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ARAŞTIRMA / RESEARCH

Comparison of clinical and radiological outcomes of titanium elastic nail and Kirschner wire in the treatment of pediatric tibia diaphyseal fractures

Çocuk tibia diafiz kırılarının tedavisinde titanyum elastik çivi ve Kirschner telinin klinik ve radyolojik sonuçlarının karşılaştırılması

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Abstract

Purpose: The aim of this study was to compare the clinical and radiological results of paediatric tibia shaft fractures treated by intramedullary fixation with Kirschner (K) wire and titanium elastic nail (TEN).
Materials and Methods: Thirtynine patients were evaluated retrospectively. Included 20 patients treated with TEN (group 1) and 19 patients treated with K-wire (group 2). At the end of the 1-year follow-up, radiological measurements for malalignment and the Flynn TEN outcome scoring system were used to compare the clinical results.
Results: According to the Flynn classification, in group 1, results were excellent in 75% and good in 25%, and in group 2, excellent in 70% and good in 30%. In any cases has not been experienced physeal early closure or refracture, nor did they need re-manipulation or re-operation, and no implant insufficiency was detected. Malalignment was found in four patients in group 1, and in two patients in group 2 of lesser than 10 degrees.
Conclusions: Even though two methods showed similar clinical and radiological results, fixation paediatric tibial fractures with K-wire may have some advantages as lower-cost and easy accessibility according to TEN.
Keywords:. Pediatric tibia fracture, titanium elastic nail, Kirschner wire

Öz

Amaç: Bu çalışmada, Kirschner Teli (K-teli) ve Titanyum Esnek Çivi (TEÇ) ile intramedüller tespit uygulanan çocuk tibia kırıklarının klinik ve radyolojik sonuçlarının karşılaştırmasını yapmayı amaçladık.
Gereç ve Yöntem: Otuzdokuz hasta retrospektif olarak değerlendirildi ve tüm hastalar TEÇ uygulanan 20 hasta grup 1 ve K-teli uygulanan 19 hasta grup 2 olarak iki gruba ayrıldı. En az bir yıllık takip sonrası hastalar radyolojik ölçümleri ve Flynn Ten skorlamasına göre karşılaştırıldı.
Bulgular: Flynn skorlamasına göre, grup 1'de % 75 mükemmel ve % 25 iyi sonuç, grup 2'de % 70 mükemmel ve % 30 iyi sonuç tespit edildi. Hiçbir vakada erken fiz kapanması, tekrar kırık, tekrar cerrahi girişim veya tespit materyali yetmezliği saptanmadı. Dizilim bozukluğu grup 1'de dört hastada ve grup 2'de iki hastada 10 derecenin üzerinde olmamak suretiyle tespit edildi.
Sonuç: Her iki grubun klinik ve radyolojik sonuçları benzerlik göstermiş olsa da, pediatrik tibia şaft kırıklarında K-teli ile fiksasyonun daha düşük bütçeli ve elde edilebilirliğinin daha kolay olması sebebiyle TEÇ'ye göre avantajlı olabilir.
Anahtar kelimeler: Çocuk tibia kırıkları, titanyum esnek çivi, Kirschner tel

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INTRODUCTION

Tibial fractures are the most common paediatric long bone shaft fractures[1]. The majority of paediatric tibial shaft fractures are treated by closed reduction and plaster cast, in accordance with the fact that, compared to adults, children have stronger and thicker periosteum and the ability of spontaneous remodelling[2-4]. These characteristics, however, are significantly decreased from the age of 12 years onward[3,5,6]. Indeed, the decreased potential for spontaneous remodelling in paediatric patients engenders a change in acceptable criteria of fracture reduction[6].

Surgical treatment is preferred in cases of open fractures, neurovascular injury, polytrauma, pathological fractures, spasticity, pulmonary dysfunction, floating knee, cranial injury, and when the reduction is lost[1,7-12]. The radiological criteria for a surgical approach are shortening of the fracture line, 10° sagittal plane, 10° varus/valgus angulation, more than 50% translation, and malrotation[2]. The surgical fixation methods are external fixator, plate and screw, titanium elastic nail (TEN) and Kirschner (K) wires[1,13,14,15].

