then introdued and advanced upwards in the same way. Now both nails lie in the distal fragment on one side of the fracture line. Then each nail was advanced across the fracture after fracture reduction which achieved by axial traction.

Once the fracture site was crossed, each nail was then advanced proximally. After crossing the fracture site the nails coulde be hammered gently up the medullary canal. One nail should stop at the level of the lesser trochanter and the other should stop at the greater trochanter short of trochanteric apophysis to avoid its injury. Average operating time was 36 minutes and average blood loss during surgery was 35 ml.

ORIF with compression plate and screws was done through a lateral approach. Often an incision was made of approximately 10 cm, taking into account the center of the fracture, a subvastus approach was performed, and straight 3.5 mm LCPs were placed. Avergae operating time was 73 minutes and avergae blood loss during surgery was 109 ml.

All of the patients were discharged on the second postoperative day, with free knee and hip mobility

based upon pain tolerance. The use of crutches and weight bearing were progressive.

After surgery, patients were assesed on an outpatient basis on postoperative day 14. The suture were removed, and isometric exercises of thigh muscles began. The patients were assessed at 3 and 6 weeks and at 3 and 6 months. During follow-up visits, the radiographic extent of the bony callus was assessed via anteroposterior and lateral radiograph of the thigh, according to Stans, et al [14]: grade 0, no identifiable bony callus; grade 1, primary bony callus formation with little or no new periosteal bone; grade 2, new periosteal bone formation on two sides of the femur; and grade 3, new periosteal bone formation on three or four sides of the femur. The mobility upon flexion and active knee extension was also evaluated. (Fig 1,2)

At the end of follow up period for each patient, Flynn's score was applied [15], (Table 1)

In addition, we evaluated complications, which were divided into minor and major complications. Minor complications were those that did not exhibit important clinical significance for postoperative outcomes, surgical complications resolved transopertaively, varus/valgus less than 10 degrees in children 6-10 years old and less than 5 degrees in those over 10 years old, and pain at the surgical scar.

Major complications were those in which an unplanned surgery was required, and those that involved persistent disability, hip or knee rigidity, malunion, nonunion, deep infection, and persistent nerve damage.

Figure 1: Seven years old, female patient, with transverse fracture right femur, pre and post operative x-rays. Consolidation at six months.

Figure 2: Eight years old, female patient, with fracture left femur treated with compression plate and screws.

Table 1: Flynn Scoring Criteria

	Exellent	**Satisfactory**	**poor**
Limb Length Discrepancy	≤1.0 cm	<2.0 cm	>2.0 cm
Sequence disorder	≤5º	6-10º	>10º
Pain	Absent	Absent	Present
Complications	Absent	Mild	Major complications and/or extended period for resolvable morbidity

Results

The mean follow–up time was 13.2 months.

The study had been conducted on 30 patients. 16 in the elastix nails group (11 males and 5 females) and 14 in the compression plate group (10 males and 4 females). The average age of all patients was 9.5 years (Table 2).

Table 2: Patients Demographics

Measurements	**TENs Patients' group**	**Compression Plate Patients' group**
Number of patients	16 (53.3%)	14 (46.7%)
Sex		
Male	11 (68.7%)	10 (71.4%)
Female	5 (31.3%)	4 (28.6)
Age		
Range	6-13 years	6-14 years
Mean Age	9.5 years	9.3 years

The AO/OTA international classification of fractures was used. The distribution and treatment has been shown in Table 3 and Table 4.

Table 3: Distribution of fractures according to AO/OTA classification

AO/OTA Classification	**Subtype**	**No.of Patients**
Type A	A1	16 (53.3%)
Type B	B3	8 (26.7%)
Type C	C1	6 (20%)

Table 4: Distribution of Patients about AO/OTA Classification and Treatment

	TENs	**Compression Plate**
A1	8 (50%)	8 (57.1%)
B3	6 (37.5%)	2 (14.3%)
C1	2 (12.5%)	4 (28.6%)

According time to union, all fractures united in a mean of 12 weeks(range 6-24 weeks). An increased time to union was associated with fixation type; the mean time to union (and standard deviation) was 16.3±7.7 weeks in the elastic nail group, and 11.2±5.2 weeks in plate group (Table 5).

Table 5: Time to Union

	Total (No.=30 fractures)	**TENs (No.=16 fractures)**	**Compression Plate (No.=14 fractures)**
Mean time to union (Stand.dev.) (wk)	12.01±7.6	16.3±7.7	11.2±5.2

stand. dev.= Standard Deviation wk= weeks

The range of movements at the knee joint in the TENs group ranged from 96 degrees to 146 degrees with an average of 138 degrees. The range of movements at the knee joint in the compression plate group ranged from 90 degrees to 148 degrees with an average of 140 degrees.

Table 6 shows comparison between the operative time and blood loss values of both patients groups.

Table 6: Comparison between the operative time and blood loss values

Variable	**TENs Mean±Std**	**Compression Plate Mean±Std**	**P value**
Age (year)	8.38±2.25	9.14±2.21	0.225
Operative Time(minute)	36.25±9.55	73.79±8.94	<0.001*
Blood Loss (cc)	35.94±38.78	109.36±40.47	0.001*

**Significant difference at 0.05 level.*

We used Mann-Whitney test to compare the age, operative time, and blood loss between the two groups of treatment. We found a siginificant difference in operative time and blood loss (the values in plate group are significantly larger than nail group), and no significant difference found between age in both groups.

