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Functional outcome of elastic intramedullary nailing for femoral shaft fractures in children

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Abstract

Background: Pediatric femoral shaft fracture is the most frequent fracture type in orthopedic practice in which males are affected more commonly than females. Currently, intramedullary fixation for the managing of femoral shaft fracture in children is widely used worldwide, including Iraq, which overcomes most of the difficulties related to other treatment modalities. **Objectives**: This study aimed to determine the clinical, functional, and radiological consequences of pediatric femoral shaft fractures achieved with a titanium elastic nail system (TENS). **Materials & Methods**: In this study, 28 children aged 5-10 years with femoral shaft fracture admitted to Shar Hospital, Sulaimaniyah, Republic of Iraq, were enrolled. Their fractures were fixed with Titanium Elastic Nail (TEN), in which a pair of the same-sized nail was used for each fracture. The outcomes were assessed using Flynn's scoring criteria. Finally, the patients were discharged the next day and followed up after 2, 4, 8, 12 and 20 weeks of surgery. **Results:** Based on Flynn's score assessment, the outcome of 85.71% of patients were excellent, 12.5% were satisfactory, and 1.79% were poor. All patients were showed a radiological unification and a conceivable full weight-bearing in a mean time of ~ 9 weeks, while their full knee variety of movement was attained in 2 months. **Conclusions:** TENS is a potential means to treat femoral shaft fractures in children as it is a simple, safe, minimally invasive, and physeal-protective with fewer complications and a high rate of good and excellent outcomes.

Introduction

Femoral shaft fracture accounts for about 2% of fractures among children and is considered one of the most predominant fractures in orthopedic practice. Factors such as the patient's age, fractures pattern and stability, and degree of fracture displacement play a major role in handling these fractures [1].

High-energy trauma including fall from height and a road traffic accident, are usually the reason for this type of fracture in which surgical intervention is usually advised as the fractures occur in the diaphysis of the bone [2].

Immediate/delayed spica cast, skin/skeletal traction on a splint, plating, inserting elastic nail, and external fixator are the management choices known for pediatric femur fractures. non-operative care in children older than six years might result in complications including reduction loss, malalignment, malunion, plaster-related difficulty, intolerance, and school absenteeism [3].

There has been an increasing tendency toward surgical operation, with the indications being extended to encompass isolated femoral fractures. Regardless of the method, the purpose of treatment is fracture

stabilization, maintenance of fracture length and alignment, promotion of bone healing, and declining the morbidity and difficulties for the child and his/her family [4].

Nancy's group first created elastic stable intramedullary nailing (ESIN) for femoral fracture in 1979 that extended its reputation over the last two decades. ESIN is used as a load-sharing device, flexible adequately to curve without crossing the physis. It is a less invasive procedure; early mobilization is allowed within 48 to72 hours. Because of its positive effects and lack of major side effects are still the favored choice for stabilizing fractures in children's long bones [5].

On the other hand, the titanium elastic nail system (TENS) is a three-point fixation system that provides stability in axial, translational, and rotational deformity, and bridging callus production is accelerated by micro-motion between fragments without disturbing the periosteum. Additionally, in this close surgery, fracture hematoma is preserved, resulting in a lower risk of infection [6, 7].

Therefore, this study aimed to confirm the clinical and surgical outcomes of TENS in children aged 5-10 years with diaphyseal femoral fractures.

Materials and methods

A. Patients

This study is a prospective observational study performed in the department of orthopedic, Shar Hospital, Sulaimaniyah, Republic of Iraq, in which a total of 28 patients with femoral shaft fractures were prepared to be treated with TENS from Feb 2021 to Feb 2022.

B. Ethical Approval

Written ethical consent was taken from all patient's parents/relatives, and it was approved by the Ethical Committee at the College of Medicine, University of Sulaimani, Sulaimaniyah, Republic of Iraq.

C. Inclusion Criteria

Pediatric patients with close fractures aged 5 to 10 years were included in this study in which their fractures pattern were transverse, spiral and oblique without associated injury.

