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Management of Diaphyseal Fractures of the Femur in Children Using Flexible Intramedullary Nails

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ABSTRACT

Background: Advantages of the elastic intramedullary nailing (EIN) in treating diaphyseal fractures of the femur include the reduction of nearly all complications.

Objective: The aim of the current work was to evaluate the results of treatment of diaphyseal fractures of the femur in children using intramedullary elastic nail.

Patients and Methods: This prospective clinical trial study included a total of 18 children with femoral diaphyseal fracture treated with elastic intramedullary nails. They were admitted at the Department of Orthopedic Surgery, Zagazig University Hospitals, Egypt and Abusalim Trauma Hospital, Libya. This study was conducted between November 2021 to May 2022. All patients were followed up for six months.

Results: According to Flynn's score, the outcomes of the operation were excellent in 14 cases, satisfactory in 3 cases, and poor in 1 case. The 18 cases were united with radiological assessment. Only 1 case had superficial skin infection and just one case had mild pain.

Conclusion: It could be concluded that if used appropriately, elastic stable intramedullary nailing (ESIN) is a successful treatment for fracture femur in children with very few consequences.

Keywords: Diaphyseal Fractures, Femur, Flexible Intramedullary Nails.

INTRODUCTION

One of the most common long bone fractures is the thighbone, or femur [(1)]. In youngsters, the femoral diaphysis is the site of 1.4%-1.7% of all bone fractures and 7.6% of all long bone fractures. Males experience 2.6 times as many diaphyseal femoral fractures as females [(2)].

Injuries can be caused by a variety of factors, such as a slip and fall, a car crash, child abuse, an accident during a sporting event [(3)]. Thigh edema, shortening, and deformity along with extreme pain were all immediate results of the fracture [(4)]. Typically, the initial diagnosis can be made with just plain anteroposterior (AP) and lateral radiographs of the affected femur [(5)]. The Müller overall fracture classification system includes a specific categorization for long bone fractures **(6)** , and it's been modified for use with broken long bones in adults through the Orthopedic Trauma Association (OTA) as well as Arbeitsgemeinschaft Für Osteosynthesefragen (AO) [(7)].

Conservative methods, such as skin or skeleton traction, are frequently employed in treatment. Surgical methods include open reduction and internal fixation with a plate and screws, external fixation and closed reduction and

internal fixation with the elastic intramedullary nails under image intensifier [(8)].

Transportation, hygiene, tolerance, malunion, as well as delayed union are just some of the issues that come up in the context of Spica casting [(9)]. Rigid internal fixation with a plate, however, has the risks of a large incision, significant bleeding, and scarring, as well as the potential complications of re-fracture and a growth disruption [(10)].

Because the periosteum is not damaged, the fracture hematoma is not lost, blood loss is reduced, the growth plate is not compromised, early walking is possible, nail removal is painless, and the patient does not have to deal with a long scar, the elastic intramedullary nail is a clear improvement over the previous methods [(11)]. There are two potential problems with protruding elastic intramedullary nails: restricted knee motion and skin infections caused by the nail's sharp end [(4)].

The purpose of this research was to evaluate the results of treatment of diaphyseal fractures of the femur in children using intramedullary elastic nail.

PATIENTS AND METHODS

This prospective clinical trial study included a total of 18 children with femoral diaphyseal fracture treated with elastic intramedullary nails. They were admitted at the Department of Orthopedic Surgery, Zagazig University Hospitals, Egypt and Abusalim Trauma Hospital, Libya. This study was conducted between November 2021 to May 2022.

Ethical Consideration:

This study was ethically approved by Zagazig University's Research Ethics Committee, and submitted them to Zagazig University (#9005-11-10-2021). Written informed consent of all the participant parents was obtained. The study protocol conformed to the Helsinki Declaration, the ethical norm of the World Medical Association for human testing.

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Inclusion criteria:

Age 6-14 years, and diaphyseal fractures of the femur.