Intramedullar fixation (IMF) of paediatric tibial fractures has several advantages. Primarily, these are the application of minimally-invasive surgery, obtaining primary callus tissue without damaging the growth plate, protection of the fracture hematoma, low infection rates, minimal scar tissue, rarely repeated fracture, early weight-bearing and short hospital stay[7,9,15-17]. Risk is inherent in bad surgical technique and insufficient surgical experience, both of which can complicate healing and return to normal function.[18]

The disadvantages of TEN are implant migration into the joint or medulla, skin irritation, necessity of additional surgery for implant removal, and high cost. But surgical fixation of paediatric tibia fractures with K-wire may have some advantages as low-cost and easy accessibility according to TEN. So, in the current study, we aimed to compare the clinical and radiological results of unstable paediatric tibial diaphyseal fractures that underwent IMF by K-wire and TEN.

MATERIALS AND METHODS

All procedures performed in this study that involved human participants were performed in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This article does not contain any studies involving animals that were performed by any of the authors. The entire study protocol was approved by the Research Ethics Committee of University of Health and Science Umraniye Research and Education Hospital under protocol number (Date: 27.11.2014, No:B.10.1.TKH.4.34.H.GP.0.01/76).

Between April 2012 and August 2018 48 consecutive patients from a single institution (University of Health and Science Umraniye Research and Education Hospital) who were scheduled to undergo tibia shaft fracture surgical fixation were retrospectively evaluated. Inclusion criteria for the study were as follows: patients with tibia diaphysis fractures, open tibia physeal lines and reduction loss during conservative treatment follow-up. Patients with pathologic fractures (n:1), tibial physeal extended fractures (n:1), additional lower limb fractures (n:3) and neuromuscular disease (n:2 patient with cerebral palsy) were excluded from the study. Two patients did not follow the further treatment in our clinic after surgery.

The 39 total enrolled patients were grouped according to the application of TEN (group 1: 14 males and 6 females) and K-wire (group 2: 13 males and 6 females) for the IMF. The mean duration of follow-up was 34.5±16.26 (23-46) months for group 1 and 31.5±19.09 (18-45) months for group 2. In addition to the patients' demographic data, aetiology of the injury, presence of an open fracture, whether fracture reduction was open or closed, time to weight-bearing, time of implant removal and all complications were evaluated.

Radiological evaluation and classification

Fracture classification was made according to the Association of Osteosynthesis/Association for the Study of Internal Fixation (AO/ASIF) principles as mid-shaft fracture of tibia (AO/ASIF classification 42). Fracture diagnosis and follow-up were examined with standard extremity cruris anteroposterior/lateral radiographs and orthoroentgenogram by using the Picture Archiving and Communication System network system, Marosis, DICOM version 5.5 (INFINITT, Seoul, South Korea). Open fractures were classified according to the Gustilo-Anderson scoring system as type I, an open fracture with a laceration less than 1 cm and clean; type II, an open fracture with a wound bigger than 1 cm without extensive soft tissue damage, and type III, an open segmental fracture or fracture with extensive soft tissue damage[19]. Irrigation and debridement were applied to all open fractures. For those with a low level of contamination, treatment was started with primary closure and prophylactic antibiotics.

The criterias for bone union were observation of callus tissue in three cortexes by periodic radiography and the ability of pain-free weight-bearing[5,6].

Complications were evaluated as malunion, non-union, refracture, infection, complications related to implant, leg length discrepancy, deformity, and joint movement limitation. In AP view, varus/valgus deformity was evaluated by measuring the angle between the lines drawn perpendicular to the proximal and distal tibial articular surfaces. Malunion was stated as coronal deformity (varus or valgus) of >5°, sagittal deformity (anterior or posterior) of >10°. Results were evaluated as excellent, satisfactory, or poor based on the outcome scoring system for TENs described by Flynn et al. (Table 1) at least one year follow up[7].

