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Functional outcomes of titanium elastic nail procedure after femoral shaft fracture in pediatric patients

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Abstract

Pediatric femur diaphyseal fractures are seen after serious traumas such as traffic accidents and fall from height. Although treatment algorithms are made according to age groups, treatment planning is individualized according to the patient and the degree of injury. In our study, we evaluated functional outcomes of pediatric femur fractures treated with titanium elastic nail (TEN). This is a retrospective study including pediatric femoral diaphyseal fractures treated with TEN between 2012 and 2021. Open fractures, pathological fractures, distal fractures involving the femoral condyles, and proximal fractures involving the trochanteric region were not included in our study. Thirty-three femoral diaphyseal fractures with complete data were identified as stable and unstable in length, and functional results and post-treatment complications were recorded by performing TEN in fracture fixation. Clinical functional results were analyzed with Flynn criteria. Thirty-three femoral fractures of 29 patients were included. Eighteen (62.1%) of our patients were boys and 11 (37.9%) were girls. The mean age was 6.51 years (4-13 years). The most common injury mechanism was traffic accidents seen in 19 patients (24.51%). The mean follow-up period after surgery was 26.6 (6-90 months) months. Stable fractures (transverse and short oblique) were found in 26 cases (78.7%) and unstable fractures (spiral/long oblique and comminuted) in 7 cases (21.7%). According to Flynn criteria, excellent results were found in 20 fractures (60.6%) and satisfactory results in 10 fractures (30.3%) and 3 poor (9.09%). There was no significant difference between stable and unstable fractures in terms of functional outcome (p=0.12). Femoral diaphyseal fractures are serious injuries that require surgery. Regardless of the type of fracture, stable or unstable in length, the results of treatment with TEN are very successful. Major complications such as nonunion and re-fracture are rarely seen with this treatment.

Keywords: Femur diaphyseal fractures, elastic nails, pediatric

Introduction

Femur fractures are a very small proportion of the fractures seen in childhood. However, these fractures mostly require surgery. They cause serious problems for both the patient and the patient's family, such as psychosocial problems, prolonged periods of hospitalization, and high costs [1]. In pediatric femur fractures, the shaft region of the femur is indeed more commonly affected compared to the distal and proximal parts of the bone. As for the gender distribution, it is generally observed that pediatric femur fractures occur more frequently in boys than in girls [2,3]. The mechanism of fracture development is divided into high-energy traumas and low-energy traumas. According to age groups, high-energy traumas in adolescence are mostly traffic accidents and falls from height, while low-energy simple falls, sports injuries, and pathological fractures due to an underlying disease can be seen [4]. Child abuse is also considered a cause of femoral

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diaphyseal fractures, particularly in under 18 months of age. [5].

In these fractures, which were previously followed conservatively with spica cast and traction, there are currently many options [6]. In general, the important factors in the determination of treatment are age, weight, and soft tissue condition related to the injury. Although a spica cast is used to treat femoral fractures in children under five years of age, most femoral diaphyseal fractures in children aged 5-12 years are treated with open reduction internal fixation, closed reduction internal fixation, or closed reduction external fixation [7,8]. External fixators, antegrade rigid intramedullary nails, plates, and screws, and titanium or steel flexible intramedullary nails are used in treatment [9-11]. There are various treatment options available for femoral shaft fractures, and the choice of method can depend on several factors such as the type and location of the fracture, the patient's overall health, and the surgeon's expertise. However, compared to open reduction and fixation using plate screws, treatment with titanium elastic nails (TEN) has the advantage of shorter hospital stay, limited soft tissue dissection, and absence of pin bottom infection and refractures seen in external fixator application [12,13]. This study aimed to evaluate the results of childhood femoral shaft fractures treated with TEN. Functional results of TEN treatment according to fracture pattern and treatment complications were investigated.

Material and Methods

Our study is a retrospective study involving patients who underwent TEN for femoral diaphyseal fractures between 2012 and 2021 in Inonu University Orthopaedics and Traumatology Clinic. This study was ethically approved by Inonu University Scientific Research and Publication Ethics Committee with decision number 4609. The inclusion criteria were patients with a follow-up period of at least 6 months, closed fracture, TEN fixations of femur fracture, the patient weight of a maximum of 50 kg or less, and complete data. Pathological fractures, open fractures, distal fractures involving the femoral condyle, proximal femoral trochanteric fractures, Femoral shaft fractures managed by non-TEN procedures, and patients with incomplete data were not included in the study. Thirty-three femoral diaphyseal fractures of 29 patients meeting these criteria were examined.

