



## The results of intramedullary fixation with titanium elastic nails in children with femoral fractures

### *Çocuklardaki femur cisim kırıklarında titanyum elastik çivilerle intramedüller tespit sonuçları*

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**Amaç:** Çocukluk dönemindeki femur cisim kırıklarında titanyum elastik çivilerle (TEÇ) intramedüller tespitin klinik ve radyolojik sonuçları değerlendirildi.

**Çalışma planı:** Retrograd yolla TEÇ ile intramedüller tespit uygulanan 35 femur kırığı (34 hasta; 20 erkek, 14 kız; ort. yaş 8.3; dağılım 5-14) çalışmaya alındı. Sonuçlar Flynn ve ark.nın TEÇ sonuç skorlamasına göre değerlendirildi. Kırık kaynama süreleri ile ön-arka ve yan planlarda açılanma miktarları radyografik olarak değerlendirildi. On dört hastada (14 kırık) bilgisayarlı tomografi (BT) ile femoral anteversiyon açıları (FAA) ve alt ekstremité uzunlukları ölçüldü ve sağlam taraf değerleri ile Wilcoxon testi kullanılarak karşılaştırıldı. Ortalama izlem süresi 28 ay (dağılım 4-48 ay) idi.

**Sonuçlar:** Flynn ölçütlerine göre 25 kırıkta (%71.4) mükemmel, dokuz kırıkta (%25.7) başarılı, bir kırıkta (%2.9) kötü sonuç elde edildi. Radyografik kaynama süresi ortalama 7.4 hafta (dağılım 5-12 hafta) idi. Üç kırıkta 10 derece veya altında yan planda açılanma, birinde ön-arka planda sekiz derece açılanma saptandı. Yedi hastada (%20.6) bacak uzunluğunda 2 cm'den az eşitsizlik görüldü. Bilgisayarlı tomografi ile yapılan FAA ölçümlerinde kırık tarafın sağlam tarafa göre anlamlı derecede retroversiyonda olduğu saptandı (p<0.01).

**Çıkarımlar:** Titanyum elastik çiviler ile intramedüller tespit, 5-15 yaşları arasındaki çocukların femur cisim kırıkları için seçilebilecek bir yöntemdir. Ancak bu yöntem sonrasında oluşabilecek rotasyon teknik bir sorun olmayı sürdürmektedir.

**Anahtar sözcükler:** Kemik çivileri; çocuk; femur kırıkları/ radyografi/ cerrahi; kırık fiksasyonu, internal/yöntem; titanyum; bilgisayarlı tomografi; tedavi sonucu.

**Objectives:** We evaluated clinical and radiologic results of intramedullary fixation with titanium elastic nails (TEN) in children with femoral fractures.

**Methods:** The study included 35 femoral fractures of 34 patients (20 boys, 14 girls; mean age 8.3 years; range 5 to 14 years) who were treated by intramedullary fixation with TEN. The results were evaluated according to the scoring system proposed by Flynn et al. Time to union and residual angulations were assessed on anteroposterior and mediolateral radiographs. Femoral anteversion angles and limb lengths were measured in comparison with the normal side by computed tomography (CT) in 14 patients and the results were compared using the Wilcoxon test. The mean follow-up period was 28 months (range 4 to 48 months).

**Results:** According to the criteria by Flynn et al., the results were excellent in 25 fractures (%71.4), successful in nine fractures (%25.7), and poor in one fracture (%2.9). The mean time to union was 7.4 weeks (range 5 to 12 weeks). Mediolateral and anteroposterior radiographs showed an angulation of 10 degrees or less in three fractures and of 8 degrees in one fracture, respectively. Limb length discrepancy of less than 2 cm was detected in seven patients (%20.6). Femoral anteversion angles measured by CT revealed significant retroversions on the fractured sides (p<0.01).

**Conclusion:** Intramedullary fixation with TEN may be the preferred method for the treatment of femoral fractures in children aged 5 to 15 years. However, residual rotation detected by CT seems to be a technical challenge to be improved.

**Key words:** Bone nails; child; femoral fractures/radiography/surgery; fracture fixation, internal/methods; titanium; tomography, X-ray computed; treatment outcome.