Table 1. Flynn TEN scoring system

	Excellent	Good	Poor
Leg length discrepancy	< 1 cm	< 1 cm	> 2 cm
Malalignment	< 5°	5-10°	> 10°
Pain	absent	absent	present
Complications	absent	mild	major/extended period for resolve morbidity

Study population

In group 1, the mean age of the patients was 11.50±3.65 (4-14) years. The TEN were blunt-ended, bent at 45°, standard 350 mm length, and of four different diameters (2.0, 3.0, 4.0 and 5.0 mm). In group 1, tibial diaphyseal fracture reduction was done in closed manner except 2 patients. For the 2 cases with loss of reduction during polyclinic follow-ups, open reduction was attempted in the operating room (Figure 1).

Figure 1. Unstable tibia shaft fracture of a 12 year-old male in pre-postoperative radiographies. a. Preoperative anteroposterior and lateral view. b. Anteroposterior and lateral view on postoperative day 1 after TEN applications. c. Anteroposterior and lateral view at 10-month follow-up

Patients were evaluated during surgery to determine varus/valgus and rotational stability and long leg cast was applied all patients. On postoperative day 1, patients were allowed to walk on the operated extremity without weight-bearing. On postoperative days 2-5, the wound site was examined in-hospital. All cases in which bone union was observed, the patients were allowed to perform weight-bearing walking. Follow-up examinations were performed once every 2 weeks for the first 2 months, then once a month for the next 4 months, and finally once every 3 months for the last 6 months. TEN removal occurred at an average of 9.40±4.78 months.

Figure 2. Unstable type 1 open tibia shaft fracture of a 9 year-old male in pre-postoperative radiographies. a. Preoperative anteroposterior and lateral view. b. Anteroposterior and lateral view on postoperative day 1 after K-wire application. c. Anteroposterior and lateral view at 4-month follow-up, when the K-wires have been removed.

In group 2, mean age of patients was 7.84±2.11 years. K-wire of 350 mm length and 2.5 mm diameter was used as the IMF material in all cases (Figure 2).

Patients were evaluated during surgery to determine varus/valgus and rotational stability and long leg cast was applied all patients. On postoperative day 1, patients were allowed to walk on the operated extremity without weight-bearing. On postoperative days 2-5, the wound site was examined in-hospital. Follow-up examinations and weight-bearing protocole were as group 1. The K-wires were removed from all patients at an average of 2.36±0.70 (2-3) months.

Surgical techniques for the TEN and K-wire application

Under general anaesthesia, patients were laid in a supine position on a radiolucent operating table. Under fluoroscopy, 2 cm skin incision was made at 1.5-2.0 cm distal from the proximal tibia physeal line.

So as not to pierce the opposite cortex, to advance easily in the medulla, and to facilitate the fracture reduction, TEN (TST Rakor Tıbbi Aletler San. ve Tic. Ltd. Şti., Istanbul, Turkey) with a blunt end and bent 45°-ended, standard 350 mm length and of 4 different diameters (2.0, 3.0, 4.0 or 5.0 mm) were selected or K-wire of 350 mm length, 2.5 mm diameter with bent 45°-ended according to the width of the intramedullar canal intraoperatively.

The medulla was awled at an angle of 45° to the tibia long axis. Before inserting the nail, the apex of the nail long axis was lightly bent to 40° in the opposite cortex. With the aid of a T-handle, the nail was advanced to the fracture line by using rotational movements. By making manual reduction, after passing the fracture line, the nail was then embedded into the distal tibia metaphysis. The second nail was applied in the same way from the other side. The parts of the nail remaining in the proximal area were bent to the distal and posterior direction to facilitate easy removal of the TEN.