After systemic examination in the emergency department, the patients were diagnosed with anteroposterior and lateral radiographs including the fracture line for femur fracture (Figure 1) and other extremity injuries. Hip supported long leg splint was applied for pain control. Patients with additional system and organ injuries were consulted with the relevant branches and preoperative approval was obtained for surgery for femur fracture. Patients with no contraindication to surgery were operated on during the first 24 hours. In the presence of surgical contraindications due to additional organ and system injuries, surgeries were performed when the patient's general condition stabilized.

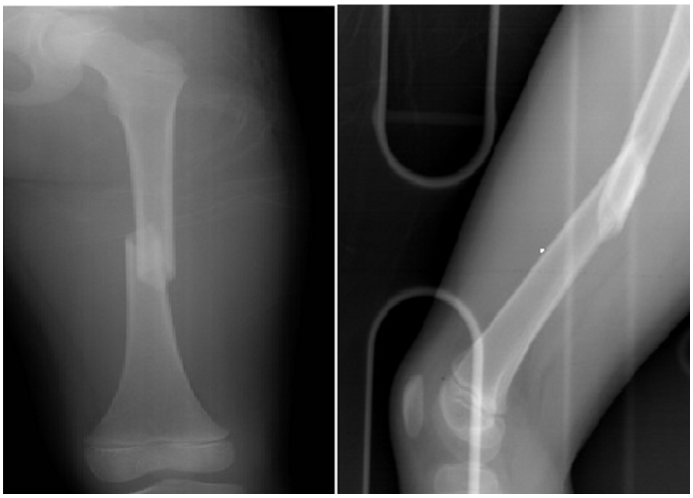

Figure 1. Anteroposterior and lateral X-ray images of femur diaphyseal fracture

Age, gender, side of the femur fracture, type and characteristic of the fracture, additional orthopedic injury, and additional organ-system injury were concomitant to the fracture, operation times, and TEN removal times were recorded. Complications related to the operation and femoral shaft fracture were evaluated. Clinical and functional results were analyzed according to Flynn et al. [14] TEN outcome scoring (Table 1). In femoral diaphyseal fractures, unstable fractures are described as a spiral or long oblique fractures and the fracture line is longer than 2 times the diameter of the femoral shaft at the fracture level [15]. Transverse and short oblique fractures are stable.

Table 1. Flynn et al. Outcome scoring [14].

	Excellent	Satisfactory	Poor
Malalignment	<1cm	<2cm	>2cm
Limb length inequality	5°	10°	>10°
Pain	None	None	Present, major
Complication	None	Minor	Severe, prolonged morbidity

Surgical prosedure

All patients were performed with general anesthesia in the supine position. The fractured extremity was cleaned and draped. A 2-2.5 cm longitudinal skin incision was made on the medial and lateral sides of the distal femur proximal to the distal epiphyseal. The fascia was opened longitudinally at the same level as the incision line and then blunt dissection was performed to reach the bone in the medial and lateral aspect of the distal femur. Under the guidance of fluoroscopy, holes were drilled perpendicular to the bone from the medial and lateral sides, 2 cm proximal to the epiphyseal line (Figure 2). The holes were then enlarged with an awl. One titanium elastic nail was inserted from the medial and one from the lateral sides until the distal part of the fracture line.

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The fractures that could be closely reduced under fluoroscopy were reduced (Figure 3). In fractures that could not be reduced closed, open reduction was performed and the nails were passed through the reduced fracture line and sent proximally along the femoral medulla. Reduction and fixation control was evaluated by fluoroscopy and the distal parts of the retrograde nails were cut and buried under the skin. Anatomic layers closed in standard fashion.

Figure 2. Fluoroscopy image of the localization of the TEN entry points in the surgery

Figure 3. Intraoperative closed reduction of the fracture

After surgery, the patients were seen in an outpatient clinic at 2-week intervals. Sutures were taken in the 2nd week. Splint was applied for 4 weeks after surgery. Union was evaluated with the appearance of callus in at least three cortical areas and full load bearing was started when the union was completed (Figure 4).

