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*Original article*

# The Application of Ilizarov Technique in the Treatment of Comminuted Distal Tibia Fractures

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**SUMMARY**

**Introduction. High-energy distal tibia fractures are characterized by great comminution and extensive lesions of the surrounding soft tissues. The risk of developing complications during treatment is high. The application of the Ilizarov's technique reduces the risk of complications significantly, and provides good final treatment results.**

**Methods. In our prospective observational study 41 patients were included. Clinical characteristics were evaluated by Gustillo-Anderson, Checketts-Otterburns and AO/OTA classification. The ASAMI protocol was used to assess bone union. Functional treatment results were represented using the modified Karlström-Ollerud scoring system. Analysis and monitoring time (follow up) was 18 months.**

**Results. Using radiographic and clinical parameters, we recorded complete healing in all fractures. In the group of 43B intra-articular fractures, circular fixator was removed after 16 weeks (range 13 - 31), while in the 43C fracture type group, it was removed after 18 weeks (range 13 - 29). The ASAMI evaluation of bone healing showed 31 (75%) excellent, 76 (15%) good, 3 (8%) satisfactory, and 1 (2%) poor result. Functional recovery results obtained after 6 months showed the mean value of 24.7 using the modified Karlström-Ollerud scoring system in three follow-up periods, which represents recovery. The results present 12 months after surgery showed the mean value of 27.6, representing satisfactory recovery, while during the last parameter measurement performed after 18 months, the value was 29.5, which indicates good functional recovery.**

**Conclusion. Transosseous osteosynthesis Ilizarov treatment applied in closed and open comminuted distal tibia fractures showed good final bone and functional results with minimal complications, and contributed to better patient's quality of life.**

*Keywords*: **Ilizarov technique, distal tibia fractures, comminuted fractures, ASAMI classification**

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## INTRODUCTION

Distal tibial fractures (DTFs) account for 0.7% of all skeletal fractures. Kannus et al. in their research of the Finnish population found an increase in the frequency of these fractures from 174 per 100,000 populations, and their increase is estimated to triple by 2030 years (1). The rates of ankle fractures are increased in people who have increased body weight and are avid smokers (2). It can be said that these are two separate factors that are correlated with frequency. No correlation was observed between the onset of menopause, the general state of health and the occurrence of an increase in DTFs (2). The causes of more frequent occurrence of DTFs in developed countries are different as indicated by previous studies and studies by the Edinburgh Orthopedic Association (3). DTFs account for 10% of all lower extremity fractures. DTFs is more common in men, however, they are rare in children and the elderly (3, 4). DTFs mainly occur as a result of traffic accidents or falls from the height. The most common patients are from 35 to 40 years old. Low-energy mechanisms are generally rotational DTFs that occur as a result of a fall or sports injury, especially while skiing (4). In the case of high-energy injuries that are associated with a large vertical force, comminuted open or closed DTFs occur (4). Also, the percentage of occurrence of compartment syndrome and blood vessel lesions is significantly lower with DTFs than proximal tibial fractures (5, 6). The Ruedi - Allgower classification was the first commonly used classification of DTF, but in the modern literature, the AO/OTA system is more often used (7, 8). Although the AO/OTA classification for DTF is logical and represents a guide for treatment and probably prognosis, inadequate interpretation by surgeons greatly hinders the proper use of this system. Achieving the stable fixation of the distal tibial joint and ensuring all prerequisites for bone union is certainly an imperative in the treatment of such demanding fractures (9 - 13). Complications of surgical treatment are not so rare. Some authors exclude the accompanying soft tissue injuries in their research, which can have far-reaching consequences on the final result of treatment (14). Casstevens and Newman, in their research, indicate the necessity of including the condition of the soft tissue in the preoperative protocol as well as the correct selection of the surgical technique (15, 16). Some authors prefer the use of an external fixator in the treatment of DTFs compared to an internal fixation (17 - 20). The Ilizarov's device proved to be effective in the treatment of these fractures, giving a low percentage of non-union and infection (21 - 23). Two-stage procedures are not necessary for the treatment with the Ilizarov device, but one-stage procedures achieve better results with minimal complications (24, 25).

The purpose of our study was to consecutively examine the clinical and radiographic results using the Ilizarov device in patients with intra-articular comminuted DTFs.