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Received: 25.09.2003 Accepted: 30.01.2004

Pediatric femoral shaft fractures constitute a major part of the referrals to the emergency orthopedics clinics.<sup>[1,2]</sup> The femoral shaft fractures in adults are mostly treated by surgical methods while in pediatric cases mainly conservative methods are preferred due to better compliance and responses to such methods in children. However, it has been noticed that conservative methods do not always have good outcomes. Problems such as angulation, malrotation, and limb length discrepancy are not effectively fixed all the time. Many authors consider that conservative methods should be indicated in children less than five years old<sup>[3]</sup> while surgical methods where intramedullary fixation is increasingly preferred are widely used in older children.<sup>[4-12]</sup>

At present, usually surgical methods are preferred since they are associated with early mobilisation and fast return to functions. When factors like easier nursing care, earlier mobilisation and rehabilitation, psychosocial factors both for parents and children and shorter return period to education are taken into consideration in spite of the bed capacity and higher costs, the surgical approach has become considerably important.<sup>[1,2,5,6]</sup> Surgical methods include open reduction and osteosynthesis by plaque, rigid or elastic intramedullary nailing, and external fixation.<sup>[3]</sup>

The titanium elastic nails (TEN) are ideal for pediatric femoral shaft fractures due to ease of use, prevention of any traction or casting complications. The treatment outcomes reported by TEN are very successful for this age group.<sup>[5,7,8]</sup> Compared to the rigid and locked intramedullary nails, the main limitation in elastic intramedullary nailing is the failure to provide full fixation particularly due to the difficulty of rotational control and consequently causing inability to press immediately. However, technically lesser traumatization, use of nails with smaller diameters, absence of drilling procedure, use of mostly the retrograde surgical technique and lack of harm to the growth cartilage are among the advantages of TEN.<sup>[9]</sup> It functions as an internal splint by uncharging the hematoma of the fracture, providing biological fixation because it is usually performed through closed technique. Furthermore, the fixation fulfills the three points principle since the nails are medially and laterally placed. The elasticity and stress distribution of the titanium elastic nails facilitates the

callus formation.

The present study evaluated the clinical and radiological results of pediatric patients, who were operated using intramedullary TEN for femoral shaft fracture, and analysed the residual rotation and shortening deformities in the femur using computed tomography (CT) after healing of the fracture in unilateral cases.

## Patients and methods

The study included 35 femoral fractures of 34 patients (20 boys, 14 girls; mean age 8.3 years; range 5 to 14) who were treated by intramedullary fixation using TEN through retrograde technique and followed up regularly at the 3rd Orthopedics and Traumatology Clinic, Ankara Numune Training and Research Hospital of the Ministry of Health between January 1993 and May 2002. When they were classified into age groups, there were 14 (41%) patients, 13 (38%) patients and 7 (21%) patients in the age groups 5-7

years, 8-10 years and 10-14 years respectively. The femoral physes were open in all patients. Thirteen patients (38%) had right while 20 (58%) patients had left femoral shaft fractures. One patient (3%) had bilateral fracture.

The cause of injury was accident by motor vehicles in 28 patients (82%), and fall from a height in six (18%) patients. According to the Gustilo-Anderson classification, the femoral fractures were open type 1 in four (11%), type 2 in two (6%) cases and type 3 in one (3%) case. And the fractures were transverse in 15 (43%), oblique in 11 (31%), spiral in 6 (17%) and multiple in 3 (9%) cases.

None of the patients had vein nerve lesion associated with femoral shaft fracture. Eleven patients (32%) had more than one injury related to orthopedics or any other systems. Whenever the patients presented themselves at the emergency service, their anteroposterior and lateral radiographies including the fracture line were taken. For pain and deformity control, hip-supported long limb casting splintages were used in all patients. No skeletal traction was used. The patients with open fractures received open fracture oriented treatment regimen.

The time elapsed between the introduction of fracture and admittance to the operating room varied from

12 hours to 7 days (mean 2.9 days) depending on the general status of the patient, supply of the material required for osteosynthesis and circumstances of the operating room.

