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Outcomes of open tibial shaft fractures treated by external fixation method

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Abstract

Tibia is vulnerable to open fractures due to its relative inadequacy of soft tissue coverage. The optimal treatment method of open tibial fractures is still controversial. External fixators are widely used as a definitive treatment method for open fractures. The aim of the current study was to evaluate the outcomes of external fixators applied for open tibial shaft fractures. All open tibial fractures treated with external fixators between December 1999 and October 2008 were reviewed retrospectively. 48 limbs of 47 patients were included in this study. Fractures were classified as Type I in 4 (8.3%), Type II in 18 (37.5%), and Type III in 26 (54.2%) according to Gustilo-Anderson classification. The mean follow-up period was 58.3 months. 28 patients (29 limbs) underwent unilateral external fixation, and 19 patients received Ilizarov ring fixator. Fracture healing rates were 100% in Type I fractures, 88.9% in Type II fractures, 81.8% in Type IIIA fractures, 28.6% in Type IIIB fractures, and 62% in Type IIIC fractures. The mean time for removal of the external fixator was 24.06±12.44 weeks. The mean time to fracture union was 27.27±13.19 weeks. According to Karlstrom and Olerud criteria, the mean functional score was 31.04±3.77. Functional results were excellent in 6 limbs (12.5 %), good in 16 limbs (33.3 %), acceptable in 8 limbs (16.7%), moderate in 10 limbs (20.8%), and poor in 8 limbs (16.7%). Deep tissue infection developed in 5 limbs (10.4%). Osteomyelitis developed in 4 limbs (8.3%). The findings of our study suggest that satisfactory results can be obtained by using external fixators for the treatment of open tibial shaft fractures.

Keywords: Tibia, open fracture, external fixation, soft tissue injury, unilateral, Ilizarov technique

Introduction

The epidemiology of open tibial fractures varies according to countries' industrial development, sporting or recreational activities of the population (soccer, American football, etc.), cultural characteristics (gunshot injuries), and traditions (falling from the roof, falling from a ladder). Due to the relative inadequacy of soft tissue coverage, the open tibial fracture incidence is 5 times higher than other long bones. It is accepted that degree of soft tissue injury is the main determining factor of the prognosis. However, there is debate on the best method of fixation [1-13]. Plate-screw fixation has not been advocated for open tibial fractures due to high rates of infection [9]. Recently, minimally invasive plate osteosynthesis has become alternative treatment modality for low grade open

fractures [5,11,13]. With unreamed tibial intramedullary nailing and external fixation, it is aimed to preserve the endosteal circulation in open fractures, to eliminate union problems and to reduce infection. Although intramedullary nails are currently preferred in Type-I and Type-II open fractures, they are not recommended in higher-grade contaminated open fractures [3,14]. External fixator is a good treatment option for open fractures with bone loss which had gross contamination by preserving the endosteal and periosteal circulation, and by permitting distraction osteogenesis [6,7,12,15]. In addition, external fixators are fast and easy to apply, and easily accessible. The disadvantages of external fixators are poor patient tolerance, pin site infection and failure of the fixator to maintain reduction [16].

The aim of this study is to present the clinical outcomes and radiological results of the external fixator application for the treatment of open tibial shaft fractures.

Materials and Methods

Seventy-three patients who were treated with an external fixator in Inonu University Turgut Ozal Medical Center for open tibial shaft

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fractures between December 1999 and October 2008 were included in this study. Patients who were eventually amputated and whose fracture were fixed by intramedullary nail were excluded from the study. Twenty-six of the study group patients who had incomplete clinical and radiological data were also excluded. Demographic data of the patients were recorded. Fractures were classified according to Gustilo-Anderson classification [17] and AO/OTA classification [18]. Mechanism of injury, associated injuries, length of hospital stay, healing and external fixator removal time and perioperative complications were evaluated. Anteroposterior (AP) and lateral radiographs of both crura were taken to evaluate tibial shortening, coronal and sagittal plane deformities.

Antibiotic administration protocol was based on the type of open fracture. Antibiotic regimens administered were recorded. Patients with type I open fractures were administered cefazolin 1 gr. intravenous (IV); patients with type II open fractures received cefazolin plus gentamicin 250 mg. IV. In patients with Type III open fractures, with severe soft-tissue injury and contamination oral 500 mg. metronidazole was included to the antibiotic regimen.

