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Functional results of the Ilizarov circular external fixator in the treatment of open tibial fractures

Tibia açık kırıklarının Ilizarov sirküler eksternal fiksatörüyle tedavisinin fonksiyonel sonuçları

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Amaç: Ilizarov sirküler eksternal fiksatörü ile tedavi edilen tibia açık kırıklarında fonksiyonel sonuçlar değerlendirildi.

Çalışma planı: Çalışmaya tibia açık kırıklı 33 hasta (26 erkek, 7 kadın; ort. yaş 38; dağılım 16-69) alındı. AO/OTA sınıflamasına göre yedi kırık tip A, 16 kırık tip B, 10 kırık tip C; Gustilo-Anderson sınıflandırmasına göre sekiz kırık grade I, 12 kırık grade II, 13 kırık grade III idi. Hastalar ortalama 5.7 gün (dağılım 3-12 gün) içinde ameliyat edildi. Beş hastada kompresyon-distraksiyon uygulanarak kemik kaynamasına yardımcı olundu. Fonksiyonel sonuçlar Karlstrom-Olerud ölçütlerine göre değerlendirildi. Ortalama izlem süresi 28 ay (dağılım 19-34 ay) idi.

Sonuçlar: Grade I ve grade II açık kırıklar arasında iyileşme süresi açısından anlamlı fark yoktu (p>0.05). Grade I ve grade III, grade II ve grade III arasında kaynama süresi açısından anlamlı farklılık bulundu (sırasıyla p=0.0001, p=0.001). Karlstrom-Olerud ölçütlerine göre, fonksiyonel sonuçlar 14 hastada (%42.4) iyi, 11'inde (%33.3) tatmin edici, sekizinde (%24.2) orta idi. Tel dibi enfeksiyonu en sık görülen (%28.4) komplikasyondu. Yedi adet K-teli değiştirildi. Osteomiyelit gelişen iki hastada (%6.1) iki K-teli çıkarılarak sekestrektomi uygulandı. İki hastada K-teli uygulamasına bağlı peroneal sinir hasarı görüldü. Fiksatör uygulamasına bağlı olarak yedi hastada ayak bileği, dört hastada diz hareketleri olumsuz etkilendi.

Çıkarımlar: Tibia açık kırıklarının sirküler eksternal fiksatör ile tedavisinde tel dibi enfeksiyon riski yüksek olsa da, erken mobilizasyon ve eklem hareketlerine izin vermesi nedeniyle fonksiyonel sonuçlar kabul edilebilir düzeydedir.

Anahtar sözcükler: Eksternal fiksatör; kırık, açık/patoloji/cerrahi; Ilizarov tekniği; hareket açıklığı, eklem; cerrahi yara enfeksiyonu/etyoloji; tibia kırığı/cerrahi/radyografi.

Objectives: We evaluated functional results with the Ilizarov circular external fixator in the treatment of open tibial fractures.

Methods: Thirty-three patients (26 males, 7 females; mean age 38 years; range 16 to 69 years) with open tibial fractures were included. According to the AO/OTA classification, there were seven type A, 16 type B, 10 type C fractures; according to the Gustilo-Anderson classification, eight, 12, and 13 fractures were grade I, II, and III, respectively. The mean time to surgery was 5.7 days (range 3 to 12 days). Compression-distraction was applied in five patients to speed up union. Functional outcomes were assessed according to the Karlstrom-Olerud scoring system. The mean follow-up was 28 months (range 19 to 34 months).

Results: Time to union did not differ significantly between grade I and II fractures (p>0.05). However, there were significant differences between grade I and III (p=0.0001) and grade II and III (p=0.001) fractures with respect to union times. According to the Karlstrom-Olerud scores, functional outcome was good in 14 (42.4%), satisfactory in 11 (33.3%), and fair in eight (24.2) patients. The most common complication was pin tract infections (28.4%). Seven K-wires were replaced. Two patients (6.1%) who developed osteomyelitis underwent sequestrectomy following removal of two K-wires. Peroneal nerve injury occurred in two patients associated with K-wires. Ankle and knee movements were adversely affected due to the external fixator in seven and four patients, respectively.

Conclusion: Although the use of the circular external fixator is associated with a relatively high risk of pin tract infections, functional results may justify its use in the treatment of open tibial fractures, with an added advantage of early mobilization.

Key words: External fixators; fractures, open/pathology/surgery; Ilizarov technique; range of motion, articular; surgical wound infection/etiology; tibial fractures/surgery/radiography.