Exclusion criteria:

Patients age less than 6 years or more than 14 years, patients with head trauma, patients with neuromuscular disorders, skeletal dysplasia, and metabolic bone disease, open fractures, pathologic fractures, and active infections and non-ambulatory patients

All participants were subjected to:

1. A thorough review of the patient's medical history and an orthopedic examination.
2. X-ray anteroposterior as well as lateral views on affected side from hip to the knee joint.
3. All patients had full preoperative lab investigation before surgery including: Complete blood picture (CBC), Random blood sugar, viral screen, coagulation studies (PT/PTT) as well as Kidney and liver function tests.

Surgical technique:

Anesthesia:

All the surgeries were done while the patients were under general anesthesia.

Patient positioning:

Positioning the patient appropriately on a standard operating table. C-arm x-ray guidance was used while the patient was lying supine during the surgery.

The steps of procedure:

Under strict sterile conditions and after draping, about 2 cm proximal to the physis, two tiny skin incisions (each about 2.5 cm in length) were made on the medial and lateral sides. Drilling or awling a hole at a 45-degree angle in the coronal plane into the bone cortex is performed under fluoroscopic supervision. It involves making an incision 2.5 cm proximal to the distal femoral physis to expose the distal femoral metaphysis.

Figure (1): hole in the cortex by awl.

Nail diameter:

X-rays of the nail can reveal the nail's precise size by measuring the diameter of the medullary canal at its narrowest point. One nail, with a diameter no more than 40% of the smallest canal's, is required.“Nail diameter = 0.4 x diameter of medullary canal.” The shape of the nail used to repair the fracture was tailored to the specifics of the injury. The nail's pointer was oriented toward the nail's concave side, indicating that the nail had been bowed.

The bow's tip was located precisely where the break occurred. The nail's optimal resistance to deforming stresses was achieved by its shape. There are two rods put in, one medial and one lateral, and they go all the way to the fracture site. If optimization of fracture reduction is required, it is done.

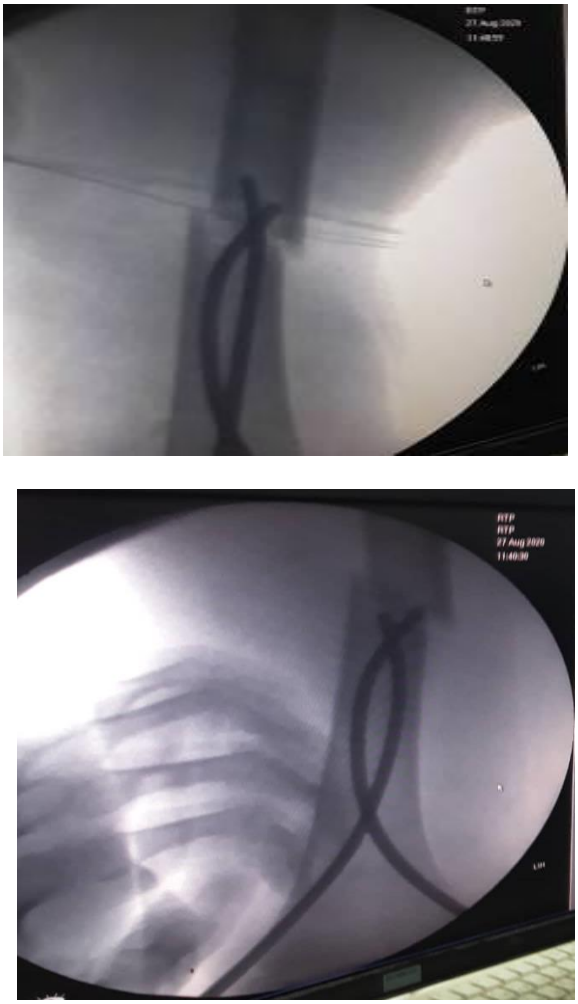


Figure (2): Two nails inserted to the level of fracture.

