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Segmental tibial fractures treated with Ilizarov circular fixator

Segementni prelomi tibije lečeni fiksatorom po Ilizarov-u

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Abstract

Background/Aim. Segmental fractures represent complex tibial injuries, featuring a unique fracture type that is most commonly caused by high-energy trauma. These fractures are considered to be a treatment challenge for orthopaedic surgeons due to their sporadic presentation, wide zone of soft tissue injury, and increased rate of complications. They are characterized by a highly unstable intermediary segment and a high rate of open fractures. The method of Ilizarov with its characteristics could offer many advantages over the existing operative techniques. This method, using a percutaneous approach, minimizes the intraoperative trauma and avoids the additional compromising of the biological environment at the fracture site. The aim of this study was to evaluate the results of the Ilizarov fixator in the treatment of segmental tibial fractures. **Methods.** We analyzed 30 patients treated with the Ilizarov fixator between 2012 and 2017. The average age of patients was 36 years (from 24 to 65). The most common mechanism of injury was a road traffic accident. Open fractures were noted in 22 cases. All fractures were reduced using indirect percutaneous techniques with a great focus on achieving the correct length, rotation, and axial alignment of fragments. All patients were advised to bear weight as tolerated from the second postoperative day. Bone healing and functional results were evaluated according to the criteria established by the Association for the Study and Application of the Method of Ilizarov. **Results.** Bone healing was achieved in all patients. The average time to union was 25 weeks (19 to 36 weeks). Bone results were excellent in 23 patients, good in five, and fair in two patients. Functional results were excellent in 22 cases, good in 5, and fair in three cases. Eight patients had minor pin-tract infections, successfully treated with oral antibiotics. Patients were without any major complications. **Conclusion.** The Ilizarov method is a safe and efficient treatment modality for segmental tibial fractures.

Key words:
tibial fractures; external fixators; ilizarov technique; recovery of function.

Apstrakt

Uvod/Cilj. Segmentni prelomi tibije predstavljaju kompleksne povrede koje se karakterišu složenim obrascem preloma i uglavnom su posledica sila visokog intenziteta. Ove povrede predstavljaju izazov u izboru načina lečenja usled svoje sporadične prezentacije, obimne zone značajno oštećenog mekog tkiva i povećane stope komplikacija. Odlikuju se izuzetno nestabilnim intermedijarnim fragmentom i visokom učestalošću otvorenih preloma. Ilizarovljev metod svojim karakteristikama nudi mnoge prednosti nad ostalim postojećim hirurškim tehnikama. Ovaj metod, svojim perkutanim pristupom, značajno smanjuje traumu operativnog polja, čime se izbegava dodatno narušavanje biološke sredine na mestu preloma. Cilj ovog rada je analiza rezultata lečenja segmentnih preloma tibije metodom Ilizarova. **Metode.** Analizirali smo podatke od 30 bolesnika lečenih metodom Ilizarova u periodu od 2012. do 2017. godine. Prosečna starost bolesnika iznosila je 36 godina (24 do 65 godina). Najčešći mehanizam povređivanja bio je saobraćajni traumatizam. Otvorene prelome imalo je 22 bolesnika. Prelomi su reponirani perkutanom tehnikom, sa velikom pažnjom na uspostavljanje adekvatne dužine, rotacije i osovine potkolenice. Svim bolesnicima je bio dozvoljen oslonac od drugog postoperativnog dana. Rezultati su procenjivani prema kriterijumima Asocijacije za proučavanje i primenu metode Ilizarova. **Rezultati.** Koštano zarastanje ostvareno je kod svih bolesnika. Prosečno trajanje primene aparata po Ilizarovu iznosilo je 25 nedelja (19 do 36 nedelja). Koštani rezultati bili su odlični kod 23

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bolesnika, dobri kod pet i umereni kod dva bolesnika. Funkcionalni rezultati bili su odlični kod 22 bolesnika, dobri kod pet i umereni kod tri bolesnka. Kod osam bolesnika konstatovana je infekcija oko igala aparata, koja je uspešno tretirana oralnom antibiotskom terapijom. Nisu uočene druge značajne komplikacije. **Zaključak.** Metoda po Ilizarovu predstavlja bezbedan i efikasan modalitet lečenja segmentnih preloma tibije.