Statistical analysis

The Number Cruncher Statistical System 2007 & Power Analysis and Sample Size 2008 (known as the NCSS & PASS) Statistical Software (Utah, United States) program was used for statistical analysis. In the evaluation of the study data, descriptive statistical methods (mean, standard deviation, median, frequency) were used. In the comparison of quantitative data, Student's *t*-test was used for comparison of parameters of two groups showing normal distribution and the Mann Whitney U-test was used for comparison of parameters not showing normal distribution. In the comparison of qualitative data, chi-square test was used.

Table 2. Sociodemographic information and fracture patterns of patients

		Group		p
		TEN[1] (*n*=20)	**K-wire[2] (*n*=19)**	
		Median±SD	Median±SD	
Age (year)		11.50±3.65	7.84±2.11	*a0.002***
Bone union (week)		9.1±1.56 (8-15)	9.4±2.36 (6-12)	a0.375
Weight-bearing (day)		46.30±11.40	41.30±8.50	*a0.348*
Limb length discrepancy (mm)		4.87±1.49	4.71±0.89	*a0.268*
Implant removal (month)		9.40±4.78	2.36±0.70	*c0.001***
Sex	female	6	6	*b1.000*
	male	14	13	
AO/ASIF classification	42-A1	6	6	*b1.000*
	42-A2	2	13	*b0.018**
	42-A3	8	0	*b0.063*
	42-B2	4	0	*b0.173*
Gustilo- Anderson classification	none	10	6	*b0.592*
	type 1	4	13	*b0.062*
	type 2	4	0	*b0.487*
	type 3A	2	0	*b1.000*

a Mann Whitney U test, b chi-square test, c independent T test

RESULTS

Mean bone union time was 9.1±1.56 (8-15) weeks in group 1 and at 9.4±2.36 (6-12) weeks in group 2. There were no significant differences in both group *p* = 0.375 (Table 2). In our series, the duration of cast application was 46.5±14.5 (12-63) days for both groups. According to Flynn classification, in group 1, 15 cases had excellent results and 5 had good results, and in group 2, 12 cases had excellent results and 7 had good results.

Group 1 has no cases of early physeal closure, refracture, implant insufficiency, reduction failure; although, one patient had 7° recurvatum and 4° varus, and three patients had varus malalignments of 3°, 6° and 10° respectively. In group 2, two patients had varus malalignments of 6° and 5° respectively. In group 1, three patients experienced numbness at the medial nail insertion site; the numbness had resolved by 6 months. In the same group, one patient experienced TEN migration, proximally. Superficial pin site infection occurred in three patients in group 2 and all were resolved upon debridement and antibiotherapy. The two groups did not show statistically significant differences in open fracture, time of weight-bearing, bone union period and limb length discrepancy (Table 2).

DISCUSSION

The application of IMF is becoming more widespread in paediatric unstable tibial shaft fractures. The reasons for preference of IMF over other implant practices are that the incisions are small and easily achieved, the stability is well protected and the application or removal of implants are not difficult.[14-16] Other additional advantages are the absence of damage to the growth plate, the recovery of the primary fracture, low infection rates, low risk of refracture, short in-hospital stay, avoidance of loss of joint range of motion, and fast return to daily physical activities.[20] There are, however, three main points which require attention in the IMF technique, namely insertion of the implant into the bone, passing the fracture line by advancing in the medulla, and achieving fracture reduction and stabilisation by final positioning of the implant.[21]

In the current study, after directing the distal end of the nails posteriorly, we drove the nail in a little more to ensure good settling in the metaphyseal area. In this manner, we are able to reduce the formation of any deformity at the fracture site or of implant loosening due to rotational movement. By applying a three-point fixation in the medullar canal with two nails crossing at the fracture line, traction force becomes compression force on the fracture line.[15] Micro-oscillations are caused at the fracture site by the elasticity of the S-shape of titanium and limited resistance to the deforming force; both of these parameters result in the stimulation of the formation of callus tissue at the fracture site.[7] In both patient groups of the current study a wire bent according to the fracture line was passed obliquely across the fracture line prior to application of the IMF material. The insertion holes for the IMF devices were made approximately 1.5-2 cm away from the tibial proximal physeal line and at the same level. The thickness of the nails were defined by measure of the narrowest part of the medullar canal made on the preoperative lateral radiographs of non-fracture side. By selecting the thickest nails, we prevented the corkscrew effect and obtained a fixation that was more stable against the forces that can create deformities also.