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Use of intramedullary nailing and external fixation instead of conservative (plaster) and dynamic compression plate fixation methods is associated with reduced complications such as misunion, extremity discrepancy and non-union in the management of tibial open fractures.[1-4] By fixation systems which have been developed to maintain the endosteal circulation in open fractures, the aim is to eliminate the union problems. Although unreamed intramedullary nailing and circular external fixation provide best protective fixation systems, both have some advantages and disadvantages. In the circular external fixator method, less damage is done by the thin K-wires of Ilizarov, however it is accompanied with a risk of developing pin tract infection. Furthermore, K-wires placed across the muscle tissue and being retained for a long period of time on patient result in restricted motion of neighbouring joints.[5]

In the present study, we evaluated the healing of fractures and the functional results in patients with tibial open fractures who had been treated by the Ilizarov circular external fixator.

Patients and method

The study included 33 patients (26 male, 7 female; mean age 38 years, range 16 to 69 years) with tibial open fracture who presented to our emergency service between September 1999 and December 2002. Twenty-seven of fractures involved the right side and six involved the left side: affected regions were proximal 1/3, medial 1/3 and distal 1/3 for six, seventeen and ten fractures, respectively. Using the AO/OTA classification, the fractures were grouped according to the degree of disruption at bones.[6] Based on this, there were seven Type A, sixteen Type B, and ten Type C fractures, in which none of them reached up to the superficial joint. The relation of fractures with location was evaluated by the Gustillo-Anderson classification; according to this classification there are eight and 12 fractures of Grade I and Grade II, respectively, and ten, two and one fractures of Grade IIIA, Grade IIIB, and Grade IIIC, respectively (Table 1). The mechanisms of fractures were as follows; eighteen out-of-car traffic accidents, seven falls from height, five motorcycle accidents and three gunshot injury. Additionally, three patients had head trauma, one had hip dislocation, and five patients had several fractures (1 lumber vertebrae, 1 corpus humerus, 1 humerus neck and corpus radius, 1 femur, 1 opposite side corpus tibia). First interventions were carried out at the emergency service. The wounds of patients with Grade I, II, and III open fractures were irritated by physiological serum of 3000, 5000, and 10000 ml, respectively; foreign material within and around the wound were debrided. Bone fragments having a disturbed relationship with soft tissue were removed from the fracture area. No antiseptic agent was added into the irrigation fluid. Patients intravenously received cephasoline sodium 1 gr. For prophylactic purposes, one dose of tetanus vaccine was applied. Extremity function test was carried out while in splint.

Surgical technique

The mean time to surgery was 5.7 days (range 3 to 12 days). Seventeen patients underwent spinal anaesthesia, and 16 were operated under general anaesthesia. The circular external fixator was preconstructed using the marked views taken prior to surgery (Figure 1a). Patients underwent surgery in supine position. While the initial K-wires were inserted into the soft tissue through plateau and ring near the ankle, muscles were tensed; the wires were attentively inserted while the muscles were functionally in full extension.

Using K-wires with olives enabled better fixation during tensioning for fractures of knee and near the ankle. No hybrid fixation was employed

Table 1. Characteristics of patients with tibial fracture

Involvement	
Right	27
Left	6
Type of fracture (AO/OTA classification)	
Type A	7
Type B	16
Type C	10
Open injuries (Gustillo-Anderson)	
Grade I	8
Grade II	12
Grade III (A-B-C)	10-2-1
Additional injuries	
Head trauma	3
Spine	1
Extremity	5