D. Exclusion Criteria

Pediatric patients with pathological fracture, polytrauma, opened fracture, and neurovascular injuries were excluded from this study. Additionally, comminuted and segmental fractures are included or excluded in your study

E. Methodology

All patients were delivered first aid in the Shar Hospital's Emergency Unit, and they were thoroughly examined to detect any associated injury. ~~Then,~~ an x-ray of the pelvis and injured femur, including hip and knee joints, were taken. Later on, the fracture was provisionally immobilized using skin traction or Thomas's splint. Finally, all the mandatory inquiries were performed, and anesthesia clearance was obtained.

Regarding the surgical operation, a small longitudinal incision about 2 cm was made in the skin, fascia was opened, the muscle fibers were splitted, and a hole was induced in the lower femoral metaphysis about 2 cm upper to distal femoral physis with a curved awl and enlarged under fluoroscopic control.

Elastic nails are available in different sizes and colors (Figure 1), and the nail size was about 40% of the canal width at the thinnest portion of the femoral shaft. Open reduction was produced through a small anterolateral cut at the fracture site in cases where close reduction could not be attained. Each pre-bent titanium elastic nail was inserted in retrograde fashion through the distal part of the femur. Divergent C shaped nails were cut short and buried under the soft tissue (Figure 2). Then, the wound was closed in layers followed by compression dressing.

All the patients received broad-spectrum antibiotics as prophylaxis, which was started just before the incision and continued 72 hours post-operatively. Knee bending movement was initiated post-operatively as tolerated. Patients were followed up after 2, 4, 8, 12, and 20 weeks. Clinical and radiographic union was evaluated at each visit. Full weight-bearing was permitted after substantial evidence of callus formation. Patients were assessed for any angular deformity and limb length discrepancy after the 12th week of surgery when consolidation was achieved.

The complications were classified into 2 types. Minor complications were fixed without further surgical intervention, such as entry site irritation, mild pain, and superficial infection, while major complications required additional operation due to long-term morbidity such as deep infection [8]. Functional outcome was assessed by applying Flynn's score (Table 1). Nail removals were done at 7-9 months' post-operation and after fracture union.

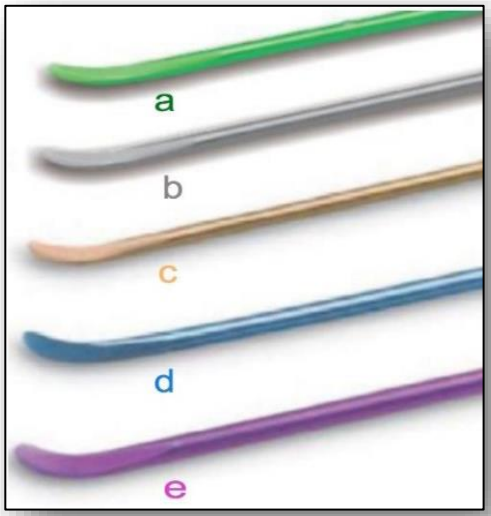

Figure 1. Demonstrates different size and color of elastic nail; (a) 2.0 mm (b) 2.5 mm (c) 3.0 mm (d) 3.5 mm and (e) 4.0 mm [9].

Table 1. Shows the Flynn's scores [11].

Result	**Excellent**	**Satisfactory**	**Poor**
Limb length discrepancy	< 1 cm	< 2 cm	> 2 cm
Misalignment	Up to 5 degree	5 to 10 degree	> 10 degree
Complication	None	Minor & resolved	Major complication
Pain	None	None	Present

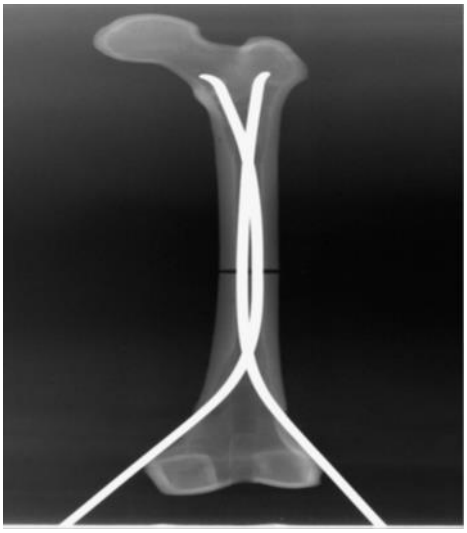

Figure 2. Shows radiograph of instrumented femur with nails in divergent C [10].

