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Research

Functional and Radiological Comparison and Evaluation of Gustilo-Anderson Type 3 Open Tibia Fractures Treated with an Ilizarov External Fixator

İlizarov Eksternal Fiksatörle Tedavi Edilen Gustilo-Anderson Tip 3 Açık Tibia Kırıklarının Fonksiyonel ve Radyolojik Değerlendirilmesi

Malik Çelik[1], Alkan Bayrak[1], Vedat Öztürk[1], Cemal Kızılkaya[2], Mustafa Cevdet Avkan[3]

[1]Bakırkoy Dr. Sadi Konuk Research and Training Hospital, Clinic of Orthopaedic Surgeon, Division of Orthopaedics and Traumatology, İstanbul, Türkiye

[2]İstanbul Bahçelievler State Hospital, Orthopaedic Surgeon, Division of Orthopaedics and Traumatology, İstanbul, Türkiye

[3]Dr. M. Cevdet Avkan Clinic, Clinic of Orthopaedic Surgeon, İstanbul, Türkiye

ABSTRACT

Objective: This study aimed to evaluate and compare the functional and radiological results of Gustilo-Anderson (G-A) type 3 open tibial shaft fractures G-A treated with an Ilizarov external fixator (I-EF).

Methods: Sixty-one patients (7 female, 54 male) who matched these criteria were included in the study. Patients who were treated with the I-EF for a G-A type 3 tibial shaft fracture between January 2013 and December 2018 were included in this retrospective study. The patients were divided into three groups: subtype 3A (I), subtype 3B (II), and subtype (III). The radiological, functional, and demographic features were also evaluated.

Results: There were no statistically significant differences between G-A classification and age, gender, body mass index, full weight-bearing time, and rotational alignment ($p>0.05$). The G-A Subtype 3A Lower Extremity Functional Scale (LEFS) score was significantly higher than those of Subtypes 3B and 3C ($p<0.05$ respectively). The time to union was shorter in G-A Subtype 3A cases than in subtype 3C cases ($p<0.05$). Coronal and sagittal alignment angulations were significantly lower in G-A subtype 3A than in subtypes 3B and 3C ($p=0.022$, and $p<0.01$ respectively). The Johner-Wruhs Score was lower than that of subtype 3C in patients with G-A Subtype 3A patients ($p<0.05$).

Conclusion: Radiological and functional outcomes worsen as injury severity increases from subtype A to C in G-A type 3 open tibial shaft fractures.

Keywords: Ilizarov-external fixation, open tibia shaft fracture, Gustilo-Anderson type 3 fracture, lefs score

ÖZ

Amaç: Bu çalışmada; ilizarov eksternal fiksatörü (I-EF) ile tedavi edilen Gustillo-Anderson (G-A) tip 3 açık tibia cisim kırıklarının fonksiyonel ve radyolojik değerlendirilmesi amaçlandı.

Gereç ve Yöntem: Ocak 2013 ile Aralık 2018 tarihleri arasında G-A tip 3 açık tibia şaft kırığı nedeniyle I-EF uygulanan hastalardan 61 hasta (7 kadın, 54 erkek) çalışmaya dahil edildi. Hastaların ortalama yaşı 38,20±9,63 (17-59 yıl) yıl, ortalama takip süresi 48,62±14,88 (26-96 ay) ay idi.

Bulgular: G-A sınıflandırması ile yaş, cinsiyet, vücut kitle indexi, tam yük verme süresi ve rotasyonel dizilim arasında istatistiksel olarak anlamlı fark yoktu ($p>0,05$). G-A Tip 3A alt ekstremite fonksiyonel skala (LEFS) skoru Tip 3B ve 3C'den anlamlı derecede yüksekti (sırasıyla $p<0,05$). G-A Tip 3A olgularında kaynama süresi Tip 3C olgularına göre daha kısaydı ($p<0,05$). G-A Tip 3A'daki koronal ve sagittal dizilim açıları Tip 3B ve C'ye göre anlamlı derecede düşüktü (sırasıyla $p=0,022$ ve $p<0,01$). G-A Tip 3A hastalarında Johner-Wruhs Skoru Tip 3C'den düşük bulundu ($p<0,05$).

Sonuç: Bu çalışmada G-A tip 3 açık tibial cisim kırıklarında A'dan C'ye kadar olan yaralanma derecesi arttıkça radyolojik ve fonksiyonel sonuçların bozulduğu belirtilmektedir.