## METHODS

Evaluation of bone and functional results in multiple intra-articular fractures of the distal tibia using the Ilizarov device was the aim of this research. The research was conducted at the Clinic for Orthopedic Surgery and Traumatology, Clinical Center of Vojvodina in Novi Sad. The study was conceived as a prospective opservational research. The research included patients with comminuted DTFs treated with the Ilizarov technique in the period from January 2015 to December 2019.

### Research procedure

The study included 41 patients, of both sexes, with high-energy intra-articular comminuted open or closed right or left DTFs. Patients who fulfilled all the inclusion criteria and who agreed with the research protocol were included in the study.

The patients were informed about the purpose of the research, and the way the research, procedures and measurements would be carried out. All patients were observed after the injury, i.e. the fracture was initially treated surgically using the Ilizarov technique. Each patient had their own research protocol, and sources were still drawn from medical histories and polyclinic documents.

Inclusion criteria for the study: patients aged from 18 to 65 years, open or closed comminuted DTFs and AO/OTA classification 43B and 43C.

Exclusion criteria: DTFs treated with another operative technique, patients with confirmed rheumatoid arthritis, diabetes and peripheral vasculopathy. All data obtained from the patients entered into the database during the follow-up period and their anonymity was guaranteed.

Adequate preoperative preparation preceded all surgeries. Broad-spectrum antibiotics were pre-

scribed prophylactically, while triple antibiotic therapy was used for open fractures with anti-tetanus protection. Radiography was performed in all patients (Figure 1), whereas CT and MR diagnostics were used in some patients.

**Figure 1.** *Preoperative AP and LL x-ray of a distal tibial fracture*

**Surgical procedure**

A C-arm was used during some parts of the operation.

Patients were placed in supination on the table with the lower leg placed on special holders made from parts of the Ilizarov apparatus. As it was impossible to fix the bone fragments manually, we used a special tool to fix them through a small slit in the skin. After straightening the articular surface of the joint, transcortical K-wires were placed. K-wires with or without an olive were used, which provided good fragmentary compression. When placing the wires, we took care of the safe anatomical zones. The wires were placed at an angle of 60 degrees. After setting the wires and radiographic checking of the fragment position, we placed the distal ring of the apparatus. It was ensured that the wires were at the maximum distance of 1 cm from the joint lines. Two more rings were added (one on the metaphyseal part of the tibia), and one was added below the tibial tubercle. The ring was connected with treatedrods, and the longitudinal axis of the tibia and its possible deviations were looked after. Often these rings, of which there were three to four, were reinforced with additional K-wires above and below to further stabilize the device.

In case of marked pilon multifragmentation (fracture 43C), we also used additional calcaneal semi-ring (horseshoe) to maintain ligamentotaxis. Two olive wires were threaded convergently through the calcaneus. In some cases, an additional wire was placed through the talus body, and finally two wires were placed through the metatarsal bones. The first wire was placed through the first, second, and third, while the second wire was placed through the fourth and fifth metatarsal bone. This horseshoe was linked to the distal tibial ring with or without hinges in the ankle joint. The operative procedure duration and exposure time to X-rays were recorded. The radiograph is displayed through the RadiAnt DICOM Viewer (Figure 2).

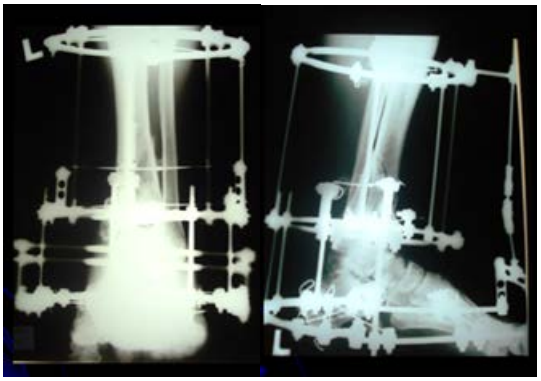

**Figure 2.** *Postoperative AP and LL x- ray of a distal tibial fracture with Ilizarov apparatus and calcaneal semi-ring*

The Association for the Study and Application of the Ilizarov Method (ASAMI) was used to assess bone healing (26). The modified Karlstrom-Olerud (mKO) scale was used to assess the functional status (Table 1) (27). Joint movement measurements were performed using an arthrometer (28).