F. Data Analysis

The data were analysis was done using Statistical Package for Social Sciences (SPSS, version 25.0). Descriptive statistics were illustrated as mean ± standard deviation, and frequencies were stated as percentages. The level of p-value was established at ≤ 0.05.

Results

Among the operated children, 22 (78.6%) of them were aged 6-8 years. Among the 28 patients followed up, a high prevalence of males 17 (60.7%) were noticed with mean and standard deviation of the weight of 24.39 ± 3.9 (Table 2).

Table 2. Shows the socio-demographic data of patients.

Variable		Frequency	Percent (%)
Age (Year)	5	3	10.7
	6	7	25.0
	7	7	25.0
	8	8	28.6
	9	1	3.6
	10	2	7.1
	Mean ±SD	7.1 ~ 7 ± 1.34	
Sex	Male	17	60.7
	Female	11	39.3
Body-weight (Kg)	< 20	2	7.1
	20 - 25	15	53.6
	> 25	11	39.3
	Mean ±SD	24.39 ± 3.94	
Total		**28**	**100 %**

Out of 28 femoral diaphyseal fractures, the fracture in 16 (57.1%) of them was on the right side. Around 17 (60.7%) of children were injured by falls while 9 (32.1%) cases were due to road traffic accidents and only in 2 cases there were falling of heavy objects on their extremities. Regarding the fracture pattern, 10 (35.7%) patients had transverse, 9 had oblique, and 9 had spiral fractures. Fractures most commonly observed in the middle third of the shaft in 17 (60.7%) cases (Table 3).

Table 3. Represents the fracture characteristics of the study.

Variable		Frequency	Percent (%)
Side	Right	16	57.1
	Left	12	42.9
Mechanism of injury	Fall	17	60.7
	RTA	9	32.1
	Falling heavy object	2	7.1
Fracture pattern	Transverse	10	35.7
	Oblique	9	32.1
	Spiral	9	32.1
Fracture location	Proximal	9	32.1
	Middle	17	60.7
	Distal	2	7.1
Total		**28**	**100 %**

All patients achieved complete radiological union at a mean of 8.6 weeks (range 6-12 weeks) (Figure 3). Improvement of knee movement was seen during each follow-up visit. About 89.3% of cases had full range of knee motion at 10 weeks, and only 10.7% achieved full knee range of motion > 10 weeks. However, 67.8 cases had partial weight-bearing at ≤ 4 weeks, while in 82.1% patients, time of full weight-bearing was achieved in ≤10 weeks. Approximately 67.9% of the parent satisfaction was excellent, while 28.6% and 3.6% were good and poor, respectively. Cross leg sitting and squatting were achieved in ≤10 weeks in 17 (60.71%) cases, while in 11 (39.29%) cases were achieved in > 10 weeks (Figure 4 and Table 4).

Six cases were complaining of mild pain and irritation at the nail entry site, only one patient had superficial infection treated by antibiotics, and only one case had a deep infection that needed debridement and antibiotics. After 3 months, we observed 2 cases of leg-lengthening about 1.5 cm, 3 cases of coronal malalignment ranging from 5 to 10 degrees of varus, and 2 cases of sagittal malalignment (5 to 10 degrees) posteriorly. Flynn's score calculated and expressed for patients and final outcomes were excellent in 85.71%, satisfactory in 12.5%, and poor in 1.79% (Table 5).

