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ARAŞTIRMA / RESEARCH

Effect of titanium elastic nailing surgery on the femoral development in pediatric femoral fractures

Çocuk femur cisim kırıklarında titanyum elastik çivileme cerrahisinin uzun dönemde femur gelişimine etkisi

Gökhan Bülent Sever[1]

[1]Sani Konukoğlu Private Hospital, Department of Orthopaedic Surgery, Gaziantep, Turkey

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Abstract

Purpose: The aim of this current study was to investigate the effect of titanium elastic nailing surgery following the pediatric femoral shaft fractures on the long-term pediatric femoral development.

Materials and Methods: Thirty-five patients with a mean age of 62.1 months(15-160) who underwent surgery with titanium elastic nailing following unilateral femoral shaft fracture in our clinic were included in this study..At the last postoperative visit, patients were further evaluated through the physical examination and comparative femoral anterior posterior and lateral radiographs.The difference in length of the lower extremities and deformities in the frontal and sagittal plane, collodiaphyseal angle, mechanical distal femoral lateral angles were all calculated and compared with the intact femoral length and angles.

Results: The mean follow-up period in our study was 69.8 months (36-120).The mean fracture union time period was 11.2 weeks(8-13).The mean implant removal time was 5.1months(2-12).At the last follow-up, 1 patient(2.8%) had 5mm shortening in the femur lenght while 3 patients' femurs(8.5%) got longer with the average of 6 ± 4mm compared to that of the intact femur. In 8 patients (22.8%), varus angulation was measured as 4.7°± 2.1 at the fracture line.

Conclusion: The treatment of femoral shaft fractures with titanium elastic nailing surgery has a limited effect on pediatric femur development in the long term. Surgical treatment of pediatric femoral fractures with titanium elastic nailing is a simple and safe method of treatment with low long-term complications.

Keywords: Pediatric femoral shaft fracture, titanium elastic nailing, femoral development

Öz

Amaç: Bu çalışmanın amacı çocuk femur cisim kırıklarında titanyum elastik çivileme ile tespit cerrahisinin uzun dönemde femur gelişimine etkisinin araştırılmasıdır.

Gereç ve Yöntem: Kliniğimizde tek taraflı femur cisim kırığı tanısı ile titanyum elastik çivileme cerrahisi uygulanmış cerrahi esnasında ortalama yaşları 62,1 (15-160) ay olan 35 hasta çalışmaya dahil edildi. Son kontrolde hastalar fizik muayene ve karşılaştırmalı femur ön arka ve lateral grafisi ile değerlendirildiler. Alt ekstremite uzunluk farkı, frontal ve sagital planda deformiteler, femur cisim boyun açısı, mekanik distal femoral lateral açılar hesaplandı ve sağlam femur uzunluğu ve açıları ile karşılaştırıldı.

Bulgular: Hastalar ortalama 69,8 (36-120) ay takip edildiler. Kırıkların ortalama kaynama süresi 11,2 (8-13) haftaydı. Ortalama implant çıkarma süresi 5,1 (2-12) aydı. Son kontrolde sağlam femurla karşılaştırıldığında 1(%2,8) hastanın femurunda klinik bulgu vermeyen 5 mm kısalık , 3(%8,5) hastada da ortalama 6±4 mm uzunluk saptandı. 8 (%22,8) hastada kırık hattında ortalama 4,7°±2,1 derece klinik bulgu vermeyen varus angulasyonu saptandı.

Sonuç: Femur cisim kırıklarının titanyum elastik çivileme cerrahisi ile tedavisinin uzun dönemde femur gelişimine etkisi sınırlıdır. Çocuk femur kırıklarının titanyum elastik çivileme" cerrahisi ile cerrahi tedavisi kolay uygulanabilen, uzun dönemde komplikasyonları az ve güvenle uygulanabilecek bir tedavi şeklidir.