**Table 1.** *Karlstrom-Olerud system (modified)*

| Sr No | Measurement | 3 points | 2 points | 1 point |
|---|---|---|---|---|
| **1.** | Pain | No | Little | Severe |
| **2.** | Difficulty in walking | No | Moderate | Severe/limp |
| **3.** | Difficulty in stairs | No | Supported | Unable |
| **4.** | Difficulty in previous sport activities | No | Some sports | Unable |
| **5.** | Limitation at work | No | Moderate | Ulcer/fistula |
| **6.** | Status of skin | Normal | Various colors | Remarkable, > 7° |
| **7.** | Deformity | No | Little, <7° | Remarkable, > 7° |
| **8.** | Muscle atrophy | < 1cm | 1 - 2 cm | 2 cm |
| **9.** | Leg length discrepancy | < 1cm | 1 - 2 cm | 2 cm |
| **10.** | Loss of motion at knee joint | < 10° | 10 - 20° | 20° |
| **11.** | Loss of motion at subtalar joint | < 10° | 10 - 20° | 20° |

Outpatient follow-up of the patient was 6, 12 and 18 months after the operation. The results of the mKO system were quantified through the final scoring system (Table 2).

**Table 2.** The f*inal scoring system*

| | |
|---|---|
| **Exelent** | **33** |
| **Good** | 32 - 30 |
| **Satisfactory** | 29 - 27 |
| **Moderate** | 26 - 24 |
| **Poor** | 23 - 21 |

The minimum duration of patient's follow-up was 18 months. Radiography was performed at the same time intervals. Patients with a semi-ring could achieve earlier support (immediately postoperatively), while those without a semi-ring had a limited support - up to the limit of tolerance.

**Postoperative procedure**

Early rehabilitation was mandatory for all patients and all patients used axillary crutches (Figure 3).

**Figure 3.** *AP and LL view of the operated lower leg in hospital conditions with partial weight bearing*

The Gustillo-Anderson classification was used for open fractures, while the Oestern and Tscherne classification was used to show soft tissue damage (29, 30). Kurgan protocol was used for postoperative

care of pin insertion site, while Checketts-Otterburns classification was used for pin infection description (31, 32). Monitoring of the apparatus was conducted: a manual test assessed the Ilizarov apparatus stability, tension of wires was evaluated by palpation, positioning of wires used in fracture was checked postoperatively by palpation, initiated compression or distraction of the apparatus and altering of some of the apparatus components was also checked. Length of hospitalization as well as the clinical findings at discharge from hospital were also recorded.

**Ethical consideration**

Research propositions of this study were reviewed and approved by the Ethics Committee (No 00-4/297) and Professional Board at our Clinic.

**Statistical analysis**

Following data control, analysis comprehended descriptive and inferential statistics methods. Jamovi (Version 2.1) package program was used in this study. Percentage distributions, median and extreme values of research data were represented. The Chi-square test was used for binary variables, and Mann-Whitney U test was used to compare continuous variables. Cronbach's Alpha Coefficient was used to test the questionnaire reliability. Statistically significant results were considered to be the ones with probability less than 5% ($p < 0.05$).

**RESULTS**

This prospective observational study was conducted during the period from January 2015 to December 2019, in which 41 patients who met all the study inclusion criteria were observed and were admitted through the Emergency Center of the CCV in Novi Sad. Among them, there were 32 men and 9 women with the average age of 49.5 years (range 18 - 65). Twelve of them were avid smokers. The right distal tibia was injured more often than the left distal tibia – 29 (70%), 12 (30%), respectively. The most common cause of injury was falling from the height, which was recorded in 21 (51%) patients, and the least was the number of injuries that occurred at work in 1 (2%) patient. High-energy injuries dominated over low-energy injuries. There were more open fractures -26 (63%) in comparison to closed fractures - 15 (37%). According to the Gustillo-Anderson classification of open fractures, type I dominated in 13 of them (50%), while the type III B occurred the least, in 2 (8%) cases only. According to AO/OTA classification, significantly more patients suffered the type 43C fractures, 33 of them (80%), while 8 of them (20%) had type 43B (Figure 4).