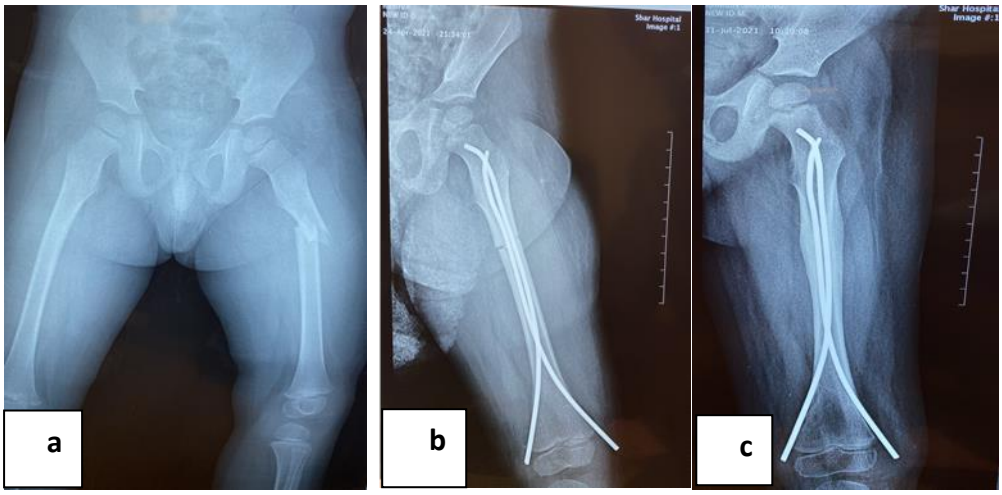

Figure 3. Shows a. Pre-operation x-ray, b. One-day post-operation, and c. After Eight weeks.

Figure 4. Shows cross legging and squatting after 10 weeks' post-operation.

Table 4. Illustrates the functional outcome of the study.

Variable		Frequency	Percent %
Full Knee range of motion (Week)	> 8	7	25.0
	8-10	18	64.3
	>10	3	10.7
	Mean ±SD	8.6 ~ 8 ± 1.97	
Time of union (Week)	> 8	5	17.9
	8-10	22	78.6
	>10	1	3.6
	Mean ±SD	8.6 ~ 8 ± 1.31	
Time of full weight-bearing (Week)	≤ 10	23	82.1
	> 10	5	17.9
	Mean ±SD	9.25 ~ 9 ± 1.29	
Parent satisfaction	Poor	1	3.6
	Good	8	28.6
	Excellent	19	67.9
Time of partial weight-bearing (Week)	≤ 4	19	67.8
	> 4	9	32.2
	Mean ±SD	4.17 ~ 4 ± 1.02	
Cross legging and squatting	≤ 10	17	60.71
	> 10	11	39.29
Total		**28**	**100**

Table 5. Represents the Flynn's scores.

Flynn Score	Poor		Satisfactory		Excellent		Mode
	Fr.	%	Fr.	%	Fr.	%	
Limb length discrepancy	0	0.0	2	7.1	26	92.9	Excellent
Misalignment	0	0.0	5	17.9	23	82.1	Excellent
Complication	1	3.6	7	25	20	71.4	Excellent
Pain	1	3.6	0	0.0	27	96.4	Excellent
Sum	**2**	**1.79**	**14**	**12.5**	**96**	**85.71**	**Excellent**

There were no statistically significant differences (P>0.05) in outcome assessment by Flynn's scores concerning sex and age, but there was a statistically significant impact of the weight on limb length discrepancy (p=0.034). Also, there was a statistically significant impact between fracture location on limb length discrepancy (p=0.043), complication (p=0.008), and pain (p=0.001) (Tables 6, 7).

Table 6. Association between Flynn's Scores and social demographic.

Flynn's Score		Sex		Age			weight		
		Male N (%)	Female N (%)	N	Mean	SD	N	Mean	SD
Limb length discrepancy	Poor	0(0.0)	0(0.0)	0	----	------	0	----	------
	Satisfactory	1(3.6)	1(3.6)	2	8.0000	.00000	2	30.0000	4.24264
	Excellent	16(57.1)	10(35.7)	26	7.0385	1.37057	26	23.9615	3.64945
Chi-Square Test (P-value)		0.104 (0.747)*		0.951 (0.339)**			5.017 (0.034)**		
Malalignment	Poor	3(10.7)	1(3.6)	4	7.0000	1.41421	4	27.5000	5.56776
	Satisfactory	1(3.6)	0(0.0)	1	6.0000	.	1	23.0000	.
	Excellent	13(46.4)	10(35.7)	23	7.1739	1.37021	23	23.9130	3.56642
Chi-Square Test (P-value)		1.159 (0.56)*		0.363 (0.699)**			1.537 (0.235)**		
Complication	Poor	0(0.0)	1(3.6)	1	8.0000	.	1	27.0000	.
	Satisfactory	4(14.3)	3(10.7)	7	6.5714	1.27242	7	23.1429	4.05909
	Excellent	13(46.4)	7(25)	20	7.2500	1.37171	20	24.7000	3.97492
Chi-Square Test (P-value)		1.737 (0.42)*		0.884 (0.426)**			0.615 (0.549)**		
Pain	Poor	0(0.0)	1(3.6)	1	8	----	1	27	-----
	Satisfactory	0(0.0)	0(0.0)	0	----	-----	0	------	-----
	Excellent	17(60.7)	10(35.7)	27	7.0741	1.35663	27	24.2963	3.97893
Significant Test (P-value)		1.603 (0.206)*		0.449 (0.509)**			0.445 (0.51)**		