Devitalized fragments of bone and necrotic soft tissues were removed during the initial debridement. 38 patients undergone primary wound closure after debridement and wound irrigation. In 2 patients with type III B and one patient with type III C fractures, acute shortening was performed, and the wound was closed primarily. The wound was closed by skin grafts in 4 patients, and with flaps in 3 patients. Unilateral external fixator was applied to 29 crura, and Ilizarov external fixator was applied to 19 crura. In 6 patients with arterial injury, primary arterial repair was performed.

All patients were instructed for weight-bearing with crutches immediately postoperatively. Within 6 weeks, all patients were allowed for full weight-bearing. Rubber bands covered with felt were assembled to external fixator to prevent ankle plantar flexion contracture.

Patients were evaluated weekly for the first month, then called for follow-up visits at 6. week, 3. month, 6. month, and at the end of first year. Presence of cortical and trabecular bridging of three of four cortices on AP and lateral radiographs was accepted as fracture healing. To enhance callus formation dynamization was applied. Over the next 2 weeks, patients were recommended full weight-bearing. The fixators were removed after the absence of pain while weight-bearing. All external fixators were removed at the outpatient clinic without anesthesia. Patella tendon bearing (PTB) cast was applied for 4 weeks. At final follow-up visit functional assessment of the outcome was evaluated by using Karlstrom and Olerud criteria [19].

Statistical Analysis

SPSS (Statistical Package for Social Sciences) for Windows version 13.0 (IBM Corp. Armonk,NY) statistical software was used for statistical analysis. Mean±standard deviation was used to define quantitative variables, number and percentage were used to define qualitative variables. Normality of data distribution was tested with Shapiro-Wilk test. In our study, quantitative variables were not distributed normally ($p<0.05$). Therefore, the difference between categories of open fractures was tested with Kruskal-Wallis test. $p<0.05$ was considered statistically significant.

Results

Patients were followed for a mean period of 58.3 months (range, 13 to 112 months). Mean length of hospital stay was 23.3 days (range, 6 to 90 days). Eleven (23.6%) of the patients were female, 36 (76.4) were male. At the time of fracture, the mean age of the patients was 35.8 ± 14.6 (range, 15 to 74). Detailed distribution of mechanism of injury is depicted in Table 1.

Table 1. Detailed description of mechanism of injury

Mechanism of injury	Number of patients	Percentage
Vehicle accident related fracture	6	12.8
Pedestrian in road traffic accident	18	38.3
Gunshot wound	10	21.2
Falling from a height	7	14.9
Fall of a heavy object	4	8.5
Work-related accident	2	4.3

19 (39.58%) of patients had fracture located on the proximal third of the tibial shaft, 26 (54.17%) had on the middle third and 3 (6.25%) had on the distal third. Fracture classification according to Gustilo-Anderson classification and AO/OTA classification is shown in Table 2.

Table 2. Fracture classification according to Gustilo-Anderson Classification and AO/OTA Classification

	Number of limbs	Percentage
Gustilo-Anderson Classification		
Type I	4	8.3
Type II	18	37.5
Type III		
A	11	22.9
B	8	16.7
C	7	14.6
AO/OTA Classification		
Type A	13	27.1
Type B	10	20.9
Type C	25	52

30 patients underwent emergency surgery, and 15 patients were operated when their medical condition stabilized. Mean time from injury to surgery was 4.21 hours (range, 2 to 7 hours) for emergency surgery, and 5.5 days (range, 1 to 14 days) for elective surgery group. The mean operation time was 132 ± 68.87 minutes (range, 45 to 360 minutes). The mean time for removal of the external fixator was 24.06 ± 12.44 weeks (range, 12 to 54 weeks). According to the fracture types, the distribution of the major findings are presented in Table 3.

The mean time to fracture union was 27.27 ± 13.19 weeks (range, 12 to 56). There was a statistically significant difference between open fracture types in terms of union time ($p=0.001$). Fracture healing

was achieved in 35 (74.4%) of the patients without requirement of bone grafting. The union rate was 100% for type I open fractures, 88.9% for type II, 81.8% for type III A, 28.6% for type III B, and 62% for type III C open fractures. After 6 months of follow-up, nonunion was observed in 12 patients. Of these, 2 were type II, 2 were type III A, 5 were type III B, and 3 were type III C open tibial fractures. Of these 12 patients, removal of external fixator and plate-screw osteosynthesis with bone grafting were applied in 2 patients. Removal of external fixator and intramedullary nailing with bone grafting were applied in 2 patients. In 2 patients, unilateral external fixators were replaced with Ilizarov external fixators. Six patients undergone cancellous bone grafting.