Anahtar kelimeler: Çocuk femur cisim krığı, titanyum elastik çivileme, femur gelişimi

Yazışma Adresi/Address for Correspondence: Dr. Gökhan Bülent Sever, SANKO University Research Hospital, Department of Orthopaedic Surgery, Gaziantep, Turkey E-Mail: gokhanbsever@yahoo.com
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INTRODUCTION

The treatment of femoral shaft fractures for pediatric patients has been controversial[1,2]. In classical text books, titanium elastic nailing (TEN) surgery is highly recommended in almost all pediatric patients between the ages of 5 and 10 years old whereas a conservative treatment between 6 months and 5 years results in failure[3]. TEN is a prominent surgical method compared to other options in the treatment of femoral shaft fractures because of providing early union, low malunion rate, minimally invasive application, not damaging epiphyseal plate, easy removal and successful union rates[4].

There are question marks about the TEN surgical technique that are likely to cause complications in the long term. In the surgical technique, the entry sites to the femur prepared to send TEN intramedullary is close to the femur distal epiphysis. However, the femur distal epiphysis is preserved as the entry points are opened by viewing under fluoroscopic control. However, to increase fracture stability, the elastic nail is directed to the medial and lateral proximal to the femur after crossing the fracture line, and preferably it is attempted to be buried at a point in the bone. It is common for this site to be adjacent to the trochanteric apophysis laterally. It is not known how much trochanteric apophysis was affected by this condition. The femoral medulla is generally fixed with at least two and sometimes three titanium elastic nails in order to increase rotational stability and anatomic reduction is not mandatory in titanium elastic nailing, because seconder fracture healing is aimed without opening the fracture site. Does these affect the femur development in the long term?

There has been a small number of study reported on whether this surgical technique has an impact on the development of pediatric femur in the long term[5]. Accordingly, the aim of this current study was to investigate the effect of TEN surgery on pediatric femur development after at least 3 years in patients who underwent TEN fixation following a femoral shaft fracture.

MATERIALS AND METHODS

In this retrospective study, 35 patients, whose mean age was 62.1 (15-160) months, and who underwent TEN surgery between February 2009 and October 2016 in our clinic following the unilateral femoral shaft fracture were included in the study (Figure 1 and 2). The study was approved by the SANKO University Ethics Committee for Clinical Research Trials (2019/04, decision no. 02) and conducted in accordance with the principles set forth in the Declaration of Helsinki. All participants gave their written consent.

Procedure

We obtained the following information retrospectively from the patients' medical history files at the hospital archive: the demographic characteristics, fracture extremity sides, comorbidities, fracture union time, and implant removal time. We excluded the patients from the current study if they had an open fracture, the metabolic or neurological joint disease, orthopedic disease (congenital short femur, coxa vara, valga, etc.), additional trauma, fractures in both femurs, and retarded development at the health extremities. At the final follow-up, all patients were evaluated by physical examination along with comparative femoral antero-posterior and lateral radiographs (Figure 3).

During the physical examination, the absolute leg length between the spina iliaca anterior superior and the medial malleolus was measured independently by two orthopedic surgeons and the measurements were then compared with the intact site. If length discrepancy was present, femoral length was compared with comparative femoral anteroposterior radiography by measuring the distances between the femoral head center and intercondylar notch. At the same time, we showed coxa vara and valga by measuring colodiaphyseal angle, and showed distal femoral deformity by measuring distal femoral lateral angle at this graphy. Two independent orthopedic surgeons calculated the femoral lengths and angles of the patients and compared them with the intact femur.

Surgical technique

Following a general anesthesia, necessary cleaning, and treatment and covering the patients, femoral distal epiphysis was marked under fluoroscopic control. Two 2 cm supracondiler medial and lateral incisions was made on the distal site of the thigh. TEN with appropriate thickness is inserted through the supra condylar medial and lateral entry sites prepared on the cortex with the help of owl, without damaging distal femoral physis[6]. During The fracture is reduced and the nail is inserted retrogradely

through the femoral canal passing the fracture site under fluoroscopic control. The nails were then fixed in the cortex near the trochanteric apophysis. While the proximal femoral epiphysis was preserved, the trochanteric apophysis was ignored. In order to improve rotational stability, the medulla was fixed with two or three elastic nails. Reduction was again checked and the nails were cut at the entry sites. The incisions were closed and then the operation was terminated.