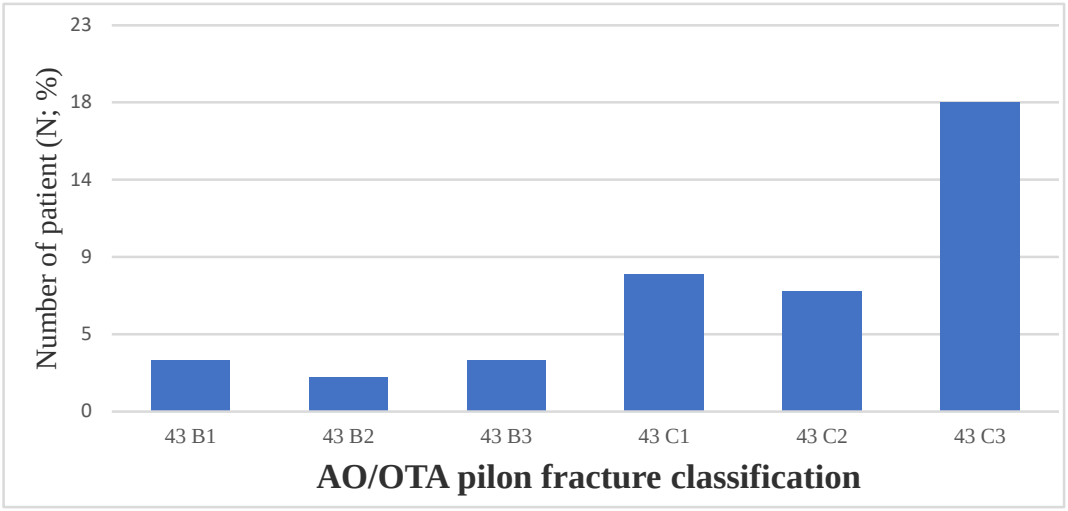


**Figure 4.** *Distribution and number of subjects according to AO/OTA fracture classification*

**Table 3.** *General data of patients from the study*

| | | n | % |
|---|---|---|---|
| ***Sex*** | Male | 32 | 78.0 |
| | Female | 9 | 22.0 |
| ***Side*** | Right | 29 | 70.0 |
| | Left | 12 | 30.0 |
| ***Mechanism of injury*** | Fall | 21 | 51.0 |
| | Traffic | 13 | 32.0 |
| | Riding | 4 | 10.0 |
| | Work | 1 | 2.0 |
| | Assault | 2 | 5.0 |
| ***Energy type*** | Low-energy | 3 | 7.0 |
| | High-energy | 38 | 93.0 |
| ***Type of fracture (Gustillo-Anderson classification)*** | I | 13 | 50.0 |
| | II | 6 | 23.0 |
| | III A | 5 | 19.0 |
| | III B | 2 | 8.0 |
| ***Diagnosis*** | Open | 26 | 63.0 |
| | Closed | 15 | 37.0 |
| ***Soft tissue injury (Oestern and Tscherne)*** | Grade 0 | 2 | 13.0 |
| | Grade 1 | 3 | 20.0 |
| | Grade 2 | 10 | 67.0 |
| ***Type of fracture 43 (AO/OTA classification)*** | 43-B1 | 3 | 7.0 |
| | 43-B2 | 2 | 5.0 |
| | 43-B3 | 3 | 7.0 |
| | 43-C1 | 8 | 20.0 |
| | 43-C2 | 7 | 17.0 |
| | 43-C3 | 18 | 44.0 |

According to Oestern and Tscherne scale, the majority of patients had degree III, in 10 of them (67%) out of 15 in total, and the least number was with 0 degrees injuries, 2 (13%) of the total number. A large number of open fractures with a large number of bone fragments and high degree of soft tissue injuries in our observation group could be a significant factor for the increase in the number of complications during treatment (Table 3).