Anahtar Kelimeler: İlizarov eksternal fiksasyon, tibia şaft kırığı, Gustillo-Anderson tip 3 kırık, LEFS skoru

Address for Correspondence: Malik Çelik, Bakırkoy Dr. Sadi Konuk Research and Training Hospital, Clinic of Orthopaedic Surgeon, Division of Orthopaedics and Traumatology, İstanbul, Türkiye
E-mail: drmalikcelik@hotmail.com ORCID ID: orcid.org/0000-0002-3696-9644

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INTRODUCTION

Owing to its location and poor soft tissue coverage, open fractures of the tibia are more common than in other bones (1). Gustilo and Anderson. (2) (1976) proposed a system of classification for open fractures that relied on the size of the related laceration, the level of soft tissue damage, and the degree of contamination and vascular damage. Open tibial shaft fractures require immediate orthopedic treatment. The standard of care for open tibial shaft fractures includes early prophylactic antibiotic therapy, surgical wound debridement, and fracture stabilization. Moreover, they play a critical role in reducing long-term morbidity (3). After infection control, the treatment goals are to reduce the deformity, correct the deformity, and equalize the limb length (4). Intramedullary nailing (IMN), plate fixation, and external fixation(EF) (AO-EF and Ilizarov-EF) are some of the current treatment options. However, these techniques are associated with various complication rates (5, 6). Although different fixation methods with satisfactory results have been used for a long time, the IMN and EF methods have begun to be preferred because they reduce secondary damage to soft tissues and bone vascularity (7). The I-EF technique is a special type of external fixator. It is used for indirect or closed reduction with fine wires and small incisions that cause minimal soft tissue damage. The wires are stretched and circumferentially supported. This resulted in better mechanical performance than monolateral external fixator, which allowed for both early ROM and weight-bearing initiation (8, 9). Our study aimed to evaluate and compare the radiological and functional results according to the severity of soft tissue damage in patients with a history of Gustilo-Anderson (G-A) type 3 open tibial shaft fractures treated with the Ilizarov technique. We will base this on the extent of soft tissue damage. We hypothesized that the functional and radiological results would worsen as the degree of injury increased in patients who underwent the Ilizarov technique. Although the worst results of type 3 open injuries have been accepted in studies comparing open fracture results in the literature, the number of studies evaluating subtypes of type 3 injuries is limited. The current study aimed to evaluate the functional and radiological results of type 3 open tibial fractures.

METHODS

Patients who underwent I-EF due to G-A type 3 tibial shaft fracture between January 2013 and December 2018 were retrospectively approved by Bakırkoy Dr. Sadi Konuk Egitim Ve Research Hospital Clinical Research Ethics Board (approval no: 2015/01/10, date: 04.01.2016). Among the patients treated with I-EF, those with a minimum follow-up period of 24 months and regular controls (1st day, 2nd, 6th, and 12th weeks, 6th month, 9th month, and 1st year) were included in the study. Closed fractures, conservative treatment, fixation with different implants, revision surgery with different implants, ipsilateral femur fractures, bilateral tibia fractures, patients with other injuries that made it impossible for them to move, intra-articular fractures, and not enough follow-up were excluded. In this period, 324 patients presented to the emergency orthopedic service with open tibial fractures. Of these, 228 were found to have type 1 and type 2 open fractures and were excluded from the study. AO-EF was applied to 25 of 96 patients presenting with type 3 open fractures and left for secondary surgery. Four of the 10 patients were amputated under emergency conditions, and six were amputated due to necrosis development during follow-up despite vascular injury repair (Figure 1). The study included sixty-one patients who met these criteria (7 females and 54 males). Patients with G-A type 3 open tibial injury were divided into three groups [G-A subtype 3A (I), subtype 3B (II), and subtype 3C (II)] (2). The radiological, functional, and demographic features were evaluated and compared.