The two nails were then hammered into the upper part of the thighbone, two, one toward the femoral neck and the other toward the greater trochanter. To ensure that the fracture had been properly reduced before the nails are seated, fluoroscopy is used after the nails had been placed across the fracture but before they were seated.
To avoid irritating the surrounding soft tissue, the nails were pulled back about 2 centimeters, the tips are trimmed, and the nails were then driven back to the femur. After the break had healed, nail could simply pull out from their exposed ends.

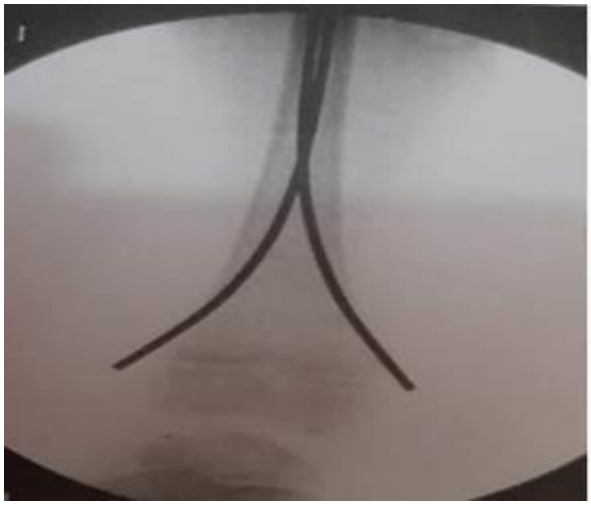


Figure (3): Two nails Cut end

Postoperative follow up:

Following surgery, a Thomas splint was used to prevent rotation.

In the aftermath of surgery, anteroposterior and lateral radiographs will be taken right afterwards. An elevated position was maintained for the lower limb by inserting a pillow under the thigh. When the surgery was over, a simple dressing was applied and changed after two days.

As soon as feasible after surgery, patients were urged to begin active knee and foot mobilization. The kid will get out of bed and start using crutches to get around as soon as possible, but he or she was extra careful not to put any weight on the wounded leg. Typically, a youngster spent one day in the hospital, while those who had had many injuries required more time.

Sutures were removed from all patients at two weeks post-op, and subsequent follow-up x-rays and evaluations of callus formation occurred every four weeks. After six postoperative months, patients' outcomes were evaluated using Flynn's grading criteria.

Statistical analysis

In order to analyze the data acquired, Statistical Package of Social Services version 20 was used to execute it on a computer (SPSS). In order to convey the findings, tables and graphs were employed.

The quantitative data was presented in the form of the mean, median, standard deviation, and confidence intervals. The information was presented using qualitative statistics such as frequency and percentage. The student's t test (T) is used to assess the data while dealing with quantitative independent variables. Pearson Chi-Square and Chi-Square for Linear Trend (X^2) were used to assess qualitatively independent data. The significance of a P value of 0.05 or less was determined.

RESULTS

Age varied from 6 years to 14 years with a mean age 7.61 ± 1.56 years with minimum 6 years and maximum 11 years. Most of the patients (72.2%) were males and (27.8%) of them were females. In this sample, approximately (55.55%) of patients experienced right-sided fractures and (44.45%) experienced left-sided fractures. Fifty percent of the patients suffered fractures in the middle third of their femurs, followed by the proximal third (22.24%), and the distal third (16.66%) (Table 1).

Table (1): Demographics

Age (years)	**No.**	**%**
<10	**16**	**88.88**
≥10	**2**	**11.12**
Sex		
Male	13	72.2%
Female	5	27.8%
Side affected	NO (18)	%
Right	10	55.55%
Left	8	44.45%
Fracture level	NO (18)	%
Distal	3	16.66%
Middle distal junction	1	5.55%
Middle Proximal junction	1	5.55%
Middle	9	50.0%
Proximal	4	22.24%
AO classification	NO (18)	%
32A1	3	16.66%
32A2	4	22.22%
32A3	11	61.12%

Table (2) shows that 16.66% had satisfactory outcomes, majority of patients (77.77%) had excellent functional outcome and (5.57%); had a bad one.