As for the time spent from the admission to start of the operative procedure, it amounted to 45 hours (range 18 – 76) on average. Out of 41 patients in total, 15 of them (36%) had preoperative trans-calcaneal skeletal traction, and these were mostly type 43C3 open fractures, while the rest 26 (64%) patients had lower leg cast immobilization. Out of 41 patients in total, 30 of them (73%) were induced into general endotracheal anesthesia, while 11 of them (27%) were subjected to spinal anesthesia. Surgery duration differed depending on fracture type and/or calcaneal semi-ring setting. Thus, in type 43B fractures, surgical procedure lasted for 95 minutes (range 80 - 170) on average, while in type 43C fractures with calcaneal semi-ring setting, it lasted for 140 minutes (range 120 - 200) on average. Average exposure of the surgeon to x-rays during surgery was 80 sec (range 60 - 240). Patients stayed at the Clinic for 6 days (range 5 - 10) on average and were discharged home after previously being trained to walk with crutches. In patients with 43C type fractures who had calcaneal semi-ring, it was removed during a check-up after 6 weeks in polyclinic conditions without anesthesia (Figure 5).

**Figure 5**. *Removal of the calcaneal semi-ring six weeks after surgery*

Out of 41 operated patients in total, 9 of them (22%) received short-term intravenous anesthesia before removing the apparatus, while in the remaining 32 (78%) patients, the apparatus was removed without anesthesia, but with prior administration of intramuscular analgesic. In patients who sustained type 43B fractures, the device was removed after 16 weeks (range 13 - 31), while in those with type 43C fractures, the apparatus was removed after 18 weeks (range 13 - 29).

Superficial infections around the pin site were recorded in 15 patients according to the Checketts-Otterburns II classification and they were successfully treated with oral broad-spectrum antibiotics, while in 10 patients Checketts-Otterburns III, infection was recorded and treated by removing the irritated wires and the administration of antibiotics. We recorded deep bone infection around the pin tract in 2 patients, and here we removed the pin, performed curettage of the inflammation site, ap-plied frequent dressings and administration of antibiotics according to antibiogram (the causative agent was *S. aureus*). The occurrence of septic arthritis, deep vein thrombosis, osteomyelitis or compartment syndrome was not recorded. We had two transient peroneal nerve lesions.

Successful healing in all fractures was noted (Figure 6). The results of bone healing are shown in Table 4.

**Table 4**. *ASAMI scoring system*

| **Bone results** | | **n** | **%** |
|---|---|---|---|
| **Excellent** | Union, no infection, deformity < 7°, limb length discrepancy < 2.5 cm | 31 | 75.0 |
| **Good** | Union + any two of the following: no infection, deformity < 7°, limb length discrepancy < 2.5 cm | 6 | 15.0 |
| **Fair** | Union + only one of the following: no infection, deformity < 7°, limb length discrepancy < 2.5 cm | 3 | 8.0 |
| **Poor** | Nonunion/refracture/union + infection + deformity > 7° + limb length discrepancy > 2.5 cm | 1 | 2.0 |


**Figure 6**. *AP and LL x-ray of the healed tibial pilon fracture after 6 months*

**Table 5**. *Presentation of mKO results after six months*

| | | n | % |
|---|---|---|---|
| Pain | Severe pain | 0 | 0.0 |
| | Moderate pain | 37 | 90.0 |
| | None | 4 | 10.0 |
| Walking difficulties | Significant / limping | 1 | 3.0 |
| | Moderate | 40 | 97.0 |
| | None | 0 | 0.0 |
| Climbing difficulties | Impossible | 2 | 5.0 |
| | With supports | 35 | 85.0 |
| | None | 4 | 10.0 |
| Difficulties during sport activities | Impossible | 39 | 95.0 |
| | Some sports | 2 | 55.0 |

| | | | |
|---|---|---|---|
| | None | 0 | 0.0 |
| Working restrictions | Impossible | 15 | 37.0 |
| | Moderate | 26 | 63.0 |
| | None | 0 | 0.0 |
| Skin status | Ulcus / fistula | 1 | 2.0 |
| | Skin discoloration | 38 | 93.0 |
| | Normal | 2 | 5.0 |
| Deformities | Significant over 7 degrees | 3 | 7.0 |
| | Low up to 7 degrees | 4 | 10.0 |
| | None | 34 | 83.0 |
| Muscle atrophy/ Tibial circumference | > 2 cm | 3 | 7.0 |
| | 1 - 2 cm | 31 | 75.0 |
| | < 1 cm | 7 | 18.0 |
| Lower-limb-length difference | > 2 cm | 0 | 0.0 |
| | 1 - 2 cm | 0 | 0.0 |
| | < 1 cm | 41 | 100 |
| Knee-joint motion range limitation | > 20 | 4 | 10.0 |
| | 10 - 20 | 30 | 73.0 |
| | < 10 | 7 | 17.0 |
| Subtalar –joint motion range limitation | > 20 | 2 | 8.0 |
| | 10 - 20 | 2 | 8.0 |
| | < 10 | 37 | 84.0 |
| Capacity of full weightbearing | Yes | 41 | 100 |
| | No | 0 | 0.0 |