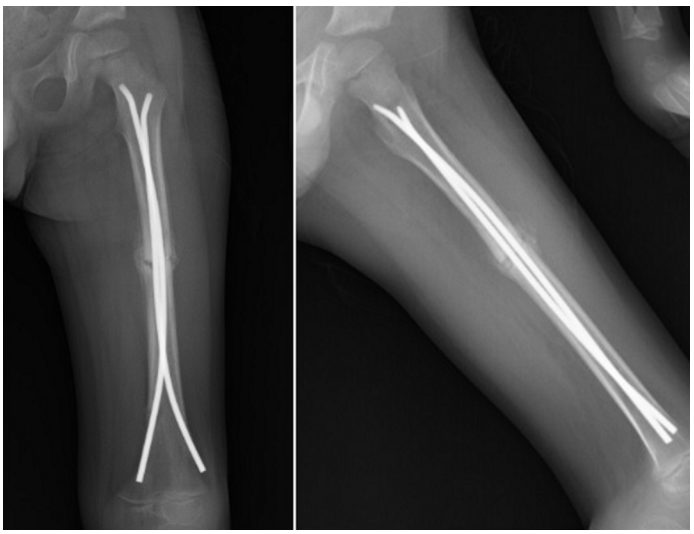

Figure 4. TEN stabilisation of femur fracture. Postoperative 5th week.Callus formation and union

Statistical analysis

The variables used in the study are summarised as median (min.-max.) according to the measurement levels, arithmetic mean standard deviation, and number (percentage). Numerical the conformity of the variables to normal distribution was analyzed by the Shapiro-Wilk test. The numerical statistically significant difference between independent groups in terms of variables Mann-Whitney U test and Kruskal-Wallis variance analysis were analyzed according to the number of groups. Multiple comparisons after the Kruskal-Wallis analysis of variance Mann-Whitney U test were used. Independent groups were compared in terms of categorical variables. Pearson chi-square and Yates chi-square were used to analyse the statistically significant difference. Pearson chi-square with correction and Fisher's exact test were used as appropriate. Multiple comparisons after chi-square tests, a significance test of the difference between two independent percentages $p \leq 0.05$ was accepted as the statistical significance level. In the analyses, IBM SPSS Statistics 25.0 package program was used.

Results

All fractures were completely united and the mean duration of union was 5.9 (4-8 weeks) weeks. Delayed union and nonunion were not observed in any femur fracture. The mean age was 6.51 years (4-13 years). The mean follow-up period of our patients was 26.6 (6-90 months) months. Demographic data of the patients and injuries concomitant to femur fracture are given in Table 2.

The etiological factor in all bilateral fractures was non-vehicle traffic accidents. In 19 patients (65.5%), the etiological factor of femur fracture was traffic accidents and 18 of 19 injuries were non-vehicle and 1 was in-vehicle. In 7 patients (24.1%), the fracture occurred after falling from a high. In 3 patients (10.3%), the fracture occurred after a direct impact to the thigh.

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Table 2. Demographic information of the patients and additional injuries

		n	%
Gender	Male	18	62.1
	Female	11	37.9
Additional osseous pathologies	Right	14	48.3
	Left	11	37.9
Additional osseous pathologies	Bilateral	4	13.8
	Tibia fracture	3	10.3
	Pubic diastasis	1	3.4
	Metacarpal fracture	1	3.4
	Mandible fracture	1	3.4
Additional injury	Liver lacerations	2	6.89
	Intracranial hemorrhage	2	6.89
	Hemothorax	1	3.4
	Pneumothorax	1	3.4
	Spleen laceration	1	3.4
	Kidney laceration	1	3.4

The mean time to surgery for the fracture after injury was 26.6 (6-90) hours. The latest surgery was performed 90 hours after the injury. Our patient who had a general condition disorder and liver laceration had a right femur diaphyseal fracture and pelvic injury.

Our patients were operated under general anesthesia in supine position. The mean duration of 33 fractured bone operations was 58.6 (35 to 145 minutes) minutes. Closed reduction and TEN procedure, which is performed without opening the fracture line in routine surgery, was performed in 27 fractures. In 6 fractures, closed reduction could not be achieved and open reduction was performed after reaching the bone by incision and blunt dissection from the lateral side of the fracture line.

In our study, 7 of 33 fractures were unstable and 26 were stable fractures. Flynn scoring results, fracture patterns, and complications in the clinical and radiological evaluation of the patients are given in Table 3. Statistically, there is no significant difference between stable and unstable fractures in terms of functional outcomes ($p>0.12$).