Table (2): Clinical outcome according to Flynn's Score among the patients:

Final outcome	**Variables**	**NO (18)**	**%**
final outcome by Flynn's Score	Excellent	14	77.77%
	Satisfactory	3	16.66%
	poor	1	5.57%

Table (3) shows that Patients took an average of 9.1± 1.83 weeks (7–12 weeks) to achieve complete union, about 61.11% ranged from 7 to 9 weeks. Most of the patients (88.88%) had full R.O.M while only (11.12%) of them had 10-degree flexion limitation.

Table (3): Time until full union range of motion among the patients and:

Variable	**Result**	
Time till full union (Weeks): Mean ± SD (Range) Median	9.1± 1.83 (7-12) 9	
Variable	**NO(18)**	**%**
Time of union		
7-9 weeks	11	61.11%
9-12 weeks	7	38.89%
Knee range of motion	NO(18)	%
R.O.M (Full)	16	88.88%
10 degree flexion limitation	2	11.12%

Table (4) shows that 9.3 ±1.79 weeks was the median range for patients' onset of complete weight bearing and between 7 and 12 weeks; (55.55%) fell within this range. As determined by the Flynn score, most patients (77.79%) did not have any limb length difference, whereas 16.66% had a 1cm lengthening and 5.55% had a 1cm shortening. Pain levels reported by patients, showing that the vast majority (88.88%) experienced no discomfort, while only 11.12% experienced mild pain. About two-thirds of the patients (72.22 percent) did not have any deformity, while eleven percent (11.1 percent), eleven percent (11.1 percent), and five and a half percent (5.58) of the patients experienced a 5 ° Varus, 5° Anterior, or 5° Posterior.

Table (4): Time of full weight bearing among the patients:

Variable	Result	
Time of full weight bearing (Weeks): **mean ± SD** **(Range)** **Median**	9.3± 1.79 (7-12) 9.5	
Variable	**NO(18)**	**%**
Time of full weight bearing **7-9 weeks** **9-12 weeks**	 10 8	 55.55% 44.45%

It is estimated that 88.4% of patients experienced no complications, 5.8% had some sort of irritation, and 5.8% developed a superficial infection (Figure 4).