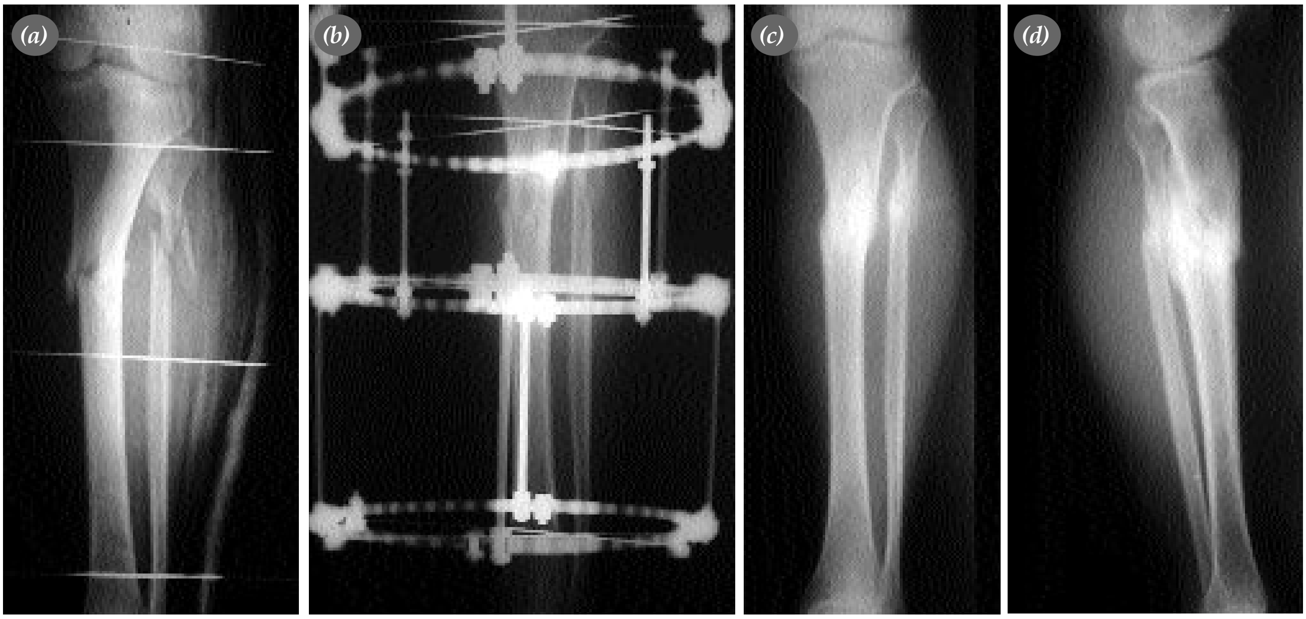

Figure 1. For a patient with Grade III A, type A2 open fracture, **(a)** anteroposterior view taken prior to surgery, K-wires being marked. **(b)** Post-operative view. **(c)** Anteroposterior view, and **(d)** lateral views following the union of fracture and removal of fixator.

by Schanz screws. Particular attention was paid to have the rings near the knee with a character of 5/8, providing unlimited knee motion. During the procedure where the K-wires are inserted over the same ring at the level of ankle, a transfixation was achieved at two planes, paying particular attention to employ the lower and upper parts of the ring (Figure 1b).

As fixator configuration, fixations were carried out by using up to four K-wires on the larger fragments of fractures over two ring frames in all patients. While the fragments of fracture were aligned by traction, particular care was given to line it up corresponding to the second metatarsal space of the medial patellar ligaments. Reduction of big fragments was achieved by means of K-wires with olive. Avoidance of any fixation on calcaneus and talus as much as possible, resulted with no restriction in the range of motion in the ankle. However, calcaneus fixation was employed in four

Figure 2. Patient's functional status following the removal of fixator.

Table 2. Functional Evaluation System by Karlstrom-Olerud[9]

Measures	3 points*	2 points	1 point
Pain	No	Little	Severe
Difficulty in walking	No	Moderate	Severe limping
Difficulty in stairs	No	Supported	Unable
Difficulty in previous sportive activity	No	Some sports	Unable
Limitations at work	No	Moderate	Unable
Status of skin	Normal	Various colours	Ulcer/fistula
Deformity	No	Little	Remarkable
Muscle arthropy (cm)	<1	1-2	>2
Shorter lower extremity (cm)	<1	1-2	>2
Loss of motion at knee (°)	<10	10-20	>20
Loss of subtalar motion (°)	<10	10-20	>20
Subtalar hareket kaybı (°)	<10	10-20	>20

*36 points, excellent; 35-33 points, good; 32-30 points, satisfactory; 29-27 points, moderate; 26-24 points, poor.

patients with fragmented fracture of distal metaphyseal region for adequate fixation.

Patients were followed-up for any development of oedema at post-operative day 1. Later on, they were allowed to mobilize by walker, and weight bearing was recommended to an extent they could have tolerated. K-wires were daily cleansed by povidon-iodine, and wounds were closed by sterile drapes. Following the discharge from hospital, care for wound and wires was carried out on alternate days. Radiographic analyses and controls for pin tract infection were carried out once a week.