Ključne reči:
tibija, prelomi; fiksatori, spoljni; ilizarov tehnika; funkcija, povratak.

Introduction

Segmental tibial fractures are very complex injuries. They are characterized by a unique fracture pattern with an intermediate fragment separated from the rest of the tibia with two different fracture lines [1]. In some cases, bone comminution is present, which additionally contributes to the severity of the injury [2]. Although tibia fractures are a frequent topic of scientific papers, little attention is given to treating exclusively segmental fractures of this bone [3]. This type of fracture is often caused by high-energy trauma. It mostly occurs in road traffic accidents, of which the most serious injuries are among motorcyclists [4].

Due to low incidence, specific fracture pattern, extensive soft tissue damage, and a significant degree of complications, these fractures represent a great challenge in treatment [5]. Out of many operating techniques in the literature, most attention is given to intramedullary nailing [6]. However, due to the unstable intercalary segment, fracture reduction is mainly the main concern of this method and may require the use of additional implantation material [3]. Many authors suggest high complication rates following intramedullary nails, including osteomyelitis (up to 47%), nonunion (up to 29%), and subsequent amputation (up to 7%). Despite numerous studies, there is no consensus on the question of surgical treatment, and the optimal treatment modality of these injuries remains the topic of debate [7].

The anatomical localization of the tibia and its subcutaneous position with a poor soft tissue cover on the medial side are the cause of the high incidence of open fractures [8, 9]. The naturally scarce vascularization of the tibia, in particular at the juncture of its distal and medial third, is additionally disrupted in the case of fracture. The effort to maintain vascularisation of fracture fragments represents a determining factor in the healing of these fractures. The exposure of the fracture site leads to disturbance of the biological environment which has a negative effect on the bone union. All of the above-mentioned factors lead to a greater tendency towards the onset of the infection, dehiscence of the wound, compartment syndrome, and nonunion [10, 11]. The complications are often not isolated, they consist of a combination of infection, nonunion, bone and soft tissue defects [12].

The method of Ilizarov with its characteristics could offer many advantages over the existing operative techniques. This method, using a percutaneous approach, minimizes the intraoperative trauma and avoids the additional compromising of the biological environment at the fracture site. Such surgical doctrine aims to utilize the complete potential of bone and soft tissue in the attainment of angiogenesis and induction of osteogenesis [13]. Indirect closed reduction is made possible by using a circular frame with thin tensioned wires. An important advantage is the possibility of achieving multiplanar and multilevel stability [7]. The sturdy construct, provided by such an external fixator, enables, at the same time, dynamic functional axial loading of the injured leg. The importance of the early weight-bearing and the initiation of movements in adjacent joints are well established in the literature [10]. One of the essential characteristics of this method is its modularity which allows the construction of a frame specific to each patient and according to each fracture pattern. This modularity also enables treatment for potential bone defects, as well as possible leg length discrepancies [14].

The aim of this study was to evaluate the results of the Ilizarov fixator in the treatment of segmental tibial fractures.

Methods

This retrospective study was conducted at the Institute for Orthopaedic Surgery "Banjica" on 30 patients with segmental tibial fractures treated with the Ilizarov external fixator from 2012–2017. The age range was 24 to 65 years with an average of 36 years; 6 patients were female, and 24 were male. All fractures analyzed in this study were defined as tibial fractures with intermediary fragments separated by two completely distinct fracture lines, type 42-C2 according to the AO/Orthopaedic Trauma Association (AO/OTA) classification [15]. Segmental fractures of the tibia were further classified according to Melis et al. [16]. There were no multisegmental fractures with four or more segments in our patient sample.

The mechanism of injury was a road traffic accident in 23 cases, falling from height in 4, and direct trauma in 3 cases. The left leg was injured in 11 and the right limb in 19 patients. Eight patients had closed fractures, and the remaining 22 patients had open tibial fractures. The open fractures were Gustilo–Anderson [17] type I in three cases, type II in four, type IIIa in eleven, and type IIIb in four cases. Five out of 8 closed fractures had grade II, and three were classified as grade I of soft tissue injuries according to the classification of Oestern and Tscherne [18].