Note// * is chi- Square Test, and ** is One Way ANOVA (F-Test), SD is Standard Deviation

Table 7. Association between Flynn's scores in relation to fracture pattern and location.

Flynn Score		Fracture pattern			Fracture location		
		Transverse	Oblique	Spiral	Proximal	Middle	Distal
		N (%)	N (%)	N (%)	N (%)	N (%)	N -(%)
Limb length discrepancy	Poor	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
	Satisfactory	0(0.0)	1(3.6)	1(3.6)	0(0.0)	1(3.6)	1(3.6)
	Excellent	10(35.7)	8(28.6)	8(28.6)	9(32.1)	16(57.1)	1(3.6)
Chi-Square Test (P-value)		1.197 (0.55)			6.271 (0.043)		
Malalignment	Poor	0(0.0)	3(10.7)	1(3.6)	1(3.6)	2(7.1)	1(3.6)
	Satisfactory	0(0.0)	0(0.0)	1(3.6)	0(0.0)	1(3.6)	0(0.0)
	Excellent	10(35.7)	6(21.4)	7(25)	8(28.6)	14(50)	1(3.6)
Chi-Square Test (P-value)		6.56 (0.161)			2.873 (0.579)		
Complication	Poor	0(0.0)	0(0.0)	1(3.6)	0(0.0)	0(0.0)	1(3.6)
	Satisfactory	2(7.1)	2(7.1)	3(10.7)	2(7.1)	5(17.9)	0(0.0)
	Excellent	8(28.6)	7(25)	5(17.9)	7(25)	12(42.9)	1(3.6)
Chi-Square Test (P-value)		2.96 (0.565)			13.841 (0.008)		
Pain	Poor	0(0.0)	0(0.0)	1(3.6)	0(0.0)	0(0.0)	1(3.6)
	Satisfactory	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
	Excellent	10(35.7)	9(32.1)	8(28.6)	9(32.1)	17(60.7)	1(3.6)
Chi-Square Test (P-value)		2.189 (0.335)			13.481 (0.001)		

Discussion

Surgical and conservative management of femoral shaft fractures in paediatrics is still debated among orthopedic surgeons. According to the literature, conventional treatment may cause union defect, joint stiffness, delayed functional recovery, prolonged hospital stay, and raised hospital costs [12].

Our study consisted of 28 cases, aged 5 to 10 years, with the mean and standard deviation of 7.1 ~ 7 ± 1.34. Moreover, most of the patients were male, and only 39.3% of patients were female. Furthermore, most participants (53.6%) weight was ranged between 20-25 kg with the mean and standard deviation of 24.39 ± 3.94). This outcome is agreed with a study reported by Sahu et al. [13], as they showed that most fractures commonly occurred in the male (68%), and also supported by another study done by Edwin et al. [9] that they

showed 76.7% of patients were male, and the mean age was 7.4 years (range 5.6-14.3 years). In contrast, a study performed by Khazzam et al. [14] reported that the average weight of patients was 36.78 kg.

The present study shows that the femoral fracture was on the right side in 57.1% of cases. Furthermore, the mean of partial weight-bearing was attained in $4.17 \sim 4 \pm 1.02$ weeks, while the time of full weight-bearing was reached in ≤ 10 weeks in 23 (82.1%) cases. These results are very close to a study conducted by Vishwanath et al. [15] in which they found that 64% of patients had a fracture on the right side with started partial weight-bearing started after one month, and the average time of full weight-bearing was in 11 weeks post-operation.