Statistical analysis

The normality of continuous data was tested through Kolmogorov-Smirnov test. Mean, standard deviation, percentage and frequency were reported as descriptive statistics while Chi-square test was used to compare the qualitative data. Statistical significance level was set at $p < 0.05$.

RESULTS

The mean follow-up period at this study was 69.8 months (ranging from 36 to 120 months). Seven of the patients (20%) were female while 28 of them (80%) were male. We observed that 15 fractures (42.8%) were located at the right side and 20 of them (57.1%) were located at the left side. Based on AO/OTA classification, 16 patients (45.7%) were in A1, 7 patients (20%) were in A2, 9 patients (25.7) were in A3, 2 patients (3%) were in B1, 1 patient (2.8%) was in B2 group.

Mean time to surgery after hospitalization was 8 hours (ranging from 2 to 24 h). The patients did not use any brace or splint following the surgery. Elastic nail insertion sites were dressed every 3 days and all the sutures were removed on the 15th operative day. None of the patients developed infection.

During monthly follow-up visits, anterior posterior and lateral radiographs of femur were evaluated accordingly with the protocol described. Weight bearing was permitted after the callus is seen on the radiographs. Implant removal was recommended after fracture union. No non-union was observed. The mean fracture union time was 11.2 weeks (ranging from 8 to13 weeks) while the mean implant removal time was 5.1 months (ranging from 2 to 12 months).

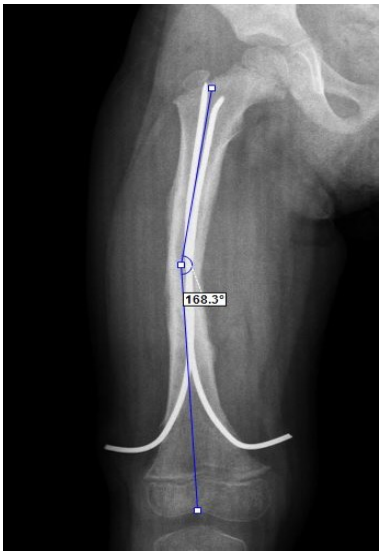

Figure1: Anterior posterior femur radiography at the postoperative 1st month of the patient undergoing titanium elastic nailing surgery.

Figure2: Lateral femur radiography at the postoperative 1st month of the patient undergoing titanium elastic nailing surgery.

Figure3: Comparative femoral anterior posterior radiography at the last control of a 17-year-old male patient.

In the first postoperative radiographic examination, we determined varus in seven patients (20%) and valgus angulation in seven patients (20%). Mean varus angulation was measured as 8.5 ± 6.9 while valgus angulation was measured as 6.6 ± 5.5. Based on the first postoperative radiographs, we found that 12 patients (34.2%) had a mean shortening of 10.3 ± 5 mm. Furthermore, 8 of these patients (22.8%) had a shortening of more than 10 mm. At the last follow-up visit, 1 patient (2.8%) had 5 mm shortening in femur length while 3 (8.5%) patients' femur length got longer with an average of 6 ± 4 mm compared to that of the intact femur. In 8 patients (22.8%), varus angulation was measured as 4.7 ± 2.1 degrees on the fracture line. The mean collodiaphyseal angle was 137 ± 5 at the fracture side while it was 136 ± 4 at the intact femur. The difference in collodiaphyseal angle was not statistically significant. Mean mechanical knee femoral lateral angle was 86 ± 3 at the fracture side while it was measured as 87 ± 2 at the intact site. The difference in mechanical distal-lateral femoral angle compared to the uninjured site did not reach to the statistically significant level.

Table 1. Evaluation of patients according to age, sex, fracture side, classification, union time and implant removal time.