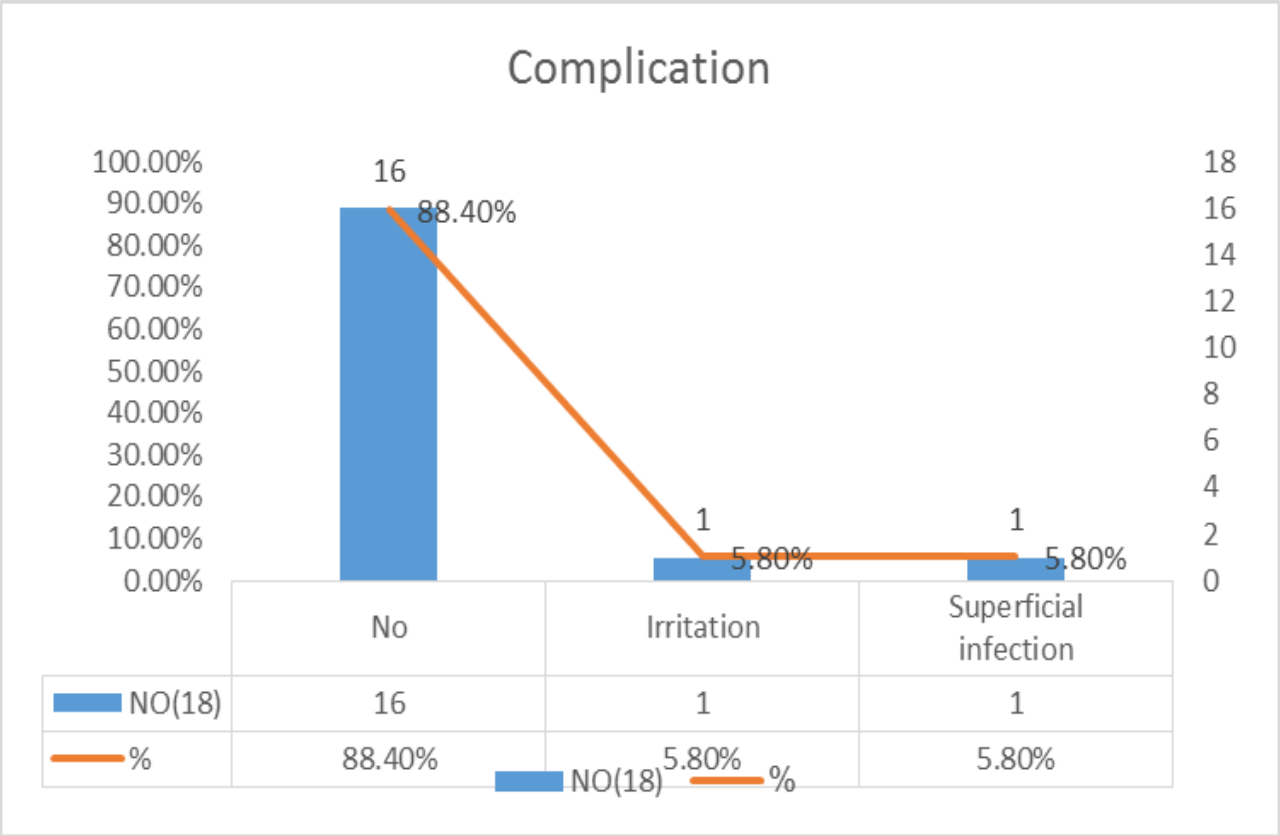


Figure (4): Complications among the patients

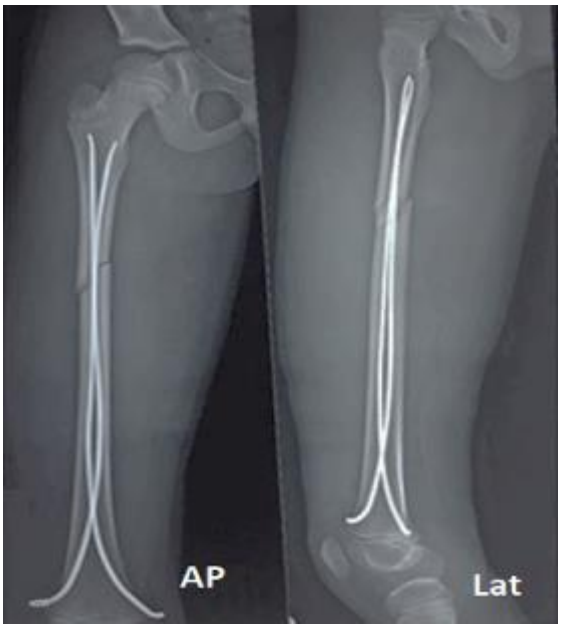
In terms of type of fracture, knee R.O.M., pain, deformity, limb length discrepancy, time to surgery, and presence of complications, there was a statistically significant difference between patients with different functional outcomes. Patients with better functional outcomes had transverse fractures, less pain, no complications, full knee R.O.M., no limb length discrepancy, and no deformity (Table 5).