After the operating area was cleaned with povidon iodine and covered while the patient was under general anaesthesia in supine position, each patient was intervened by short linear incision initiating from the medial and lateral of the femoral distal, 3-3.5 cm proximal of the physal and extending 2.5 cm to the distal. After the fascia was opened, the muscle fibres of the quadriceps femoris were passed and the bone was reached. Following the careful division of the periost, a hole was opened in the bone vertical to the 2.5-3 cm proximal of the distal physis. The hole was enlarged by bizz, and the medulla was angled using clips. Each titanium elastic nail was retrogradedly advanced from the medial and lateral femoral distal metaphyseal. As the curves in the nail are used as a reference point, it was inserted into its pre-bent shape.



**Figure 1.** Preoperative anteroposterior radiography of the transverse fracture at femoral proximal 1/3 in an eight years old girl.

In cases where the nail couldn't be advanced, it was bended as per the anatomy. And, close reduction was tried under the control of fracturescopy. The patients who could not be closely reduced were intervened by short incision using the blind-hand technique, and the soft tissues inhibiting the reduction were removed without seeing the fracture line, and then the nails were advanced to the proximal field. Preferably we tried to advance both nails to reach the proximal; but when this failed, at least one of them was proceeded to the proximal part of the femur. The failure to advance one of the nails to the proximal of the femur was observed only in three cases. No bone grafting was used for any of the patients; traction table and tourniquet were not used. The reduction was achieved closely in 25 fractures (71.4%), and by blind-hand technique in 10 cases (28.6%). In patients who could not be closely reduced, the wound was washed thoroughly with serum physiological solution after the bleeding control, and a vacuum discharge cannula was placed.

The mean procedure time was 55 minutes (range from 25 to 100 minutes). The most important factor, which had an impact on the time was the experience level associated with the technique used. The cross cortex was damaged in four patients during nailing, which didn't result in any problem and the nails were fixed by providing better bending without any problem. Six patients (18%) underwent postoperative blood transfusion. No blood transfusion was required for patients who had closed reduction. All patients received first generation cephalosporin prophylaxis, which was initiated at preoperative 12 hours and lasted until postoperative 24-48 hours. The total duration of hospitalization was mean 5.5 days (range from 2 to 14 days), and the postoperative duration of hospitalization was mean 2.8 days (range from 1 to 7 days).

The patients were allowed to walk using a crutch at postoperative days 5-7. Partial weight was allowed in mean five weeks (range from 3 to 8 weeks) and full weight in mean 6.8 weeks (range from 4 to 12 weeks).

Even though stability was considered efficient in the patients for whom the titanium elastic nails were first used, a spica splint covering the knee and ankle was used during the postoperative three weeks in order to control the pain and prevent pressing. For the subsequent cases, this method was abandoned, and it was never applied to any patient other than those who

were considered unstable. At postoperative second week, all patients were invited to be re-examined, and motion range exercises were initiated for the joints.

The mean follow-up period was 28 months (range from 4 to 48 months).

The results were evaluated according to the TEN scoring system used by Flynn et al. (Table 1). Radiographical evaluations were also performed. Also, radiographical evaluations were done at monthly intervals, and the union period of fractures were determined. Observing new bone trabecules bridging along the fracture line in the anteroposterior and lateral views was interpreted as radiographic union (Figure 2a, b).

The bilateral femur length and femur anteversion angulations were measured by CT in 15 patients (16 fractures), and they were compared to the values of

the normal side in 14 patients (14 femurs), the results of the patient with bilateral fracture being excluded.

The limb length discrepancy was measured by axial views in patients who underwent CT, and by ortho radiological graphics method in the other patients.

The computed tomography views were obtained by using the imaging characteristics of Hitachi W 950 SR and GE Sytec SRI devices, 120 kV, 90 mA, 2 sec, and taking sections in 512x512 matrix with 5 mm section thickness and interval. The patients were examined when they were lying on their backs. No sedation was required for any of the patients. A splint, which provides immobilization, was used particularly during the femoral anteversion measurements.