Our outcome regarding the time of full weight-bearing is similar to a study reported by Yadav et al. [16], in which they reported a full weight-bearing in 10 weeks. In contrast, Kayaokay et al. [17] displayed that the patients started earlier weight-bearing at 6.3 weeks (4-8 weeks).

Moreover, we showed that 60.71% of patients were able to squat and cross leg sitting at 10 weeks which is the lesser time when compared to a study conducted by Panchal et al., 2017 [18], which showed that 95.1% of patients were able to squat and cross leg sitting at 12 weeks. In addition, most of the mechanisms of injury were falls (60.7% cases), followed by road traffic accidents (32.1% cases), and falling of heavy objects (7.1% cases).

Most of the fractures (35.7%) were patterned transversely, and 60.7% of the fracture location was in the middle 3rd. Similar findings were noted in a study conducted by Manjunath et al., 2019 [19] in which mid-shaft fractures was seen in 68% of the patient; also most common fracture was a transverse pattern (31%). Also, they showed that most of the fractures were due to road traffic accidents (54%), followed by falls (46%). At the same time, Mani et al., 2015 [20] showed that fall was the most common mechanism of injury observed in 57.14% of patients.

On the other hand, in 64.35% of patients, full range of knee motion was achieved in 8-10 weeks which is contrary to a study conducted by Kumar et al., 2021 [7] in which the majority of the patients achieved full range of knee motion in 3 weeks, while the result is similar to a study reported by Panchal et al., 2017 [18] in which 82.9% patients achieved a full range of knee movement at 6 weeks.

In the current study, union time was 8-10 weeks in most cases, with an average of 8.6 weeks. A similar finding was noted by Tamrakar et al., 2017 [11] and Kawalkar et al., 2018 [21] that showed all fractures were united radiologically with a mean duration of 8.17 weeks with a range of 6 to10 weeks and 8 -12 weeks with a mean of 9 weeks, respectively.

According to Flynn's score, our results showed that the final outcome was excellent in 85.71% of patients, satisfactory in 12.5% patients and poor in 1.79% of patients. In this respect, Reza, 2020 [22] exhibited excellent in 68% cases, satisfactory in 24% cases, and poor in 8% cases, while Naseem et al., 2015 [23] showed excellent in 17 (85%) cases, satisfactory in 2 (10%) cases and poor in 1 (5%) patient only. Moreover, Palate et al., 2012 [24] displayed excellent in 60% cases, satisfactory in 35% cases, and poor in 5% cases.

Instantly, we found leg length discrepancy of about 1.5 cm in 2 (7.1%) patients, which is similar to a study reported by Sarkar et al., 2013 [25] that found 2 cases (2.85%) with limb length discrepancies in which the injured limb was about 1.5 cm greater than the normal limb.

Regarding the association between Flynn's score and socio-demographic data, there were no statistically significant differences ($p>0.05$) (or association) between all Flynn parameters concerning sex and age. In contrast, there was a statistically significant difference ($p=0.034$) between weight and limb length discrepancy.

Finally, regarding the association between Flynn's score, fracture pattern and fracture location, our results showed that there was a statistically significant difference (or association) between fracture location and limb length discrepancy (p=0.043), complication (p=0.008) and pain (p=0.001). In comparison, there was no statistically significant difference (or association) between fracture location and malalignment (p=0.579). Moreover, there was no statistically significant difference (p>0.05) (or association) between Flynn's score and fracture pattern.

Conclusions

In conclusion, we revealed that TENS is effective and reliable treatment for pediatrics long bone fractures, especially in older children over six. TENS is a simple, safe, minimally invasive with rare complications that do not interfere with the growth and blood supply of the femoral head and has minimal periosteal stripping and rapid bone healing. In addition, a relatively easy learning curve, associated with a shorter hospital stay, quick return to daily activity and schooling, avoids prolonged and uncomfortable immobilization and cosmetic damage is minimal.

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Conflict of Interest

The authors declare no conflict of interest to this study.

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