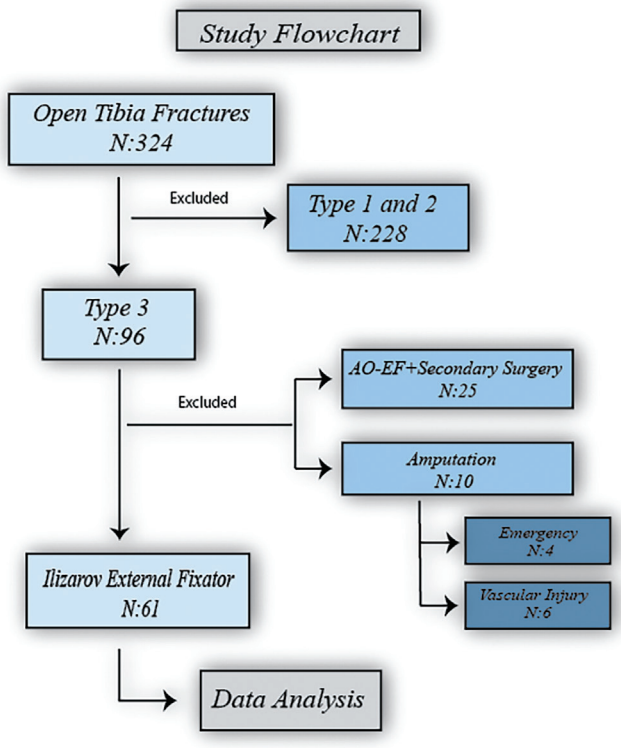

Figure 1. Study Flowchart (Include-Exclude Criteria)

AO-EF: Arbeitsgemeinschaft für Osteosynthesefragen-External fixator

Surgical Procedure

The surgical procedure was performed in the supine position without the use of a tourniquet on a radiolucent table under general or spinal anesthesia. The fixation was performed using the technique described by Ilizarov (10). In addition, hybrid fixation was added to the classic Ilizarov technique. Hybrid methods using k-wire and Schanz screws were preferred for the Ilizarov frames. The wounds were covered with a wet dressing, and the patients were taken to the hospital. Tetanus prophylaxis was applied in the emergency department, as indicated in the literature (11). Preoperatively, 1 g of cefazolin was administered. Dual antibiotic therapy was administered during the postoperative period. Cefazolin 100 mg/kg/day (dose divided into three doses IV every 8 hours) and gentamicin 5-7.5 mg/kg/day (dose divided into three doses IV every 8 hours) were administered. In patients with penicillin allergy, clindamycin was administered on 15-40 mg/kg/day (dose divided into three and IV every 8 hours).

Functional Evaluation

Hip, knee, and ankle range of motion (ROM) exercises and weight-bearing exercises are immediately recommended in the early postoperative period, as patients tolerate them. Patients were followed-up in the outpatient clinic with knee and ankle joint ranges of motion under control. The ROM of the joints was measured using a goniometer. Follow-up after the first year was performed at 3-month intervals, and after 2 years, annually. The LEFS score was used for clinical evaluation. LEFS has been shown to have good reliability and predictive correlation in assessing the lower extremity. In addition, it is a reliable and valid tool for monitoring healing in patients with tibial shaft fractures (12, 13). The patients' LEFS scores and coronal and sagittal alignment information were obtained from the medical records of the last postoperative controls. The rotational alignment information was collected and evaluated from the physical examination information in the patient files.

Radiological Evaluation

Postoperative radiographs were obtained on the 1st day, 2nd, 6th, and 12th weeks, 6th month, 9th month, and 1st year. Two orthopedic specialists who were not involved in the study performed radiological evaluation. Coronal and sagittal alignments and Johner-Wruhs scores were evaluated from the last postoperative anteroposterior (AP) and lateral radiographs (14, 15). The radiological end result was graded as good when there was <1 cm of shortening, <50 of angulation, less than 10% of ad latus shift, and no clinically detectable rotational malunion. It was graded as satisfactory if there were 1-2 cm of shortening, <50 of angulation, and less than 10% lateral displacement. The radiological results were graded as poor, with a 1-2 cm shortening and/or 5-100 angulation (16). For rotational alignment evaluations, the line connecting the midpoint of the knee joint and the point between the malleoli in the ankle joint was compared with the line connecting the uninjured side when the patients were in the supine position (16). The ankle is normally in 12-150 external rotation. In comparative measurements with the uninjured side, 0-50 rotation was accepted as excellent, 5-100 was good, 10-150 rotation was fair, and >150 rotation was considered poor (16). Varus-Valgus angulations were evaluated on AP and lateral radiographs. 0-10 varus-valgus was accepted as excellent, 2-50 varus-valgus was good, 6-100 varus-valgus was fair, and >100 varus-valgus angulation was evaluated as poor (16). The angular results obtained on the long tape that included the knee and ankle were recorded. The union was decided by the Johner-Wruhs score. Patients were taken for AP and lateral X-rays, and at three points, cortex healing was accepted as a union. (Figure 2)