The femoral anteversion angle (FAA- the angle between the femoral neck and composite lines which



**Figure 2.** The (a) anteroposterior and (b) lateral views demonstrating the union, before the intramedullary fixation was removed, at the postoperative sixth month of the patient at Figure 1. The (c) anteroposterior and (d) lateral views at the postoperative first year after the nails were removed.

**Table 1.** The scoring criteria with titanium elastic nails <sup>[7]</sup>

	Excellent	Successful	Poor
Limb length discrepancy	<1.0 cm	<2.0 cm	>2.0 cm
Sequence disorder	5°	10°	>10°
Pain	Absent	Absent	Present
Complication	Absent	Mild	Major complication and/or extended period for resolvable morbidity

are tangent above and below both condyles was measured using axial sections from the femur neck and femur condyles by CT.

The measures of both side femurs obtained by computed tomography were statistically compared using Wilcoxon test;  $p < 0.01$  and were considered significant.

## Results

According to the TEN criteria by Flynn et al.,<sup>[7]</sup> the results were excellent in 25 fractures (71.4%), successful in nine fractures (25.7%) and poor in one fracture (2.9%).

The mean time to radiographical union was 7.4 weeks (range from 5 to 12 weeks). The union lasted 12 weeks in the patient with a butterfly like fracture, and he was allowed to carry weights later than the others. This patient had a recurrent fracture at the postoperative month 5 due to a fall from height when the nail was situated at the medulla.

There was a 10 degree or less angulation in the lateral plate in three of the fractures, and one patient had an eight degree angulation in the anteroposterior plate.

Seven patients (20.6%) developed limb length discrepancy less than 2 cm. The discrepancy was associated with height in three patients and shortness in three patients. 18 mm discrepancy was found in the patient who underwent surgery due to bilateral femoral shaft fracture. The side with the butterfly like fracture was longer. The limb length discrepancy was not described as a complaint by the patients and their relatives. None of them required additional surgery.

The FAA measurement values were found equal or very close to the opposite 'normal' hip values in four of the 15 patients whose rotation angles were measured. Three of these patients had spiral, and one had transverse fracture. Ten patients had retroversion over 10 degrees compared to the healthy side,

**Table 2.** Results obtained by computed axial tomography

No	Sex	Age	Fracture	Type of fracture	Length discrepancy Up to 2 cm	Femoral anteversion angle Fractured side Normal side	
1	Male	13	Left	Transverse	N/A	+8	+27.5
2	Male	9	Right	Oblique	N/A	-15	+1.5
3	Female	12	Left	Transverse	Taller	+6	+27.5
4	Female	6	Left	Spiral	N/A	+3	+6
5	Female	10	Right	Oblique	N/A	-4	+12
6	Male	8	Left	Spiral	Shorter	+12	+9
7	Female	10	Left	Oblique	N/A	-5	+22.5
8	Male	8	Right	Spiral	N/A	+25	+23
9	Male	11	Left	Transverse	Taller	+30	+30
10	Male	9	Left	Oblique	Uzun	-5	+7.5
11	Male	10	Left	Transverse	N/A	+4	+16
12	Female	6	Right	Spiral	N/A	+1	+10
13	Female	7	Right	Transverse	N/A	+10	+24
14	Male	7	Left	Oblique	N/A	-8	+14

where four had transverse and six had oblique fractures. One patient had a nine degree retroversion (Table 2). The statistical evaluation showed that the difference was significant when the FAA was compared with the opposite side ( $p < 0.01$ ).

During the clinical examination, it was observed that both steps taken were symmetrical while walking. No inward or outward pressing was seen. Each patient had a full motion range of joints.

Non-union, infection, disturbance in the trochanteric growth and myositis ossification, which are potential complications in surgery for femoral shaft fractures didn't develop in any of patients.

It was planned to remove the intramedullary nails at the end of postoperative first year for each patient (Figure 2c, d). No problem occurred even though the nails were removed later in six patients.