**Table 6.** *Correlation between functional status and degree of deformity after one year*

| | | valgus-varus admission | ante/re-curvatum admission | valgus-varus dismissal | ante/re-curvatum dismissal |
|---|---|---|---|---|---|
| **Functional status** | **Rho** | 0.411** | 0.240 | 0.281* | 0.319* |
| | **p** | 0.003 | 0.091 | 0.043 | 0.021 |
| | **N** | 41 | 41 | 41 | 41 |

Legend: Rho - Spearman's Rho

The results of clinical findings after 6 months are shown in Table 5.

Karlstrom-Olerud score was observed using the Cronbach's alpha after 6, 12 or 18 months. After half a year it was 0.829, after a year 0.858 and after 18 months 0.880. All Cronbach's alpha values were over 0.8, which shows reliability in this study.

According to the Spearman's correlation coefficient, we identified the factors that influenced better functional results.

Using the Spearman's analysis, we obtained a high correlation between the functional status of the patient and the connection with the degree of deformity as well as weight-bearing after one year (Tables 6 and 7).

Mann-Whitney U test did not show a correlation of functional status with age and gender during the monitored interval. In our sample population, there were no statistically significant age differences in functional status. Through Spearman's analysis, we obtained a high correlation of functional recovery and bone status (Table 8).

According to the mKO scale, progress was recorded throughout all the three follow-up periods. The mean was 24.7 after half a year, 27.6 after a year, and it arose to 29.6 after 18 months (Table 9).

**Table 7.** *Correlation between functional status and full weight-bearing after one year*

| | | Full weight-bearing (dismissal) | Month of weight-bearing accomplishment |
|---|---|---|---|
| **Functional status** | **Rho** | 0.233 | -0.324* |
| | **p** | 0.100 | 0.024 |
| | **N** | 41 | 41 |

**Table 8**. *Spearman correlation coefficient (functional and bone status)*

| | | 6 months | 12 months | 18 months |
|---|---|---|---|---|
| **Functional status after 6 months** | **Rho** | 0.521** | 0.479** | 0.418* |
| | **p** | 0.002 | 0.0005 | 0.018 |
| | **N** | 41 | 41 | 41 |
| **Functional status after 12 months** | **Rho** | 0.002 | 0.361* | 0.345* |
| | **p** | 0.027 | 0.041 | 0.005 |
| | **N** | 41 | 41 | 41 |
| **Functional status after 18 months** | **Rho** | 0.214 | 0.356* | 0.601** |
| | **p** | 0.245 | 0.050 | 0 |
| | **N** | 41 | 41 | 41 |

Legend: Rho - Spearman's Rho

**Table 9.** *Descriptive statistics by mKO scale*

| | | AM | Me | SD | Min | Maxi |
|---|---|---|---|---|---|---|
| **Functional status (after 6 months control)** | Ilizarov | 24.701 | 25.000 | 1.587 | 22 | 28 |
| **Functional status (after 12 months control)** | Ilizarov | 27.658 | 28.000 | 1.603 | 24 | 30 |
| **Functional status (after 18 months control)** | Ilizarov | 29.569 | 29.000 | 1.851 | 26 | 33 |