Complications were noted during the course of treatment as follows:

In the TENs‘ patients group, 6 patients exhibited complications, 3 patients had skin irritation at site of nail insertion which disappeard after nail removal, 2 patients had varus deformity 8-10 degrees which were asymptomatic and another one patient had knee stiffness which require mobilization under general anaesthsia.

On the other hand, the compression plate patients‘ group exhibited more frequent complications; 4 patients had delayed wound healing, one of them exhibited deep wound infection which require thorough cleaning of the wound operatively, one patient showed knee rigidity which improved spontaneously, another 2 patients had loss of reduction, one due to a peri-implant fracture after a fall and the second one had a broken plate due to early weight bearing. (Table 7)

Table 7: Postoperative outcome

Outcome Measure	**TENs Patients‘ group**	**Compression Plate Patients‘ group**
Wound healing complications	3 (18.7%)	4 (28.5%)
Deformity	2 varus (12.5%)	2 loss of reduction (14.2%)
ROM in degrees	140º	148º
Knee stiffness	1 (6%)	1 (7%)

ROM= Range of movement

The final functional outcome by using Flynn score were compared between both groups is shown in (Table 8).

Table 8: The final functional outcome by using Flynn score

Flynn Score	Nail		Plate		P. value
	No.	%	No.	%	
Satisfactory or poor	4	25%	5	35.7%	0.694
Excellent	12	75%	9	64.3%	

Here, we used Fisher Exact test to see if there was an association between the treatment method and the Flynn Score, the test showd that there is an association as we can see that the P value is more than 0.05.

Discussion

The treatment of femur fractures in children aged between 6-14 years is prefreably surgical, but the ideal treatment is controversal. The most frequently used options are compression plates or elastic nails. Elastic nails have an advantage over plates fixation, as the technique requires minimal invasion of the soft tissues, but the principle disadvantage is a higher percentage of instability and malalignment complications.

In children from 6 to 14 years old, the primary surgical options for femoral shaft fractures include external fixation[16], plate and screw fixation[17], and intramedullary nailing[18]. Hansen et al., (1992) recommended the use of plate osteosynthesis. It has the disadvantage of large soft tissue dissection, an increase in the risk of infection and delayed union, nonunion besides a need for secondary operation to remove the implant[19].

The concept of flexible intramedullary nails was first proposed by Eriksson and Hovelius in 1979 for the treatment of femoral shaft fractures. Good results with flexible Ender nails have been reported in the 5-10 year age group by Heinrich et al.(1994) and Kissel and Miller(1989). Ligier et al first published their results of having fixed 123 femur fractures with Titanium elastic nails in the age group 5-16 years, and they reported 1 case of deep wound infection, 13 cases of superficial ulceration at nail insertion site and no disability or gait disturbance at 1 year follow up[20]. Flynn et al studied 49 pediatric femur fractures treated with TENs nails and reported no case of mal-alignment or limb length discrepancy of more than 1 cm. They also reported 8 cases of nail tip irritation at insertion site.

Another retrospective review was performed on 60 diaphyseal femoral fractures in 58 patients treated with submuscular plates. All of the fractures healed , and all patients returned to full activity. Two of the 58 patients(3%) suffered a major complication; an implant failure and a deep infection in an exposed fracture. None of the patients ehhibited clinically significant misaligment or leg length discrepancy. All of the patients underwent implant removal without complications[21].

We performed a comparison of treatments in pediatric femoral fractures to determine differences in clinical outcomes and improvements between Titanium elastic nails and compression plates, assessing radiographic evolution to determine time to union, knee mobility, and complications associated with the use of either method of treatment. Jolly A et al.(2016), reported time to union to be 10.7 weeks with the use of plate, while it was 14.3 weeks with the use of elastic nails[22].

Olivo CA et al. (2017), reported complete consolidation at 12 weeks with the use of plates, whereas in the patients treated with TENs, that was delayed up to 24 weeks [23].

In our study we had similar comparative results regarding time to union, which was 16.3 weeks in the TENs patients group and 11.2 weeks in the compression paltes group.

Intraoperative parameters that were compared were intraoperative blood loss and total time duration of surgery. The average time duration of surgery and intraoperative blood loss in the TENs group were 36 minutes and 35 cc respectively. In comparison to another study conducted by Jolly A, at al. The operative time was nearly the same but the blood loss was higher. In the compression plate group and in comparison with the same previous study, again, the opertive time was slightly longer but with lower blood loss.

In our study, we faced complications, which were realtively higher in compression plates group regarding wound healing complications. One case in the compression plates group needs operative debridement of the wound because of deep infection. In the elastic nail group, only 3 patients suffered irritation at the nail insertion site. Malalignment complications observed at 2 cases of the nail group, whereas, loss of reduction due to re-fall or early weight bearing were observe at 2 cases of the compression plate group.

Furthermore, in our patients, range of movement of the knee was significantly greater in patients treated with compression plate during the study, but with complete union there were no significant difference between the two groups of patients. The final

functional outcome between the two groups according to Flynn's score is insignificant.

Leg length discrepancy which is a relatively common complication after ORIF of pediatric fractures with plate and screws was not apparent here because of short term follow up. Other studies with longer follow up is needed to evaluate such a problem.

Conclusion

No single fixation method can be considered superior in all types and patterns of pediatric diaphyseal femur fractures between 6-14 years of age. Titanium elastic nails can be considered better method of treatment regarding lesser rate of surgical wound complications, less soft tissue damage, shorter operative time and less blood loss. On the other hand patients treated with compression plates exhibited better results with respect to consolidation and knee mobility. In addition, the use of plate is the best option as it is easier to control rotational and angular deformity and gives better stability at the fracture site.

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