## Discussion

It has been commonly accepted that surgical intervention is indicated in pediatric femoral shaft fractures in cases of open fractures, multi-trauma, concomitant head injuries, burns and neuromuscular wounding. However, the number of publications suggesting that surgery can also be considered for isolated femoral fractures is gradually increasing. Due to the achievements such as earlier return to functions, no or less joint inflexibility, lesser wound tumor compared to other surgical methods, lesser complications of infection, refracture and malunion, earlier mobilization in patients with multi-trauma, reduction in the duration and cost of hospitalization, intramedullary nailing has become one of the methods of choice in children, too. [1,2,5,6,10]

In children, the interventions using elastic intramedullary nails are technically easier than the use of rigid nails. [5,11,12] Ender intramedullary nails are also commonly used in pediatric femoral shaft fractures. [1,2,4,13-15] However, the canal diameter is a restrictory factor in the Ender nails; also, they are very hard and smoothly extendable across the cortex whereas titanium nails can be easily used in youngsters and femurs with smaller diameters. The use of intramedullary nailing in children can be antegrade [5,6,16,17] or retrograde [1,2,7,13-15].

The studies have shown that the intramedullary fixation by TEN can be performed in children

between 2.5 and 17 years old. [7,15,18] Recently it appears that the use of intramedullary nailing before six years old has been increasing. [7,15,18] However, the antegrade nailing is not recommended before eight years old due to its complications. The mean age was 8.3 years (range from 5 to 14 years) in our study.

Some authors report that they used intramedullary nailing in pediatric femoral open fractures up to stage 3B defined by Gustilo-Anderson. [1,6,13,19] In our study, types of fractures were as follows; type one in four patients, type 2 in two patients and type 3A in one patient.

It appears that most of the fractures that were operated on by intermedullary nailing were transverse. [1,2,7,12,13] Flynn et al. [7] reported that the most feasible fracture type was transverse fracture in 1/3 medial shaft for TEN, and Linhart and Roposch [15] stated that out of 17 fractures where they intervened using elastic intramedullary nailing, eleven were complicated and six were long oblique. The majority of our patients (43%) had transverse fractures.

Some authors report a mean hospitalization duration of 5 to 10 days with this method. [1,6,13] The mean duration for hospitalization was 5.5 days (range from 2 to 14 days) in our study.

The most common complication in femoral shaft fractures is the discrepancy between the lower extremity lengths, which occurs particularly in extension and is frequent between 2 and 10 years of age. [1,2,5] No significant discrepancy was found between the limb lengths in the intramedullary nailing carried out in older children and adolescents. [20-22] Heinrich et al. [1] reported that 22% of their patients had an extension over 5 mm, and 11% had a shortness under 5 mm. In a study comparing several methods including elastic nail, traction and casting, the most shortness was observed in the early casting group, which was followed by external fixator group whereas tallness was observed only in the external fixator group. [23] In our study, we found discrepancy less than 2 cm in seven patients (20.5%), which provided no clinical evidence.

Another common complication in pediatric femoral shaft fractures is the malunion. Herndon et al. [24] reported that malunion developed in seven of 24 patients who were treated with traction while no

malunion was observed in 21 children who were treated using intramedullary nailing. In the antegrade elastic intramedullary nail (TEN) practices carried out by Carey and Galpin,<sup>[5]</sup> no clinically significant rotational or angular deformity were found while an angulation less than five degrees was evident in the frontal and coronal plate of the radiographic follow-up. In an antegrade and retrograde TEN study by Galpin et al.<sup>[6]</sup> it was reported that 35 out of 37 patients had excellent improvement in terms of angular deformity. We had angulation less than 10 degrees toward varus/valgus or antero/posterior only in four femurs (11.4%).

The protection of rotational stability by elastic intramedullar material is limited compared to the other material; it may not prevent shortness or rotation problems, particularly in segmental, long oblique, long spiral and fragmented unstable fractures; sometimes pelvi-pedal casting or other additional fixation methods may be required for the rotation control of the fracture.<sup>[14, 25]</sup> Although we found no significant rotational deformity in the clinical examination, there was a relative retroversion in 10 of the 14 patients (71.4%) with unilateral femoral fracture compared to the healthy extremity, which didn't result in any complaint concerning functional or cosmetic deformity by the patients. However, we don't know what cosmetic or functional problems may arise in children in the long term with this relative retroversion, which was objectively demonstrated. Six of the 10 patients who had retroversion over 10 degrees compared to the opposite normal hip had long oblique fractures while four had transverse fractures. The fracture in one patient with retroversion of nine degrees more compared to the opposite normal hip was a long spiral fracture. Even though the retroversion of these fractures was relative compared to the opposite side hips, five hips had absolute retroversion less than 0 degrees (Table 2) where all five included long oblique fractures. These findings suggest that elastic intramedullar fixation cannot maintain rotational stability which was achieved during the operation in the long oblique, long spiral, fragmented and segmentary fracture cases as is stated in the literature.<sup>[7, 25]</sup> We checked the anatomical position of the patella and trochanter major during the fixation in our cases, and clinically confirmed that the rotation after fixation had been corrected. The rotational problems observed during the follow-up sug-