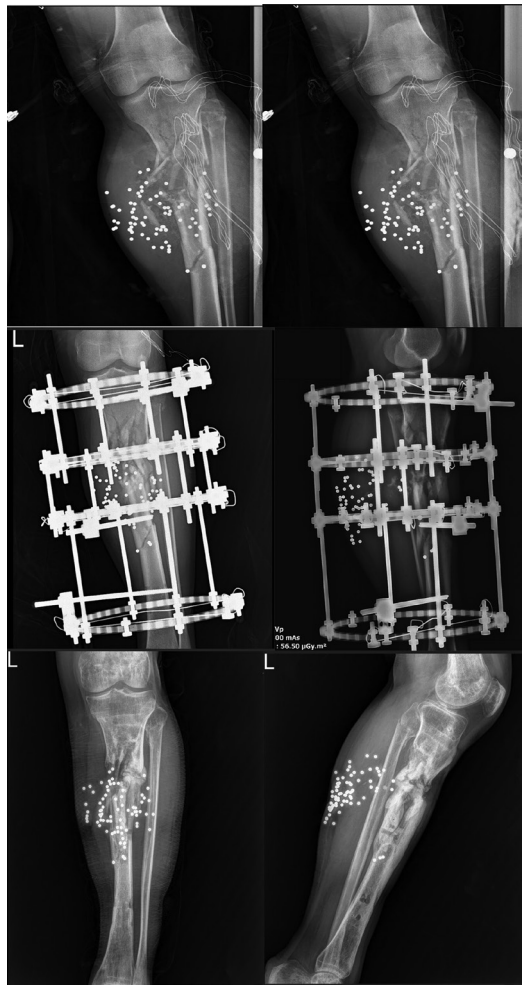

Figure 2. Ilizarov external fixator treatment. Patients underwent anteroposterior and lateral X-rays and at three cortex healing was accepted as a union

Statistical Analysis

The Number Cruncher Statistical System 2007 (Kaysville, Utah, USA) software was used for statistical analysis. Descriptive statistical methods (median, first quarter, and third quarter) were used to evaluate the study data. The Shapiro-Wilk test and graphical examinations were used to assess whether quantitative data were suitable for normal distribution. The Kruskal-Wallis test and the Dunn-Bonferroni test were used to compare quantitative variables that did not show a normal distribution between more than two groups. The Pearson chi-squared test and the Fisher-Freeman-Halton test were used to compare qualitative data. Statistical significance was set as $p<0.05$.

Results

The mean age of the patients was 38.20±9.63 (17-59) years, and the mean follow-up period was 48.62±14.88 (24-96) months. The demographic and clinical characteristics of the patients are presented in Table 1. No statistically significant difference was found between the distribution of age, time to surgery, length of hospital stay, operation time, and full load times according to the G-A classification ($p>0.05$). The LEFS scores differed significantly depending on the G-A classification ($p<0.01$). The group with G-A classification Type 3A had significantly higher LEFS scores than those with Types 3B and 3C ($p=0.017$; $p=0.001$; $p<0.05$). The union time was significantly different according to the G-A classification ($p<0.05$); the significance of the union time of the group with Type 3A was found to be significantly lower than the cases with Type 3C ($p = 0.008$; $p<0.05$). According to the G-A classification, gender and body mass index did not differ significantly ($p>0.05$). The coronal sequence differed significantly depending on the GA classification ($p<0.01$). The G-A Type 3A group had a significantly lower coronal alignment score than the Type 3B and 3C groups ($p=0.043$; $p=0.001$; $p<0.01$). There were significant differences in sagittal alignment based on the G-A classification ($p<0.01$).

Table 1. Demographic characteristics of the patients

		n	%
Gender	**Female**	7	11.5%
	Male	54	88.5%
BMI (kg/m²)	**Normal**	31	50.8%
	Overweighted	30	49.2%
Side	**Left**	27	44.3%
	Right	34	55.7%
Vascular repair	**None**	50	82.0%
	Artery	8	13.1%
	Vein	3	4.9%
	Nerve	1	1.6%
Gustillo classification	**3A**	41	67.2%
	3B	11	18.0%
	3C	9	14.8%
Graft/flap	**None**	52	85.2%
	Graft	6	9.8%
	Flap	3	4.9%
		Mean±SD	Median (min-max)
Age		38,2±9,63	39 (17-59)
Time to surgery (hours)		13,38±12,28	9 (3-72)
Operation time (minutes)		75,21±15,86	71 (58-150)
Hospitalization (days)		5,41±5,65	4 (2-29)
Follow-up time (months)		48,62±14,88	49 (24-96)
LEFS Score		76,85±20,84	83,8 (22,5-100)
Full weight-bearing time (weeks)		8,89±2,72	8 (5-19)
Union time (weeks)		14,26±3,6	13 (11-26)