Legend: AM - Arithmetic Mean, Me - Median, SD - Standard Deviation

## DISCUSSION

DTFs are a great challenge for the traumatology surgeon. The treatment of these fractures is based on the status of soft tissues, degree of comminution and damage to the joint sustained at the time of injury (10). Historical results of conservative treatment and the first attempts at limited internal fixation led to the development of AO guidelines for open reduction and internal fixation (7, 12). In fractures with severe soft-tissue damage and metaphyseal comminution, the introduction of plates and screws through extensive exposure is associated with high failure rate and severe complications, such as surgical wound infections, osteomyelitis, and non-healing (13 - 16, 18). External fixator use in treating pilon fractures allows restoration of length, limb stabilization, and mechanical axis correction. In fact, with external fixator used as neutralization device, there is no need for large plates causing increased risk of infection and skin sloughing (32). Facilitating bone transport, ensuring limb stability and low risk of tissue damage are the advantages of the Ilizarov device (33). In our study, we recorded an average bone healing time of 16 weeks (range 13 - 31) in type 43B fractures, while in type 43C fractures it was 18 weeks (range 13 - 29). Vidyadhara et al. in a series of 21 patients with complex DTFs treated between 1998 and 2002 using the Ilizarov apparatus showed an average union time of 26.6 ± 4.2 weeks (from 20 to 34 weeks), (23). Ramos et al. in their observational prospective study of intra-articular pilon tibia fractures treatment in 39 patients, recorded average frame healing time (removal) in 15 weeks (range 11-22 weeks) (34). Lovissetti et al. conducted a study with a sample of 30 patients treated using two similar surgical procedures in AO 43C tibial pilon fractures (Ilizarov apparatus and Sheffield external fixator), and recorded an average healing time of 21.4 weeks, with 10 to 41 weeks range (21). Papadokostakis et al. in their study in 2008, which included a systematic literature analysis of the treatment of intra-articular fractures AO/OTA type C3 using spanning and sparing (non-spanning) external rigid and dynamic fixators, found that the average healing time was 4.3 months (21 weeks), with a range of 2.7 - 8.9 months (35). Considering everything mentioned so far, we can conclude that our results related to the healing of pilon tibia fractures using the Ilizarov apparatus largely coincide with the results of other authors. Furthermore, the same authors in their study in 2008, including a systematic analysis of the literature on the treatment of intra-articular fractures AO/OTA type C3 with spanning group A and sparing (non-spanning) group B using external rigid and dynamic fixators, took details of non-healing data from 12 studies (35).

Nine non-healed fractures out of 131 fractures were recorded in group A (6.8%), and 12 out of 230 in group B (5.2%), which was not significant. Poor healing was also monitored through 12 studies with 353 fractures in total. Group A (179 fractures) had statistically significant higher incidence of poor healing compared to group B (174 fractures), [24 (13.4%) vs 10 (5.7%), Fisher exact test, $p < 0.04$)]. Data were not sufficient to determine any relationship between the factors that could influence the processes of healing, non-healing or poor healing (35). Our study's category "poor bone result" was recorded in

1 (2%) respondent. Lovisetti et al. reported 30 AO type 43C tibial fracture cases treated by transosseous osteosynthesis – the Ilizarov technique in the study. Excellent and good restoration of articular structure were present in 27 cases, and good clinical results were recorded in 15 cases. There were no cases of pseudoarthrosis or deep infection. Healing occurred in all cases (21).

In the study conducted by Milenković et al. of 59 patients with different types and locations of extra-articular fractures of the lower leg, 19 cases involved the distal parts of the lower leg. Of the total number of patients, 32 (54, 23%) cases, the highest grade of open fractures (type III) according to the Gustillo - Anderson classification was found (36). All patients were treated with the "Mitković" type external fixator. The union rate without complications was 77.96% (46). The nonunion and delayed union rate was 15.25% (9). Malunion rate was 6.77% (4). Pin tract infection rate was 13.55% (8). Compartment syndrome was observed in 5.08% (3) of patients. The average time of fracture healing was 26 weeks (6.06 months). The final functional outcomes according to the Lower Extremity Functional Scale (LEFS) were excellent in 37 (62.71%), good in 15 (25.42%), moderate in 5 (8.47%) and poor in 2 (3.38%) patients. In the study conducted by Milenković, we found a shorter union time (18 weeks), complete union in all fractures, deep infections - pin tract infection in 2 patients, without compartment syndrome and with better functional results, although different functional scales were used to determine the functional status. We registered that the mKO scale is more detailed and gives practitioners more information about the functional status of the lower leg. Furthermore, this study surveyed intra-articular fractures of the distal tibia, which are more demanding for surgical treatment and leave more severe consequences for the architecture of the ankle joint.