gest that the elastic fixation was inefficient in terms of rotation in given complicated fracture models. We believe that if TEN fixation is going to be used in such type of fractures, use of bracing or cast fixations covering the hip, knee and ankle for a period of three weeks postoperatively would be beneficial.

Tonnis and Heinecke<sup>[26]</sup> proposed that the femoral anteversion -particularly when reduced to 0 degrees- developed in children after rotation corrective varus osteotomy couldn't be corrected by reformation process. Fabry et al.<sup>[27]</sup> observed that no significant change was seen in the femoral anteversion values after eight years of age in children. When it has been considered that corrective proximal femoral osteotomies are also fractures created for treatment purposes and that the mean age of our patients was 8.3 years, we assumed that the retroversion problem would not be corrected by the reformation process in our cases, particularly in femoral shaft fractures in the proximal area. However, even though we didn't demonstrate it with objective data like walking analysis, the absence of complaints from parents and subjectively unnoticed walking deformities like pressing inward or outward led us to assume that the rotational deformities determined by CT were compensated by the hip, knee and subtalar joints or tibial torsion.

It is controversial as to whether the changes in the relative and absolute femoral anteversion angles cause hip osteoarthritis after the growth is complete or not.<sup>[26, 28, 29]</sup> It has been reported that hip constriction and labral tears may occur in patients with reduced femoral anteversion or retroversion, and femoral retroversion may lead to femur-headed epiphysis slippage.<sup>[26]</sup> In a cadaver study, Eckhoff et al.<sup>[28]</sup> have shown that the knee osteoarthritis is associated with reduced femoral anteversion. Therefore, the children, who are in transition to adolescence with reduced femoral anteversion value, are under risk in terms of the development of knee osteoarthritis. Based on this, we believe that the cases found to have reduction in the femoral anteversion should be followed up until their growth is complete, and even after that.

Other recognized complications after fixation with titanium elastic nails and Ender nails are the pain the outer part of the nail caused and erosion to the skin. In order to prevent any soft tissue irritation,

only a small part of the nail should be left outside the distal metaphyseal cortex, and the nails must never be bent into the soft tissue.<sup>[12,30]</sup> Luhmann et al.<sup>[30]</sup> indicated that the technical problems can be minimized if the part of the nail which is left outside the femur is smaller than 2.5 cm and the biggest diameter of the nail is used. No soft tissue irritation was observed in any of our patients.

Flynn et al.<sup>[7]</sup> found very few complications in a multi-center study with 58 cases on whom they performed TEN. First callus tissue emerged in four weeks on the average. In this study, the nail was routinely removed in at the sixth month while early removal was required only in five cases due to soft tissue irritation; but it has been reported that it didn't affect the stability. Also, loss of reduction was observed in three patients during the postoperative period; five of the nine fractures in the proximal area improved with an angulation over 5 degrees. Following the surgery, two children had 15 degrees rotational asymmetry; and six patients had limb length discrepancy of 1-2 cm. Two patients had deep tissue infection, which had improved before any osteomyelitis developed; and the nail was advanced to the distal in one patient; and a fracture was observed in one patient after the removal of the nail.

In a study performed with antegrade and retrograde TEN, Galpin et al.<sup>[6]</sup> found myositis ossificans in six of 37 patients; and they reported that four of these had no clinical or functional significance. In a patient with closed head injury and brachial plexus paralysis, phase 4 myositis ossificans was observed and surgically removed. No myositis ossificans was observed in our study.