Problems related with pin tract were assessed in accordance with measures of Paley.[7] According to this classification, Grade I problems include inflammation of soft tissue and erythema; Grade II, serous discharge in addition to inflammation; and grade III, inflammation, erythema and purulent discharge. During follow-up, oral antibiotics and wound dressing were used in case of any erythema and serous discharge was observed at the end of pins; in case of purulent discharge, the patient was hospitalized, antibiotic treatment and wound dressing two times a day (morning and evening) were initiated in accordance with the result of culture-antibiogram. a) (b) (c) (d)

In case of any increase in discharge, the patient was re-operated to replace the K-wire and parenteral antibiotic treatment was initiated. With callus, a sign of union, connecting elements of fixators were checked and degree of stability was maintained eliminating the gaps. During subsequent follow-ups, when anteroposterior and lateral radiographies revealed the continous presence of an union tissue (callus) in three of the four cortexes, dynamization was achieved by loosening the connecting screws for 1 or 2 rounds.[8] External fixators were removed if there is absence of pain during weight bearing following dynamization, and of any abnormal movement in the line of fracture during physical examination (Figure 1c,d). Union was supported by use of compression-distraction in five patients. Following the removal of fixators, maintanence of transfixated regions was continued. Patients were asked to weight bear with a crutch at week 1, and subsequently followed by full weight bearing without crutch (Figure 2). Functional results were assessed in accordance with the Karlstrom-Olerud scoring system[9] (Table 2). The mean hospitalization time was 16.7 days (range, 9 to 63 days), and mean follow-up time was 28 months (range, 19 to 34 months).

For statistical evaluations, in-group analyses were carried out by one-way ANOVA and Bonferoni tests, and inter-group analyses by Pearson correlation test.

Table 3. Union time by grades of open fractures

Grade	Number	Mean union time	Distribution
I	8	15.6 weeks	12-22
II	12	18.5 weeks	14-29
IIIA	10	25.2 weeks	21-30
IIIB	2	27.5 weeks	25-30
IIIC	1	32 weeks	

Table 4. Karlstrom- Olerud functional scores by grades of open fractures

Grade	Number	Mean ± standard deviationI
I	8	31.4±1.8
II	12	30.5±3.0
III (A-B-C)	13	28.7±3.1

Results

Mean time to union by grades of open fractures is shown in Table 3. The functional results in accordance with the Karlstrom-Olerud scoring system were good in 14 (42.4%), satisfactory in 11 (33.3%), and moderate in eight (24.2%) patients (Table 4).

The most common complication was pin tract infection (28.4%). In patients who were treated by daily pin-site care and oral cephalosporine, seven K-wires were replaced and parenteral antibiotic was initiated due to continous purulent discharge. Two patients who developed osteomiyelitis (6.1%) underwent sequestrectomy following removal of two K-wires, and healing was achieved following antibiotic treatment which was determined by antibiogram. No significant difference was observed between Grade I and Grade II in patients with open fractures (p=0.324). A significant difference was found between Grade I and Grade III, and Grade II and Grade III in the time to union (p=0.0001, p=0.001, respectively). Three of five patients who underwent compression-distraction had Grade II, and remaining two had Grade III open fractures. Of the Grade II patients two had type A2 and one had type B2 fractures

Compression was applied until contact was achieved at the tips of bones and pain occurs; then waited for one day. Distraction was applied as 4x0.25 rounds/day for three days.

Compression-distraction procedures were repeated until callus tissue became visible. The callus tissue was formed within three weeks in patients with Type A fracture while it took five weeks in patients with type B fractures. Temporary fixation and fasciocutaneous skin grafts were applied in two patients with Grade IIIB and IIIC fractures. They were followed up without removing the circular external fixator.

Three patients developed neurovascular complication. Two of them had iatrogenic peroneal nerve damage associated with use of K-wires; peroneal damage occurred before the surgery in one of them. In patients with iatrogenic peroneal nerve damage, position of crossing K-wire was changed, which resulted in improvement of peroneal damage during follow-up. Of Karlstrom-Olerud scores, seven patients had been adversely affected by ankle movements and four patients by knee movements. The examination of external fixators in patients with restricted range of knee motion revealed that medial hamstring tendons had not been taken into consideration during the anterolateral-anteromedial transfixation of K-wires at the first ring. It was found out that in four of the patients with restricted range of ankle motion, the ankle was transfixated by calcaneal pin placement during the installation of the device and calcaneal fixation was terminated upon onset of union; and in three patients three K-wires were placed on two planes over the lower and upper parts of the ring at the ankle level in order to increase the stabilization in fixation of fragmented distal metaphyseal fractures. The restricted range of knee motion was corrected by rehabilitation in these patients; however, three patients sustained a 10° restricted motion in the ankle, particulary during dorsiflexion.