Table (5): Comparison between patients with different functional outcomes regarding patients characteristics among the patients:

Variable	Excellent		Satisfactory		Poor		χ^2	p
	NO. (15)	%	NO. (2)	%	NO. (1)	%		
Age group								
< 10 years	13	53.3	2	50.0	1	00.0	3.1	0.2
≥ 10 years	2	46.7	0	50.0	0	100.0		
Sex								
Male	10	73.3	2	100.0	1	00.0	1.4	0.5
Female	5	26.7	0	0.0	0	100.0		
Type of fracture								
Oblique	3	20.0	0	50.0	1	0.0	14.8	0.005*
Transverse	11	80.0	1	0.0	0	0.0		
Spiral	1	0.0	1	50.0	0	100.0		
Level of fracture								
Distal	2	13.3	0.0	0.0	0.0	0.0	9.3	0.3
Middle distal	1	6.7	0.0	0.0	0.0	0.0		
Middle	1	6.7	0.0	0.0	0.0	0.0		
Proximal Middle	9	60.0	0.0	0.0	0.0	0.0		
Proximal	2	13.3	2	100.0	1	100.0		
Mechanism of injury								
FFH	1	13.3	2	0.0	0	100.0	6.5	0.3
Direct trauma	1	6.7	0	0.0	0	0.0		
RTA	10	60.0	0	100.0	1	0.0		
FD	3	20.0	0	0.0	0	0.0		
Knee R.O.M								
Full R.O.M	15	100.0	2	100.0	0	0.0	41.3	0.001**
10 degree flexion limitation	0.0	0.0	0	0.0	1	100.0		
Deformity								
No	13	93.3	1	0.0	0	0.0	36	0.001**
<5° Varus	0	6.7	1	0.0	1	100.0		
<5° Anterior	1	0.0	0	50.0	0	0.0		
<5° Posterior	1	0.0	0	50.0	0	0.0		
Time to surgery								
1 day	13	100.0	1	50.0	1	0.0	22.6	0.001**
2 days	1	6.7	1	50.0	0	0.0		
6 days	1	0.0	0	0.0	0	100.0		
Limb Length Discrepancy								
No	14	100.0	1	0.0	0	0.0	26.4	0.001**
1 cm Lengthening	0	0.0	1	100.0	1	0.0		
1 cm Shortening	1	0.0	0	0.0	0	100.0		
Pain								
No	15	100.0	2	100.0	0	0.0	18.5	0.001**
Mild	0	0.0	0	0.00	1	100.0		
Complications								
No	15	100.0	1	50.0	0	0.0	10.4	0.001**
Yes	0.0	0.0	1	50.0	1	100.0		

*

(A): Pre-operative AP and Lat X-ray **(B): Post-operative AP and Lat X-ray.**



(C): AP and Lat X-ray at 6 months follow up.

Figure (6): A 9 years old male, presented with history of RTA, requested X-ray showed fracture proximal 1/3 short oblique Rt femur, AO classification 32A2 (Figure A). The patient was treated with Elastic intramedullary nails at 2nd day post admission (Figure B)**,** and then discharged on same regime. At the end of follow up (6 months) the final outcome was excellent according to Flynn's score (Figure C).

DISCUSSION

Children and adolescents frequently suffer from diaphyseal femur fractures (DFF), which are serious long-bone injuries with substantial direct and indirect medical expenditures. DFF account for up to 1% of all pediatric fractures and 33% of long bone fractures, with an annual incidence of up to 1 in 5,000 [12].

An elastic stable intra-medullary nail offers three-point fixation, axial, transitional, and bending stability by opposing distraction and compression forces at the fracture site [13].

In this study, there were 18 patients (13 males and 5 females), with a mean age 7.61 ± 1.56 years ranged from 6 to 14 years, were treated by using elastic stable intramedullary nailing (ESIN) for treatment of femoral shaft fractures.

Most (72.2%) of our group were males and (27.8%) of them were females, the same sex composition was detected in a study conducted by **Kasirajan *et al.*** [13] in 52 kids were included in the retrospective look at data, with 30 boys (or 57.6%) and 18 girls (or 42.4%).

Perhaps the greater acceptance of higher-risk play activities among boys explains why men seem to be in the majority when it comes to fractures. Also, in comparison to women, they have greater opportunities to interact with the natural world through engaging in activities such as sports and car-use and this was supported by **Mughal and colleagues** [14] who found a male-to-female ratio of 2.21 to 1.