According to Karlstrom and Olerud criteria, the mean functional score was 31.04 ± 3.77 (range 25–36). Karlstrom and Olerud functional scores were 34.75 ± 1.5 (range 33–36) in type I open fractures, 33.83 ± 2.47 (range 26–36) in type II open fractures,

30.2 ± 2.39 (range 27–34) in type IIIA open fractures, 27.28 ± 2.28 (range 25–31) in type IIIB open fractures, and 27.25 ± 2.54 (range 25–33) in type IIIC open fractures. Functional results were excellent in 6 crura (12.5 %), good in 16 crura (33.3 %), acceptable in 8 crura (16.7%), moderate in 10 crura (20.8%), and poor in 8 crura (16.7%).

Pin tract infection was observed in 12 patients (25.53%). Three patients were hospitalized and treated with parenteral antibiotics. Eight patients with superficial infection were treated with daily pin care. The pin removal was performed in 1 patient.

Deep tissue infection developed in 5 patients (10.4%). Of these patients, 3 were type III B, 1 was type III A, and 1 was type III C. These patients were treated with parenteral antibiotic, debridement and irrigation. Osteomyelitis developed in 4 patients (8.3%). One of them was type III A, 2 were type III B, and 1 was type III C. Debridement, sequestrectomy and parenteral antibiotic treatment were applied to these patients.

Table 3. Major findings according to fracture type

Type of fracture	Length of hospital stay (days)	Operation time (minutes)	Time for removal of the external fixator (weeks)	Time to fracture union (weeks)
Type I	12.75 ± 6.23 (7–21)	130 ± 73.48 (90–240)	17.25 ± 4.78 (12–23)	18 ± 5.16 (12–24)
Type II	13.27 ± 9.14 (6–45)	107.2 ± 43.12 (60–220)	18.77 ± 9.84 (12–54)	22.1 ± 10.3 (15–56)
Type III A	20.4 ± 9.58 (7–34)	94.5 ± 28.7 (45–150)	20 ± 7.4 (12–36)	22.1 ± 7.9 (12–38)
Type III B	39 ± 24.67 (21–90)	137.14 ± 23.6 (120–180)	36.85 ± 10.12 (26–52)	40.71 ± 10.96 (28–56)
Type III C	41.12 ± 24.28 (11–90)	231.25 ± 89.03 (80–360)	33.25 ± 15.22 (14–54)	38.25 ± 14.67 (16–56)

Discussion

Open tibial shaft fractures present a significant challenge for surgeons, due to precarious vascularization and lack of soft-tissue envelope of the tibial shaft. These fractures are prone to non-unions and infections [1-3]. It has been accepted that the severity of the soft-tissue injury is the most important factor determining the outcome of open tibial shaft fractures. However, there is a debate concerning the best method of fixation in these fractures. Currently, there is no widely accepted optimal fixation method for the management of open tibial shaft fractures. Although, there is no agreement regarding the treatment method, there is a consensus on the managing principles of open fractures, which consists of rapid irrigation, debridement of nonviable tissues, appropriate antibiotic administration, and primary fracture stabilization [2,3,20]. Early closure of the wound reduces infection, increases union rates, and reduces amputation rates [2,20]. Fischer et al., reported significantly better results in patients with wound closure before 2 weeks when compared to delayed wound closure [20]. In our cohort group, early primary wound closure was applied in 38 cases, acute bone shortening was needed for 3 cases prior to primary wound closure. We assume that achieving early soft tissue coverage is one of the reasons to have high union rates and low infection rates in our cohort group.

Various treatment modalities have been advocated for open tibial shaft fractures including closed reduction and casting, fixation with plate and screws, intramedullary nailing and external fixation

methods [3-14]. In the literature, it has been stated that the rates of malunion and nonunion increased with conservative treatment. Disadvantages such as joint stiffness, muscle atrophy and malunion rates up to 30 % have been reported [21]. Adequate stability at the fracture site can be achieved with intramedullary nails or external fixation. Fixation with plate and screws is not recommended for patients with severe soft tissue injury due to high infection rates. Bach and Hansen compared the outcomes of plate-screw fixation and external fixator in 56 patients with type II and type III open tibial shaft fractures. In plate-screw fixation group, soft tissue infection rate was 35%, severe osteomyelitis rate was 19%. In patients treated with external fixator, osteomyelitis was observed in 3% of cases, and pin site infection in 10 %. They concluded that, the rate of both soft tissue and bone infection rates were significantly lower in external fixation group and they recommended external fixation for primary treatment method for open tibial shaft fractures [9]. Ağuş et al. reported that, deep infection rate following plate-screw fixation was 6%, malunion rate was 6%, and nonunion rate was 6%. They stated that these results were comparable to the results obtained by other treatment alternatives, and plate-screw fixation can be considered as a treatment method for open tibial shaft fractures [22]. Satisfactory outcomes have been reported with the application of intramedullary nailing with or without reaming in patients with type I and type II open fractures. However, their usage in heavily contaminated fractures is still controversial [10,13]. Henley et al., compared the results of unreamed intramedullary nails with external fixation in patients with type II, type IIIA, and