Calcaneal skeletal traction was applied to the injured leg in order to maintain leg length and alignment of bony fragments until definitive surgery was performed. All open injuries were initially treated with meticulous debridement and irrigation followed by plastic surgical management, if needed, in order to achieve appropriate soft tissue closure.

The soft tissue condition had a crucial role in planning the definitive operation moment. The Ilizarov frame

application was dependent on soft tissue swelling degree and healing of the soft tissue reconstruction in conjunction with the plastic surgery department. Prophylactic first generation cephalosporin antibiotics were administered intravenously in all cases for three days, with additional aminoglycoside antibiotics, in cases of open fractures for five days. All operations were performed by the same surgical team under spinal or general anaesthesia. Thromboprophylaxis with low-molecular-weight heparin was carried out for four weeks after the initial trauma. The fractures were reduced with the indirect percutaneous technique with a great focus on gaining the correct length, rotation, and axial position of the fragments. The Fracture was stabilized with one or two rings *per* segment depending on its length in a 'near-far' pattern. The intermediate fragment was reduced and fixated using the opposed olive wires technique.

The postoperative care consisted of daily performed pin-site dressing and passive knee and ankle motion exercises in addition to isometric quadriceps strengthening. All patients were advised to bear weight as tolerated from the second postoperative day. The patients were evaluated clinically and radiographically using standing radiographs once a week for the first six weeks and then in one-month intervals. The external fixator was removed when mature bridging callus on anteroposterior and lateral radiographs was established, and patients achieved painless full-weight bear walking. An example is illustrated in Figure 1. Bone healing and functional results were evaluated according to the criteria established by the Association for the Study and Application of Method of Ilizarov (ASAMI) [19].

For data description, we use a measure of central tendency (arithmetic mean) and measures of variability (minimum and maximum value).

Results

The patients were followed up for 14 months on average (range from 12 to 21 months). The time that passed from the injury until surgery was 7 days in most cases (4 to 12). The individual preoperative details and surgery outcomes for all patients in this study are shown in Table 1.

Twenty-nine fractures healed completely following the initial application of the Ilizarov frame without the necessity for any bone healing stimulating procedure. One patient that

Fig. 1 – A 46-year-old man with closed segmental tibial fracture: (a) Initial anteroposterior and lateral radiographs; (b) After application of the Ilizarov fixator; (c) Radiographic and (d) clinical appearance six months after the removal of the frame showing complete bone union with fragments in residual recurvatum and varus position.

Table 1

Preoperative patient details and surgery outcome

Case	Gender/ age (years)	Injury	Type (Gustilo)	Melis class.	Fixator time (weeks)	ASAMI score	
						bone	function
1	M/61	RTA	IIIa	II	30	Excellent	Good
2	M/33	DT	Close	III	24	Excellent	Excellent
3	F/24	RTA	I	II	25	Excellent	Excellent
4	M/49	Fall	IIIb	I	36	Fair	Fair
5	M/52	RTA	Close	I	25	Excellent	Excellent
6	M/27	RTA	IIIa	IV	27	Excellent	Excellent
7	M/48	RTA	IIIa	II	26	Good	Excellent
8	M/26	RTA	II	I	21	Excellent	Excellent
9	F/42	DT	IIIb	I	30	Good	Excellent
10	M/28	RTA	Close	I	19	Excellent	Excellent
11	M/31	Fall	IIIa	IV	26	Excellent	Good
12	M/24	RTA	I	I	20	Excellent	Excellent
13	F/36	RTA	Close	II	21	Excellent	Excellent
14	M/43	RTA	IIIa	II	25	Good	Good
15	M/34	RTA	II	III	23	Excellent	Excellent
16	M/40	RTA	IIIa	II	29	Excellent	Excellent
17	M/35	DT	Close	II	22	Excellent	Excellent
18	M/29	RTA	I	I	25	Excellent	Excellent
19	M/65	RTA	IIIb	II	30	Good	Fair
20	F/34	Fall	IIIa	II	27	Excellent	Excellent
21	M/26	RTA	II	IV	25	Excellent	Excellent
22	M/25	RTA	IIIa	II	29	Excellent	Good
23	M/46	RTA	Close	I	19	Excellent	Excellent
24	F/31	RTA	IIIa	I	28	Excellent	Excellent
25	M/26	RTA	IIIb	II	30	Good	Fair
26	M/27	RTA	II	III	19	Excellent	Excellent
27	M/40	Fall	Close	IV	22	Excellent	Excellent
28	F/27	RTA	IIIa	II	25	Fair	Good
29	M/29	RTA	Close	III	20	Excellent	Excellent
30	M/45	RTA	IIIa	IV	29	Excellent	Excellent