Age (month)	Gender (F/M)	Side (R/L)	Follow up (month)	Classsification (AO/OTA)	Union (Week)	Implant removal (month)
62.1 (15-160)	7/28	15/20	69.8 (36-120)	A1=16. A2=7. A3=9. B1=2. B2=1	11.2 (8-13)	5.1 (2-12)

Table 2. Evaluation of patients according to deformities of femur bone.

	Deformity (Varus,Valgus,LLD)	CDA	mDFLA
Postoperative first Xray	Varus=8,5°± 6,9° (n=7,%20) Valgus=6,6°±4,5° (n=7,%20) Shortness=10,3±5 mm (n=12,%34,2)		
Last control Xray	Varus=4,7°±2,1° (n=8,%22,8) LLD(Shortness)=5mm (n=1,%2,8) LLD(Lenght)=6±4mm (n=3,%8,5)	Fracture side=137°±5° Intact side=136°±4°	Fracture side=86°±3° Intact side=87°±2°

LLD: Limb length discrepancy, CDA: Collodiaphyseal angle, mDFLA: Mechanic distal femoral lateral angle.

DISCUSSION

The optimum treatment for pediatric femoral fractures is still controversial. While nonoperative treatment had been the most common choice in the past, pediatric orthopedic surgeons have avoided long-term immobilization in the last 20 years because of the disadvantages such as malunion, limited range of motion, delayed functional return, and long-term hospitalization[7-9]. Since titanium elastic nailing surgery allows early mobilization, allows micromotion hence promote fracture healing, does not harm the epiphysis, and has the advantages of easy application, this surgery has become the ideal treatment in the surgical treatment of closed pediatric femoral shaft fractures of all ages[1,10,11]. Based on their study involving the findings of 30 pediatric patients (their age ranged from 6 to 15 years old) with femoral diaphyseal fractures, Kayaokay et al.[12] highlighted that TEN surgery is an effective and easy surgery along with minimal complication. Similarly, in another study on 27 children under the age of 6 who were treated with TEN surgery following the femoral fractures, Donati et al.[1] reported that the TEN surgery is safe, mini-invasive, and has high patient satisfaction. In accordance with the previous studies, fracture union occurred in all the patients (6 of them were under 6 years old and 29 of them were between 6 and 15 years old) in our study. We also did not observe any complication which supports the previous studies' findings.

In the treatment of femoral shaft fracture with TEN, the reduction of the fracture is checked under image intensifier. Since the fracture line is not opened and intramedullary fixation is used, the anatomic reduction is often not achieved but an acceptable reduction is provided such as less than 20 degrees

sagging in the coronal plane and 30 degrees sagittal plane, less than 1 cm shortening and rotation less than 10 degrees[13]. The form of fracture healing in such case is secondary fracture healing which may affect the length of femur and therefore the length of lower extremity in the growing child[14]. Although the surgical technique of TEN fixation of the femoral shaft fracture preserves the physis, an entry hole is opened just above the distal physis. However, it is not known if it disrupts the nutrition of distal physis. Moreover, the trochanteric apophysis is ignored during the surgery along with the possibility of any occurred damage which may have an impact on the collodiaphyseal angle most probably. Another possible effect is that fixing the medulla as much as possible to ensure rotational stability could have an impact on the medullary blood flow. All these possibilities led us to investigate the long-term effect of this surgery on the femoral development of pediatric patients. Our cumulative findings showed that 4 patients (11.4%) had length differences in femurs without functional limitation compared to that of intact femurs, and 8 patients (22.8%) had angulation that did not affect the function in the fracture line (4.7 ± 2.1), suggesting that the aforementioned possibilities were not likely to happen.

This study has some limitations. The main limitations of this study are; lack of comparison, lack of large numbers in a single center. Femoral head anteversion and rotational deformity could not be investigated by computer tomography in order not to expose the children to high radiation.

Taking all into consideration, our findings suggest that the long-term effect of fixation with TEN on femoral development is within the physiological limits. The fixation with TEN for pediatric femoral shaft fractures is a safe surgical treatment method with a low complication rate.

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