type IIIB open fractures. In this prospective study, 104 crura were stabilized with IMN and 70 were stabilized with external fixator. Infection was observed in 13% of cases in IMN group and 21% of external fixation group. When infection rates compared, there was no significant difference between the groups. They concluded that development of infection is more likely affected by the severity of the soft tissue injury, not by the implant selection [23]. In our study, none of the patients with type I or type II open fractures had deep infection or osteomyelitis. Deep infection and osteomyelitis rates were 10.63% and 8.3%, respectively. Our results support previous findings that suggest severity of the soft tissue injury can be considered as the most important factor determining the risk of both soft tissue and bone infection.

In recent years external fixators have been enhanced, due to its advancement in design and increase in stability, external fixators have been a valid option for the definitive treatment of open tibial shaft fractures. Various external fixation systems have been presented, and most widely used ones are limb reconstruction system external fixators, AO external fixators, Hoffman devices, and Ilizarov ring fixators systems [6,7,12]. Recently, Ex-fi-re fixators, which ensure multiplanar fixation and higher stability, have been used more frequently. Helland et al. reported result of 50 patients with type II and type III open tibial shaft fractures who treated with Ex-fi-re fixators. The mean time to fracture union was 20 weeks. They observed infection at the fracture site in one patient, and bone grafting was required in 3 patients [24].

Beltsios et al. reported that 87.27% of complex tibial shaft fractures could be treated primarily with unilateral external fixators [7]. Marsh et al. treated 101 patients with open tibial fractures with a unilateral dynamic axial fixator following debridement. Their union rate was 95%, and mean union time was 24.6 weeks. The reported that, 95% of healed patients had less than 100 of angulation in any plane. They concluded that dynamic axial external fixators provide adequate stability and may be applied after initial debridement, and change of the implant is not required at follow-up [25]. In our study, we obtained fracture healing in 25 crura (%86.2) which treated with unilateral external fixator without any need to change the fixation device. 93.1% of the healed extremities had less than 100 of angulation in any plane. Our study confirmed that unilateral external fixators can be used safely and effectively as a definitive treatment device in open tibial shaft fractures. In addition, we assume that the application of unilateral fixator is advantageous compared to Ilizarov type fixators in providing early soft tissue closure.

Ilizarov external fixators allow to form various types of configurations, which make them an effective and safe treatment option when compared to alternative treatment methods. They have superior adjustable features in providing reduction, alignment and length both intraoperatively and postoperatively [26]. Due to these features, lengthening, angulating, translational and torsional maneuvers can be performed simultaneously. By performing corticotomy and distraction osteogenesis with an Ilizarov external fixator, shortening of the limb can be prevented with a single procedure without the need for bone grafts [27]. In our case series, autograft was applied in 4 patients. In 4 of our cases, distraction osteogenesis was applied over Ilizarov due to fragmentation and large bone defects. Union was achieved in 2 cases by changing the unilateral fixators with Ilizarov ring fixator. In this study, patients

with bone defect who needed acute shortening, patients with extensive soft tissue defects, and patients with union problems were treated by distraction and compression, and union was achieved with the Ilizarov technique.

In our study, functional scores were found to be lower especially in type III B and type III C open fractures. In terms of Kalstrom-Olerud scores, there was a statistically significant difference according to open fracture type ($p=0.0001$). This shows that severity of soft tissue injury has a significant effect on prognosis, as stated in the literature [12].

Limitations of this study were the open fracture types were not homogeneous and they were not compared with another treatment modality. In order to decide which fixation method should be applied in fracture fixation, standard groups should be formed according to the type of open fracture and the extend of fracture fragmentation. Studies designed to compare different treatment methods in standardized groups were needed.

Conclusion

In conclusion, our findings demonstrate that Ilizarov ring fixators should be considered as the primary treatment modality for comminuted and defective open tibial shaft fractures as it allows distraction osteogenesis. Unilateral external fixators remain as a safe and efficient option in the management of less severe open tibial shaft fractures.

Conflict of interests

The authors declare that they have no competing interests.

Financial Disclosure

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Ethical approval

Ethics committee approval has been obtain with number of 2009/287 from Inonu University Ethics Committee.

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