Thus, Golubović et al., in the studied series of 24 patients with closed segmental fractures of the lower leg and average age of patients of 43.57 years treated with external unilateral fixator type "Mitković" recorded fracture healing without severe complications in 20 patients (83.33%). In 4 (16.67%) patients, the complications were more severe and required further surgical treatment (37).

We used the mKO system for the quantification of functional outcome. The average functional recovery score of 24.7 was present at a half-year follow-up, which is considered to be moderate recovery by other researchers. The follow-up of functional postoperative recovery after one year revealed a satisfactory recovery rate, with the average score of 27.6, whereas the average score of 29.5 that was recorded at the last check-up strongly suggests good functional status according to most authors (22, 32 - 35, 38). In a retrosprective study of 21 patients with high energy tibia pilon fractures treated using the Ilizarov technique, Vidyadhara et al. found encouraging results with good functional outcome in 76% patients. There were no long-term problems with fracture healing, and no patients required ankle arthrodesis (23). The results of our study show a high correlation between the functional status of the patient and the connection with the degree of deformity as well as weight-bearing. We believe that these results of bone fusion and functional recovery after the use of the Ilizarov device support its more intensive use.

## CONCLUSION

Transosseous osteosynthesis Ilizarov treatment applied in closed and open comminuted distal tibia fractures showed good final bone and function results with minimal complications and contributed to better patient's quality of life. We believe that Ilizarov method is a reliable treatment in comminuted DTFs, both in acute setting and revision surgery. It enables better fracture stabilization, minimal soft tissue damage, and early mobilization.

## Conflict of interest

All authors declare that they have no conflicts of interest.

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# Primena Ilizarovljeve tehnike u lečenju višekomadnih preloma donjeg okrajka golenjače

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## S A Ž E T A K

**Uvod. Visokoenergetski prelomi distalne tibije odlikuju se velikom kominucijom i obimnim lezijama okolnih mekih tkiva. Rizik od stvaranja komplikacija tokom lečenja je visok. Primenom Ilizarovljeve tehnike u velikoj meri smanjuje se rizik od nastanka komplikacija i dobijaju se dobri krajnji rezultati lečenja.**

**Metode. U našu prospektivnu opservacionu studiju bio je uključen 41 pacijent. Kliničke karakteristike pacijenata praćene su uz pomoć Gustillo–Anderson, Checketts–Otterburns i AO/OTA klasifikacije. Procena koštanog srastanja vršena je uz pomoć ASAMI protokola. Funkcionalni rezultati lečenja prikazivani su pomoću modifikovanog Karlstrom–Olerud bodovnog sistema. Vreme analize i praćenja iznosilo je 18 meseci Rezultati. Radiografskim i kliničkim parametrima zabeležili smo potpuno srastanje kod svih preloma. U grupi intraartikularnih preloma 43B cirkularni fiksator je odstranjen nakon 16 nedelja (opseg 13–31), dok je kod onih sa tipom preloma 43C odstranjen nakon 18 nedelja (opseg 13–29). ASAMI procena koštanog srastanja dala je sledeće rezultate: 31 (75%) odličan, 76(15%) dobrih, 3 (8%) zadovoljavajuća i 1 (2%) loš rezultat. Funkcionali rezultati oporavka primenom modifikovanog Karlstrom–Olerud bodovnog sistema u tri perioda praćenja dali su nakon šest meseci srednju vrednost od 24,7, što predstavlja oporavak. Rezultati nakon 12 meseci od operacije daju srednju vrednost od 27,6, što predstavlja zadovoljavajući oporavak, dok je na poslednjem merenju u 18. mesecu ta vrednost iznosila 29,5, što je ukazivalo na dobar funkcionalni oporavak.**

**Zaključak. Primenjen Ilizarovljev tretman transosealne osteosinteze kod zatvorenih i otvorenih višekomadnih preloma distalne golenjače dao je dobre krajnje koštane i funkcionalne rezultate sa minimalnim komplikacijama i doprineo boljem kvalitetu života ispitanika.**

*Ključne reči:* **Ilizarov metod, prelomi donjeg okrajka golenjače, višekomadni prelomi, ASAMI klasifikacija**