In patients with skeletally immature but wider tibial medulla, four nails can be inserted. In these patients, bending the nails before application is not important because stability is achieved more from the three-point fixation than from filling of the canal. We applied this technique to one patient in group 1. In the follow-up, the third wire was found to have migrated proximally. To prevent this in future cases, the distal end of the nail must be well embedded in the metaphysis or the number of nails in the medulla must be increased.

Intramedullar K-wire in the fracture line provides immobilisation with the combination of stable and elastic fixation. By embedding the wires in the metaphysis, axial stability of the bone is provided. Rotational stability is achieved by crossing two bent K-wires, resulting in the formation of a three-point fixation. By allowing a certain amount of movement in elastic mobility in the fracture site, diagonal forces become compression forces. This stimulates indirect callus formation.[4]

Thus, stable and dynamic fixation is obtained in the fracture with this technique. There was no need to bend the K-wires into a C- or S-shape before application in the patient group of young children. However, bending the K-wire before application in patients close to adolescence with unstable fractures increases the stability. Intramedullar K-wire is sufficient to obtain alignment and length in stable fractures which are not fragmented or oblique.[13] However, in the current study, we bent the K-wires before application for all the patients in group 2.

Despite these advantages, it should be kept in mind that delayed union, non-union, wound problems and infection may occur in the late paediatric age group with severe open fractures.[20] In the current study, after irrigation and debridement of open fractures in the operating room, prophylactic antibiotherapy was started. Surgery was applied to group 2 patients with open fractures on the same day as the trauma. Any infection did not occur in these patients.

Limb length discrepancy, generally no more than 5 mm, is the most frequent complication resulting from lengthening of the tibia following fracture or malreduction.[3,4] In the current study, the operated side was longer than the non-fractured side in both groups of patients but that did not lead to any clinical problems in any case. Another most common postoperative complaint was irritation and superficial pin side infection caused by the proximal end of the nail. As the wire ends was left outside the skin, superficial pin site infection was detected in three patients of group 2. Three patients in group 1 had numbness around the medial skin incision, probably due to damage of the infrapatellar branch of the saphenous nerve. Also, in paediatric tibial fractures, post-surgical sagittal or coronal plane malunion can be an indication for resurgery. In a previous study of paediatric tibial fractures, it was shown that malunion of more than 10° led to permanent deformity in 33% of the cases[3]. In the current study, five patients in group 1 recurvatum angulation and five patients in group 2 had varus below 10°; however, this did not lead to any clinical or cosmetic problems compared to each patient's normal extremity.

The limitations of the current study are the low number of patients and the age differences between the two study groups. In general, the majority of paediatric tibial fractures are treated conservatively and this results in surgical treatment being applied to a small number of fractures. The age difference between the groups in our study was due to the preference for K-wire application being mostly in younger children.

In conclusion, either TEN or K-wire application is a simple, reliable, and effective method with low complication rates for tibial fracture treatment in children aged between 5-14 years if surgery is indicated. However, two methods showed similar clinical and radiological results, fixation paediatric tibial fractures with K-wire may have some advantages as low-cost and easy accessibility according to TEN. Further prospective studies with wider case series are required to compare the results of different fixation methods.

Yazar Katkıları: Çalışma konsepti/Tasarımı: GA, TK; Veri toplama: ÇÖ, BK; Veri analizi ve yorumlama: GA; Yazı taslağı: GA, TK, ÇÖ; İçeriğin eleştirel incelenmesi: TK, BK; Son onay ve sorumluluk: GA, TK, BK, ÇÖ; Teknik ve malzeme desteği: GA. TK, ÇÖ; Süpervizyon: GA, ÇÖ; Fon sağlama (mevcut ise): yok.
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