M – male; F – female; ASAMI – Association for the Study and Application of the Method of Ilizarov; RTA –road traffic accident; DT – direct trauma.

had open type IIIb fracture showed no signs of the union after a prolonged period of time due to frame loosening and required new frame application. The patient was successfully treated as stiff nonunion with distraction-compression osteogenesis [20] at the fracture site with the eventual union after 36 weeks. The bone healing time was defined as the time from operation to the removal of the fixator. In our study, bone union time was 25 weeks on average (19 to 36 weeks). Proximal callus formation was observed between the second and fifth week. The time needed for distal callus formation was a little longer and ranged from 3 to 7 weeks.

The open fracture wounds were all localized in the anterior aspect of the lower leg. Five patients had partial-thickness soft tissue defects without exposed bone. They were all treated by a plastic surgeon with a split-thickness skin graft. Four patients had exposed bone with full-thickness soft tissue defects that needed coverage with adequate flaps.

No major complications, such as osteomyelitis or amputation, occurred in any of the patients. None of the patients required blood transfusion. In our study, there were no cases of pulmonary embolism, deep vein thrombosis, soft tissue necrosis, or palsy of the peroneal nerve. There were no signs of compartment syndrome in any patient before or after the surgery. Three patients had breakage of the frame wire that required replacement, and eight patients had minor pin-tract infections, successfully treated with oral antibiotics. Signs of deep infection were not observed in any patient secondary to pin-track infection. Patients analyzed in this study did not have any other skeletal injuries or injury to other organs or organ systems.

An adequate tibial alignment was noted on standing radiographs in 28 cases. Two patients had residual valgus and antecurvatum of 15°. No rotational deformities were observed. None of the patients required treatment for tibial axis malalignment.

The bone results were excellent in 23 cases, good in five, and fair in two cases. Out of two patients with fair bone results, one had shortening of the lower leg with additional valgus deformity more than 7°, and one patient had shortening of the lower leg with associated antecurvatum deformity of more than 7°. The functional results were excellent in 22 patients, good in 5, and fair in three patients. Among the three patients with fair functional results, one patient had knee pain and reduced ankle dorsiflexion with consequent limping, and the other two patients had knee pain with extension deficit and limping.

Discussion

Segmental tibial fracture is described by many studies as a unique type of injury associated with a high complication rate [6]. Woll and Duwelius [2] described segmental tibial fractures as "an extremely high-risk injury". They noted postoperative complications more frequently than in any other category of the tibia fracture.

The optimal treatment of segmental tibial fractures represents a very complex surgical problem. Reduction and fixation pose a significant challenge with fracture patterns featuring great axial and rotational instability [21]. The results of conservative treatment are negligible to have any value and be further considered in the treatment of these types of fractures. Intramedullary stabilization is the most frequently analyzed method in previous stud-ies [6, 22]. Many disadvantages and problems were reported by various authors using this method. Both reaming and non-reaming techniques have their drawbacks, such as decreasing cortical circulation of an intermediary fragment, endosteal necrosis, and increased infection rate when used in open fractures [23, 24]. The Ilizarov external fixator is a commonly used method for treating complications after failed internal fixation of the tibia [6].