Angular deformity within acceptable limits was seen in 4 fractures with stable fracture patterns and 2 unstable fractures. One patient with bilateral transverse fractures had 8 degrees of angulation in both femurs. Two unstable fractures in two different patients had an anteroposterior angulation of 7 degrees. A spiral fracture and a comminuted long oblique fracture with butterfly fragments had angulations of 7 and 9 degrees, respectively. In 4 different femur fractures of 4 patients, a length difference of less than 2 cm but more than 1 cm was determined without clinical complaints by the patients. Poor results were found in 3 fractures of two patients. In an unstable spiral and comminuted fracture, more than 2 lengthenings were found on the fractured side during follow-up after union. In a patient we operated on

Table 3. Fracture patterns, functional outcomes and complications

		n	%
Fracture type	Stable	26	78.7
	Unstable	7	21.7
Fracture style	Transverse	15	45.4
	Oblique	11	33.3
	Long oblique/spiral	5	15.1
	Spiral and fragmented	2	6.06
Clinical outcomes by scoring	Excellent	20	60.6
	Satisfactory	10	30.3
	Poor	3	9.09
Scoring of unstable fractures	Excellent	2	6.06
	Satisfactory	4	12.12
	Poor	1	3.03
Scoring of stable fractures	Excellent	18	54.54
	Satisfactory	6	18.18
	Poor	2	6.06
Major complication	Limb length inequality (2cm>)	2	6.06
	Angulation-malunion (10°>)	1	3.03
	Nonunion-refracture-septic arthritis or osteomyelitis	0	0
Minor complication	Angulation-malunion (5°> and 10°<)	6	18.18
	Limb length inequality (1cm> and 2cm<)	4	12.12
	Nail tip irritation	2	6.06
	Superficial tissue infection	1	3.03

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for bilateral transverse fracture, there was an angular deformity of 12 degrees in the left side femur fracture with more than 2 cm limb inequality. None of our patients described severe pain after union.

In patients operated on for femur diaphyseal fractures, we planned to remove the nails within 1 year after the union. In 30 fractures, implants were removed. In 3 fractures, implants could not be removed due to the absence of continuity in the follow-up. The mean removal time was 12.04 months (2-66 months).

In terms of postoperative complications related to femoral diaphyseal fractures, loss of reduction and reoperation, nonunion, refracture and myositis ossificans did not occur in any of our patients. Superficial wound infection was observed in 1 patient (3.45%). Nail tip irritation, which is one of the most common complications after the TEN procedure, was seen in 2 patients (6.9%). It was treated by removing the implants.

Discussion

Pediatric femur fractures are more common in boys than girls and account for 2% of all pediatric fractures. However, these fractures are the most common cause of orthopedic hospitalization in childhood [16,17]. In terms of the mechanism of these fractures, the most common causes are traffic accidents and falls from height. While motorbike accidents increase in adolescence, femoral shaft fractures due to violence such as gunshot wounds can also be seen in this age group [18]. In our study, the majority of our patients were male following the literature. The most common mechanism of injury was non-vehicle traffic accidents. The mean age of our patients was 6.51 years. Our patients, who were mostly in the preschool and primary school age group, did not have an etiology of fracture due to motorbike accidents and increased violence, which are prominent in adolescence.

In a recent large study, a total of 172 pediatric femur fractures were evaluated. 129 of the fractures were isolated femur fractures and 43 fractures had injuries in addition to femur fracture. In this study, there were fractures in the other extremities of the same patient with a femur fracture. In addition, head, abdomen, and chest injuries were also given [19]. In another study, 96 femur fracture cases were evaluated and additional injuries to the fractures were reported in 22 cases [18]. In our study, in an isolated femur fracture, there were also pelvic and tibia fractures and serious injuries involving intracranial hemorrhage, liver and spleen lacerations. The mechanism of these fractures in the pediatric age group is usually high-energy trauma. These fractures may be isolated, but it is a fact that they may be associated with pathologies that may be fatal after severe trauma.

Treatment planning in pediatric femoral diaphyseal fractures is categorized according to age groups. To 6 months, conservative methods such as Pavlic bandage in infants and spica casting between 6 months and 6 years of age are the basic approaches [20]. However, due to advantages such as shorter immobilization time and early functional return, the tendency towards surgery in femoral shaft fractures has increased in recent years. In addition to flexible intramedullary nailing, materials, and methods such as external fixators, rigid intramedullary nails, standard plates, and submuscular plating are available in surgical treatment. Even though flexible intramedullary nailing is traditionally preferred in children between the ages of 5 and 11 years, studies have shared series of patients treated with TEN from 2.5 years of age to 17 years of age. [14,21]. In our study, a 4-year-old patient with a bilateral transverse fracture and a 13-year-old patient were operated on with TEN.