The removal interval for TEN in our study is longer than the intervals presented in the literature. We usually removed the nails at the end of the postoperative first year, which results from the fact that femoral shaft fractures usually occur during summer time and the healing period corresponds to the school time. None of the patients had fracture after removal of the nail; only one patient had a second fracture when the nail was still at the medulla and after the first fracture was unified.

Very successful results and low complication rates were also obtained in the studies performed with the Ender nails.<sup>[1,4,13,20]</sup> Karaoglu et al.<sup>[31]</sup> per-

formed fixation by Ender nail on the 29 femoral shaft fractures of 27 children between 10 and 16 years old; and they reported that they had achieved successful results for a length discrepancy of 1.7 cm in one patient who developed osteomyelitis and emphasized the advantages of the method they called "fracture treatment allowing motion" for earlier return to the school and social environment. Ozturkmen et al.<sup>[2]</sup> reported union at 6.6 weeks for all of the 26 children who were operated on using retrograde Ender intramedullary nails. In this study, they found varus/valgus in two patients, slight angulation in the anteroposterior plane in two patients; and clinically non-significant limb length discrepancy in six cases.

Many studies recommended allowing walking using crutches after the pain was eliminated without pressing following the intramedullary nailing.<sup>[11,12]</sup> Some authors report that they do not limit the mobilization after the osteosynthesis.<sup>[13]</sup> Flynn et al.<sup>[7]</sup> used a knee-fixating device to control the pain, to support quadriceps and to prevent the end of nail causing any soft tissue irritation in the knee until the callus tissue appears (4-6 weeks). The patients were able to walk at day nine on the average with the help of equipment, and at week 8.5 on the average (range from 2 to 12 weeks) without the equipment. In another study comparing several methods, the earliest full pressing was achieved by carved nails, which were followed by elastic intramedullary nails, plaque (almost identical to early casting), early casting, casting after traction and external fixator respectively.<sup>[23]</sup> We used fixation methods limiting the mobilization in the first patients treated with TEN; however they were not used for further patients if it was not required. If the patient could tolerate it, he/she started to ambulate with a crutch, which usually happened at week five. Partial pressing was at mean five weeks (range from 3 to 8 weeks) and full pressing was at mean 6.8 weeks (range from 4 to 12 weeks).

Kiely<sup>[32]</sup> biomechanically compared the application by two nails in C shape, which we also used in our study, with two straight nails or combination of one S shaped and one C shaped nail for intramedullary nailing in femoral shaft fractures, and indicated that there was basically no difference between the groups. This method has been suggest-



ed to provide wider choices for the surgeon to shape the nails during the operation.

Although excellent results were reported with antegrade locked nailing in pediatric femoral shaft fractures<sup>[21]</sup>, several case reports<sup>[33]</sup> and subsequent studies [16] demonstrated the risk of deformity in femoral proximal and of avascular necrosis in the femoral head. Even though the risk of avascular necrosis is very low, this complication cannot be successfully treated. The intramedullary nails are technically placed through where the growth cartilages are absent. Carey and Galpin<sup>[5]</sup> performed antegrade elastic intramedullary nailing in 25 cases; they didn't observe disturbance in the growth of the big trochanter apophysis, and they found no significant change in the neck-shaft angle. Canale and Tolo<sup>[34]</sup> suggested that both antegrade and retrograde intramedullary nailing can be considered for children over 10 years old; and they indicated that the closed antegrade nailing could cause a growth problem in the big trochanter apophysis and delicacy in the floor of the femoral neck in smaller children. Gage and Cary<sup>[35]</sup> reported that no remarkable disturbance of growth would be possible in cases where growth in the trochanter major apophysis is disturbed after eight years old. Intramedullary fixation by Künthsher nail is not recommended during adolescence due to the engraving in the medulla and potential damage to the trochanter major apophysis.<sup>[34]</sup>

In conclusion, the intramedullary fixation by TEN is a method of choice for lower complication rate, good outcome, placement of nails and easier postoperative maintenance in the femoral shaft fractures of patients aged between 5 and 15 years. However, the rotation demonstrated by postoperative CT is still a major technical challenge in fixation by TEN.

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