High-energy mechanisms of injury are commonly followed by severe soft tissue defects. As a result of the damage to the surrounding soft tissues, approximately 53–80% of segmental tibia fractures are open injuries [25]. Following trauma, both endosteal and periosteal blood supply of the intermediate segment are damaged. As this circulation is naturally precarious, any sustained damage additionally compromises the healing potential [5]. The ideal treatment of the fracture should avoid additional disturbance to the soft tissues and bone, strive to preserve the remaining blood supply, and provide a structured environment that stimulates osseous biological processes toward bone union [6]. Taking these aims into consideration, the Ilizarov method should meet all those requirements [26].

All patients in this study with closed fractures show excellent bone results. In contrast, most of the patients with open injuries had lower grades of final bone and functional results. Only one of four patients in this study with type IIIb open fractures achieved excellent bone results. Patients with closed and open fractures were analyzed in the same sample group. The reason was that the aim of the research was not to compare these two types in terms of treatment methods and outcomes, which is one of the drawbacks of the study.

In our study, functional results were excellent in 22, good in 5, and fair in 3 patients, which corresponds to the findings of Oztürkmen et al. [6]. The physiological bone alignment was shown on all radiological evaluations, except in two patients with valgus and antecurvatum of no more than 15°.

All patients in our study achieved bone union. One of the possible reasons for such a high healing rate is the preservation of the local blood supply and initial biological environment. Only one patient required additional surgery in terms of reapplication of fixator after aseptic loosening. A similar union rate is reported in other smaller series [6, 27, 28]. Three studies that analyze the value of the Ilizarov method in treating segmental tibia fractures have shown consistently high rates of the primary union of at least 90%, with very low rates of complication [6, 27, 28]. The series described by Oztürkmen et al. [6] demonstrated that 22 out of 24 cases healed without further intervention; Tilkeridis et al. [27] reported 30 out of 33, and Giotakis et al. [28] 18 out of 20 patients achieving satisfactory union.

In the research of Foster et al. [7], the average time to union was 23 weeks, and Giotakis et al. [28] present their results with the median time to union of 21.7 weeks (range 12.8–31 weeks). Our findings correlate highly with those studies. In our research, we saw that the distal callus took an extended time to be formed (3–7 weeks) compared to the proximal fracture site, where the time range was 2–5 weeks. Oztürkmen et al. [6] propose that the fixation at the distal fracture site be as firm as possible because the distal tibial shaft has a natural tendency of showing prolonged union. As opposed to this, Giotakis et al. [28] reported no difference in bone union time observed between the proximal and distal fracture levels.

In order to promote fracture healing, modifications of the fixator are possible at any point of treatment. Trauma-induced bone defects, concomitant rotational or angular malalignment can be easily corrected by frame adjustments. This advantage of the Ilizarov fixator reduces the need for possible additional operations used to correct the resulting deformities. One of the significant problems is the achievement of adequate rotational stability of the distal part of the tibia. According to Audigex et al. [29], the distal fracture site is usually more unstable than the proximal one. Even in cases where the distal fragment is short, the Ilizarov method ensures its stable fixation [26].

Most patients with severe soft tissue injury require reconstructive surgical techniques, such as skin grafts or flaps, which may prolong the time until definitive bone fixation [7]. In our series, the maximal waiting time for the operation was twelve days which did not decrease reduction ability and the bone union potential. By utilizing bone compression and distraction, the Ilizarov method has the effect on increasing the bone and the surrounding soft tissue blood supply [6]. On routine radiographic follow-up, we noticed callus being formed earlier on the posterolateral aspect than on the anteromedial cortex of the tibia. These observations emphasize the significance of soft tissue coverage and blood supply preservation.

Pin-track infections and patient intolerance to wearing the external device are some of the most common drawbacks of this method. Despite this, pin-track infection is easily treated with regular pin-site dressing and oral antibiotics [7]. Eight patients in our study had minor pin-tract infections successfully treated with oral antibiotics, without any serious complications in terms of osteomyelitis.

Conclusion

The Ilizarov method is a safe and efficient treatment modality for segmental tibial fractures. This surgical technique could provide a high rate of bone union with predictable functional outcomes. Low incidence of soft tissue complications, early mobilization, and weight-bearing, as well as good functional recovery, all correlate amiably with other literature results and advocate that the Ilizarov external fixator should be one of the first treatment options for these complex injuries.

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