LEFS: Lower Extremity Functional Scale

The sagittal alignment score of the G-A Type 3A group was much lower than that of the Type 3B and 3C groups (p=0.022; p=0.001; p<0.05). Johner-Wruhs Score was used to discuss union. The Johner-Wruhs score differed significantly according to the G-A classification (p<0.05); the significance of the Johner-Wruhs score of the G-A classification Type 3A group was found to be significantly lower than that of the Type 3C group (p=0.028; p<0.05). The rotation distributions according to the G-A classification do not show a statistically significant difference (p>0.05). Vascular injury and graft/flap application were performed in the G-A Type 3C subgroup (1 patient had only vein repair, 2 patients had both arterial and vein repair, and 6 patients had only arterial repair). Patients were assessed for full weight bearing when removing their crutches (Table 2).

Discussion

The most significant finding of our research was that G-A subtype 3C fractures had worse functional and radiological outcomes than other types of fractures. Previous research has demonstrated that fractures of the G-A type 3 have been associated with high rates of chronic infection and non-union, with the former being 38% and the latter being 50% (17, 18). Complications, such as infection and non-union, make the treatment procedure more time-consuming and

Table 2. Relationship between demographic features, functional outcomes, and radiological outcomes in the G-A subgroups

		G-A Subtype 3 (A)	G-A Subtype 3 (B)	G-A Subtype 3 (C)	[a]p-value
Age	Mean±SD	38.71±9.25	37.00±11.19	37.33±10.34	**0.940**
	Median (min-max)	38 (20-59)	38 (20-52)	39 (17-46)	
LEFS Score	Mean±SD	83.70±18.94	69.27±15.12	54.87±17.73	**0.001****
	Median (min-max)	88.8 (22.5-100)	76.25 (42-87.5)	55 (27.5-83.8)	
Fully weight-bearing (weeks) Median (min-max)	Mean±SD	8.59±2.47	9.82±3.06	9.11±3.41	**0.241**
	8 (5-19)	9 (6-18)	8 (6-17)		
Union time (weeks) Median (min-max)	Mean±SD	13.15±2.02	14.73±4.45	18.78±4.74	**0.011***
	13 (11-21)	13 (12-26)	21 (12-24)		
		n (%)	**n (%)**	**n (%)**	**p-value**
Gender	**Female**	4 (9.8)	2 (18.2)	1 (11.1)	[b]**0.828**
	Male	37 (90.2)	9 (81.8)	8 (88.9)	
BMI (kg/m²)	**Normal**	21 (51.2)	4 (36.4)	6 (66.7)	[b]**0.404**
	Overweight	20 (48.8)	7 (63.6)	3 (33.3)	
Coronal alignment (Prasad et al. 19)	**Excellent**	35 (85.4)	5 (45.5)	0 (0.0)	
	Good	6 (14.6)	5 (45.5)	6 (66.7)	
	Mild	0 (0.0)	1 (9.1)	3 (33.3)	
	Median (min-max)	1 (1-2)	2 (1-3)	2 (2-3)	[a]**0.001****
Sagittal alignment	**Excellent**	35 (85.4)	5 (45.5)	0 (0.0)	
	Good	5 (12.2)	3 (27.3)	7 (77.8)	
	Mild	1 (2.4)	3 (27.3)	2 (22.2)	
	Median (min-max)	1 (1-3)	2 (1-3)	2 (2-3)	[a]**0.001****
Johner Wruhs Score	**Excellent**	28 (68.3)	7 (63.6)	2 (22.2)	
	Good	11 (26.8)	2 (18.2)	5 (55.6)	
	Mild	2 (4.9)	2 (18.2)	2 (22.2)	
	Median (min-max)	1 (1-3)	1 (1-3)	2 (1-3)	[a]**0.03****
Rotational alignment (Prasad et al. 19)	**Excellent**	33 (80.5)	7 (63.6)	6 (66.7)	
	Good	7 (17.1)	4 (36.4)	3 (33.3)	
	Mild	1 (2.4)	0 (0.0)	0 (0.0)	
	Median (min-max)	1 (1-3)	1 (1-2)	1 (1-2)	[a]**0.462**

[a]Kruskal–Wallis test/Dunn-Bunferroni test, [b]Pearson Ki kare test/Fisher Freeman Halton test *p<0.05 **p<0.01
G-A: Gustilo-Anderson, SD: Standard deviation, Min-max: Minimum- maximum

have an impact on the patients' ability to function regularly and their quality of life (19).