The use of flexible intra-canal nailing in pediatric femur fractures has become quite common and is first choice for fractures other than severe soft tissue trauma and multiple injuries. Nails are made of steel or titanium. The implants are cheaper and the teaching curve for the surgical procedure is simple. In addition, they have the advantages of being less invasive, earlier mobilization, and short hospital stays [22]. We performed retrograde bilateral TEN in our patients. Our mean surgical time was 58.6 (35-145 minutes) minutes. We think that our surgical time is short even in our bilateral fracture patients. In open reduction, we reached the fracture line through a small incision from the lateral side, and the fracture was reduced by blunt dissection with preservation of soft tissues. Bleeding was minimal in this approach without serious dissection.

In a study that analyzed functional outcomes, according to the Flynn criteria, 75.5% had excellent results, 17% had satisfactory results, and 7.5% had poor results. [23]. In another study, excellent and satisfactory outcomes were noted in 19 of 20 patients in the treatment of femoral fractures with TEN in pediatric patients aged 6-14 years. [24]. In another study in which fractures of 30 patients were evaluated, excellent and good results were found in 24 cases and poor results in 6 cases [25]. Our results are similar to the literature and we did not have any nonunion cases. When our patients were evaluated according to Flynn criteria, 90.9% excellent and good results were obtained.

Transverse and short oblique fractures have a stable pattern. TEN is mainly preferred in the treatment of these fractures. Major complications and the need for revision after the TEN procedure in long oblique/spiral or comminuted fractures that are unstable in length have been reported [26-28]. On the contrary, in a study, stable and unstable fractures were compared in terms of complications and reoperation, and no significant difference was found between the results [12]. In our study, 26 of 33 fractures were stable fractures in transverse and oblique patterns. And 7 fractures were unstable. In terms of functional results, one patient with bilateral transverse fractures and one unstable fracture with long oblique fragments had poor results in our study. In statistical analysis, stable or unstable fractures did not make a difference in terms of functional outcomes. We think that treatment with TEN is highly effective and safe for all fractures.

Complications in the treatment of these fractures with TEN are divided into major and minor complications. Major complications

generally include pathologies such as malunion, nonunion, septic arthritis, and osteomyelitis, which require a second surgery and may cause disability. Minor complications include pathologies such as delayed union, superficial wound infection, and pain due to nail tip irritation [29]. In a study by Ali A. Siddiqui et al. [12] involving 57 patients, a total of 29 complications were observed. 26 of these complications were minor complications. The most common cause was implant tip irritation and pain seen in 25 patients. The total complication rate was 47%. In another study evaluating TEN complications, it was observed that the most common causes of complications were nail tip irritation, pain, inflammation, and bursitis [30].

In our study, complications were seen in 48.4% of 33 femur fractures. Contrary to the literature, the most common complications were malunion (18.1%) and limb length inequality (12.1%), which developed within acceptable limits. Nail tip irritation was seen in only 6.06% of fractures: The nail was removed and treated with antibiotics. A length discrepancy of more than 2 cm was seen in 2 fractures in 2 different patients and one patient with bilateral fractures had a 12-degree angular deformity in addition to the length discrepancy. Nonunion and re-fracture did not develop in any of our patients. There was no statistical difference between stable and unstable fractures in terms of complications. Including the 3 fractures with major complications, none of our patients had clinical complaints and no additional surgery was performed.

Our study has a few limitations. Firstly, it is a retrospective study. Secondly, our study is a single-center study. Lastly, our patient number and follow-up period are relatively few. Multicentre and prospective studies with a larger number of patients and longer follow-up periods may be more successful in evaluating the functional outcomes and late complications of TEN treatment.

Conclusion

In conclusion, pediatric femoral diaphyseal fractures are serious injuries usually seen after high-energy trauma and treated surgically. In surgical treatment, intramedullary nailing with TEN gives satisfactory results regardless of fracture type and characteristics. Major complications such as re-fracture and nonunion are rare.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
Our study was ethically approved by Inonu University Scientific Research and Publication Ethics Committee with decision number 4609 on 23/05/2023.

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