Regarding the affected side, approximately (55.55%) of patients experienced right-sided fractures and (44.45%) experienced left-sided fractures. Possible explanations include a preference for using one's legs over the other. However, **Frei and coworkers** [12] found that 15 of 30 children who were examined had fractures to their left femurs (68.2%).

Regarding site of fracture, Fifty percent of the patients suffered fractures in the middle third of their femurs, followed by the proximal third (22.24%), and the distal third (16.66%). It was similar to who reported of those fractures, 28 were on the right side (58%) and 20 were on the left side (42%), with the majority (36 fractures) occurring in the middle part of the limb.

61.12% of our sample had a transvers fracture (AO 32A3), followed by oblique fractures (AO 32A2) (22.22 percent), and spiral fractures (16.66 percent) (AO 32A1). The results were nearly agreed with **Akinyoola *et al.*** [15] who stated that fracture line was greenstick in 0.7% , oblique in 26.1%, transverse in 38.4%, comminuted in 10.6%, and spiral in 24.6%, and of 134 individuals studied.

Most of our group (88.88%) had full R.O.M while only (11.12%) of them had 10-degree flexion limitation, and at the end of the follow-up period, all patients in the trial by **Govindasamy *et al.*** [13] had full range of motion in their hips, knees, and ankles based on clinical evaluation.

This table shows that Patients took an average of 9.1± 1.83 weeks (7–12 weeks) to achieve complete union, about 61.11% ranged from 7 to 9 weeks.

About 9.3 ±1.79 weeks was the median range for patients' onset of complete weight bearing and between 7 and 12 weeks; (55.55%) percent fell within this range.

This disagreed with **Nascimento *et al.*** [16], their research revealed that the average amount of time spent in traction prior to surgery ranged from 5.3% to 11.3%. We successfully closed all the fractures. In general, patients who had their ESINs implanted spent 9.4 days in the hospital. Surgery usually required a period of recovery lasting about 7.7 weeks. Partial weight bearing was permitted 3.3 weeks following surgery, on average (ranging from 1 to 8 weeks). In general, patients were given the all-clear to resume weight bearing after 8.8 weeks.

In our study of 18 cases, 16.66% had a satisfactory outcome, majority of patients (77.77%) had excellent functional outcome and 5.57 percent; had a poor one.

Our outcomes were like **Govindasamy *et al.*** [13] clinical evaluations utilizing Flynn's criteria, with outstanding results in 40 kids (83%), and adequate findings in 8 kids (11%). (17 percent). No one in the class did poorly. Leg length reduction occurred in 5 of 48 instances (10%), with 4 children experiencing minor reductions (less than 5 mm) in limb length.

The final outcomes of **Nascimento *et al.*** [16] abnormalities included 12 cases of valgus (40%) and 3 cases of varus (10%), 23 cases of anterior angulation (76.6%), 5 cases of posterior angulation (16.7%), 28 cases of angulation (93.3%), and 3 cases of complaints (0.6%). (10.0 percent).

Regarding complications among our group, 88.4% of patients experienced no complications, 5.8% had some sort of irritation, and 5.8% developed a superficial infection. This was like **Shemshaki *et al.*** [17] only 3% of the 23 paediatric patients got a postoperative infection.(13%).

Also, **Govindasamy *et al.*** [13] nail ends causing skin irritation and impingement was the most common issue they saw in their study, which included 12 patients (25 percent).

Finally in **Frei *et al.*** [12] study, reactive bursitis affected 2 of 22 children (9 percent), subcutaneous nerve irritation affected 1 of 22 children (4.5%), and proximal cortical perforation affected 1 of 22 children (4.5%).

CONCLUSION

It could be concluded that if used appropriately, elastic stable intramedullary nailing (ESIN) is a successful treatment for fracture femur in children with very few consequences.

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Conflict of interest: Nil.

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