Vascular injury and the need for soft tissue repair, such as grafts or flaps, are among the reasons for poor functional outcomes in G-A subtype 3C injuries (20). According to the findings of our research, patients with subtype 3C (group III) underwent surgical procedures, such as graft/flap application and vascular repair.

Kumar et al. (21) conducted a study and found that the results for G-A subtypes 3A to 3C deteriorated in open fractures of the tibia. According to the findings of our research, patients in group I (subtype 3A) had higher LEFS ratings than those in groups II (subtype 3B) and III (subtype 3C) who suffered tibial open fractures. The fact that this is the case shows that the long-term functional results are deteriorating in a way that is directly proportional to the degree of injury that was caused (from subtype 3A to subtype 3C). I-EF is often used for tibial fractures with open, infected, comminuted, or segmental bone loss (22). I-EF is often used for the management of tibial fractures that involve open, infected, comminuted, or segmental bone loss (20). Because I-EF offered a more biomechanically stable fixation, the patients were able to engage in effective weight-bearing during the early stages of treatment. There is evidence that early weight bearing has a beneficial effect on the soleus muscle. Stable fixation, early weight bearing, and the beginning of range-of-motion physical activity at an earlier stage have positive effects on mobilization and muscle function (23, 24). In our study, there was no statistically significant difference in the duration of full weight bearing between the groups. As a result of the steady fixation with the I-EF and the fact that it is a system that is capable of carrying weights in the early period, we think that the entire weight-bearing times are similar as well.

After open high-energy lower extremity trauma, the relationship between the length of time elapsed before surgical debridement and the risk of infection is in proportion (25-26). Westgeest et al. (27) reported a late union rate of 17% in a prospective analysis of 736 open fractures. The current study also found a correlation between union time and injuries to soft tissues. According to our findings, the union time in group I (G-A subtype 3A) was shorter than that in group II (G-A subtype 3C). The Johner-Wruhs score (15) and the criteria set up in the study conducted by Prasad et al. (16) showed that the radiological results of patients who were assigned to group I (G-A subtype 3A) were considerably superior to those of patients who were assigned to groups II and III.

In the treatment of compound tibial diaphyseal fractures, Mangukiya et al. (28) reported that the AO monolateral fixator had superior functional and radiological outcomes compared with the extremity reconstruction system. Bayrak et al. (29) showed that I-EF results were more positive in a study in which they compared the Ilizarov external fixator and monolateral external fixator in comminuted tibia fractures resulting from gunshot injury. According to the findings of our research, group I (G-A subtype 3A) had superior coronal and sagittal alignment compared to group III (subtype 3C). The belief that we have is that the deterioration of bone tissue integrity that occurs in type 3C fractures is the cause of the increase in alignment issues. We found that the results worsened than the severity of the injury and the damage to the soft tissue increased. This study is in addition to studies that are currently unavailable. The present study has several limitations, such as its retrospective design, lack of randomization, and relatively small number of patients. When I-EF is used for the treatment of GA type 3 open tibial shaft fracture, the study has a long follow-up period and a cohort of patients. These are two positive aspects of the study. Another aspect of the study is that it demonstrates the application of I-EF as a permanent treatment for wounded patients who have open fractures of the tibia shaft at the time of injury.

CONCLUSION

In conclusion, although our findings were positive in the patients to whom we used the Ilizarov technique, we discovered that the clinical and radiological results were worse as the severity of the wound grew (G-A subtype A to C). This was the case even if our results were positive.

ETHICS

Ethics Committee Approval: Patients who underwent I-EF due to G-A type 3 tibial shaft fracture between January 2013 and December 2018 were retrospectively approved by Bakırkoy Dr. Sadi Konuk Egitim Ve Research Hospital Clinical Research Ethics Board (approval no: 2015/01/10, date: 04.01.2016).

Informed Consent: Since this study was a retrospective study, patient consent was not required.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: M.Ç., A.B., M.C.A., Concept: M.Ç., V.Ö., Design: M.Ç., A.B., V.Ö., Data Collection or Processing: A.B., V.Ö., C.K., Analysis or Interpretation: M.Ç., A.B., V.Ö., C.K., Literature Search: M.Ç., A.B., M.C.A., Writing: M.Ç., V.Ö., M.C.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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