Discussion

Open fractures of tibia present risks due to insufficient soft tissue at the anterior part of the leg and presence of tissue loss in high-energy traumas.[3,10] Amount of contamination of the wound, degree of soft tissue damage and experience of the surgeon are important determinants in the outcome of the treatment.[5,11,12] Although immobilization by casting is the first line treatment in the management of such fractures, use of intramedullary nailing and external fixator methods have been widely accepted with development of new surgical techniques and materials.[2-5,10,12] What remains unchanged in the course of management is the prompt evaluation of the open fracture, tissue debridement under sterile conditions, initiation of appropriate antibiotic (first generation of cephalosporine ± aminoglycoside) treatment and fixation of the fracture.[12-14] Union problems and infection development are common complications in casting and fixation by plate-screw. In studies with lower infection rates, the higher rate of union problems due to lack of stable fixation is notable.[4,15] Technological developments in the fixation systems reduced the rate of complications associated with implant failures.[10,11,13,14] The energy inducing the fracture also affects the vitality of the surrounding soft tissues around the fracture. During implantation, no additional damage should be generated to the tissues with already impaired supply.[11,16,17] Use of implants with wider diameters, which were developed to overcome the rotational and axial stability problems of the unreamed intramedullary nailing systems has become rare due to high risk of infection resulting from necrotic material and increased heat.[9-12,16,18]

Therefore, preferred treatment is not to open up the fracture line, and to use fixation materials less harmful to tissues. Complications may develop in the open fractures of tibia treated by external fixation, requiring removal of the device. Infections developing as a result of K-wires may result in complications including osteomyelitis, mainly delayed union.[5,19] With this method providing early mobilization and early weight bearing, complications such as infection and delayed union also have impact on functional results.[5,19-21] Union problems were addressed by autogenous bone grafting and dynamization. In our study, the fixation modules were closely monitored for the first four weeks as the early dynamization carried out by loosening the fixator may lead to delay in union. Dynamization is recommended following the mineralization in the callus tissue.[22] Compression-distraction was applied in five patients with delayed union. Three of them had Grade II, and two had Grade III open fractures; type of fractures were A2 at 1/3 proximal of tibia in two patients and B2 at medial 1/3 in three patients. We believe that the delayed union in these patients resulted from the inefficient fixation and extreme activity between fragments of the fractures.

As early uncontrolled dynamization causes extreme activity along the K-wires, problems such as pain, infection resulting from bottom of pins are common.[5,13,22] Loss of active tissues and damage by bacteria in patients with advanced contamination and impaired tissue may result in delayed union, even loss of extremity.[13,20]

Rate of deep pin tract infections and results of treating these infections by a combination of first generation cephalosporine and aminoglicoside in our Grade II patients with severe soft tissue impairment were similar to other studies.[5] In our study, we obtained results adversly affecting the outcome such as replacement of seven K-wires, use of sequestretomy accompanied with replacement of two K-wires, and development of osteomyelitis in one patient although healing was achieved in most of the patients with daily wound care.

In cases requiring use of flaps during the closure of tissue defects, circular external fixators may need to be removed.[5] It is extremely important to close the fracture as early as possible as well as debridement in preventing the infection.[13]

Debridement and closure of open wounds in our patients were carried out under sterile conditions within a short period of time. No wound was left to secondary healing. Twentytwo of the treated 33 patients had Grade II and Grade IIIA tissue injuries. Although use external fixator or unreamed intramedullary nailing in patients with such injuries for fixation is still controversial, surgeon's experience is effective in selecting the fixation method.[1,5,11,23] In our study, infections developed in patients with Grade IIIB and IIIC fractures; development of chronic osteomyelitis was prevented by K-wire replacement, sequestrectomy and appropriate antibiotic treatment.

Time to union was significantly longer and functional score was lower in patients with Grade III open fractures compared to other groups. We think that lower functional score was associated with longer use of fixator.

Technical constraints such as infections from wire placement, restriction of wire placements near the joints, and no repair of soft tissues are still a problem in the use of external fixator. However, as it allows the patient to be mobilized with full weight bearing being the most important advantage of this method, use of circular external fixator maintains its importance in the management.

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