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Address: 1 Kraljice Natalije Street, 11000 Belgrade, Serbia
☏ +381 11 4092 776, Fax: +381 11 3348 653
E-mail: srparhiv@bvcom.net, Web address: www.srpskiarhiv.rs

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Original Article / Оригинални рад

Aleksandar Božović[1,2,†], Rade Grbić[1,3], Dragiša Milović[2], Zlatan Elek[1,4], Dušan Petrović[2], Ljubomir Jakšić[2], Goran Radojević[2]

Treatment of tibial shaft fractures with external fixation type Mitković – Analysis of 100 patients

Лечење прелома потколенице спољашњом фиксацијом по Митковићу – Анализа 100 болесника

[1] Faculty of Medicine, University of Priština, Serbia;
[2] Health Center Kosovska Mitrovica, Department of Orthopedic Surgery, Serbia;
[3] Clinical Hospital Center Priština, Serbia;
[4] Health Center Kosovska Mitrovica, Department of Surgery, Serbia

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† **Correspondence to:**
Aleksandar BOŽOVIĆ
Department of Orthopedic Surgery
Anri Dinana bb, 38220 Kosovska Mitrovica, Kosovo, Serbia
E-mail: **dr.sasabozovic@gmail.com**

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Treatment of tibial shaft fractures with external fixation type Mitković – Analysis of 100 patients

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SUMMARY

Introduction/Objective Tibial shaft fractures (TSF) are one of the most common fractures. External fixation (EF) may be used to treat TSF.
The aims of this study was to analyse treatment TSF with Mitkovic EF.
Methods The study included 100 patients with TSF treated with Mitkovic EF was a primary and definite method of treatment. and the results compared to literatures data.
Results Gender structure was M 67% and F 33%, aged from 10-71yrs. The most common cause is falling and twisting the leg (59%). Closed fractures were observed in 76 patients (57.4% A AO, 25.4% B AO and 17.1% C AO) and open fractures in 34 patients (50% I GA, 32.35% II GA and 17.64% III GA). The average time period from injure to surgery was 2.5 days (4h–9 days). Bone healing was achieved in 93% of patients. Average healing time was 18.4 weeks (11–32 weeks). Distribution of complications (pin site infections: minor 10% and maior 4%, nonunions 6%, ARDS 1%, osteitis 2%). It wasn't DVT and neurovascular damage. EuroQol score was excellent in 82% of patients.
Conclusion Mitkovic EF can be used for treating all types of TSF. Functional results of treatment by this method are excellent.
Keywords: tibial fracture, etiology, pathology, surgery; fracture fixation, instrumentation, methods; external fixators; osteosynthesis

САЖЕТАК

Увод/Циљ Преломи потколенице (ПП) су једни од најчешћих прелома и могу се лечити спољашном фиксацијом (СФ).
Циљ овог рада је био да анализира резултате лечења ПП са СФ по Митковићу.
Метод Студијом је обухваћено 100 пацијената са ПП лечених СФ по Митковићу као примарним и дефинитивним методом лечења. Резултати су упоређени са литературним подацима.
Резултати Било 67% мушкараца и 33% жена, старости 10–71 година. Најчешћи узрок је пад са извртањем ноге (59%). Затворених прелома је било код 76 повређених (тип А АО 57,4%, тип Б АО 25,4% и тип Ц АО 17,1%). Отворених прелома је било код 34 повређених (тип I ГА 50%, тип II ГА 32,35% и тип III ГА 17,64%). Време до оперативног захвата било је 2,5 дана (4ч–9 дана). Зарастање је постигнуто код 93%, а време зарастања је било 18,4 (11–32) недеље. Компликације лечења су биле: минор инфекција клина 10%, мајор инфекција клина 4%, незарастање 6%, АРДС 1%, остеитис 2%. ДВТ и неуроваскуларних оштећења није било. Анализа квалитета живота помоћу *EuroQol* скора била је одлична у 82%.
Закључак СФ по Митковићу се може употребити за лечење свих типова ПП. Функционални резултати лечења овом методом су одлични.
Кључне речи: преломи потколенице, етиологија, хирургија; фиксирање прелома, инструменти, методе; спољни фиксатори; остеосинтеза

INTRODUCTION

Tibial shaft fractures (TSF) are common long bones fractures and they have great importance. The National Center for Health Statistics (NCHS) reports an annual incidence of 492,000 fractures of the tibia and fibula per year in the United States [1].

Treatments of these injuries are controversial, whether it is a non-surgical and surgical treatment. Also the method of surgical treatment used is controversial [2].

The role of external fixation (in further text EF) in the treatment of these injuries is great and EF is widely used for surgical treatment in accordance with a proper indication. There are 3 methods of using the EF for treatment of TSF: 1. EF as a primary and definitive treatment [3], 2. EF combined with internal fixation [4, 5], 3. Conversion EF to internal fixation [6].

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The Mitković EF has been used for a long time for surgical treatments of TSF [7, 8]. Biomechanical tests of this type EF showed remarkable stability of fixation and good biochemical conditions for bones healing [9].

The aim of this study is to describe the method of Mitkovic EF with the M20 external fixator in surgical treatment of TSF, examine the effectiveness of this method by analysing 100 patients treated by this method and compare our results with the data in the literature.

METHODS

Patients

This study included 100 patients with TSF who were surgically treated in the period 2011-2015. at the Department of Orthopedic Surgery in Kosovska Mitrovica. The surgical treatment was carried out in accordance with the following indications: 1. open TSF, 2. unstable TSF, 3. "damage control" surgery, 4. fractures with "indicators of instability"[10], such as soft tissues damages, involvement of apophysis or articular surface, the excessive distance of fragments etc. All the patients were treated using the method of Mitkovic EF with M20 external fixator. EF we used as the primary and definitive treatment method.

In this study, we analyzed the age, gender structure and causes of injury. For the classification of fractures we used the AO classification of closed fractures and Gustillo-Anderson classification of open fractures (GA). At the end of the treatment we analyzed the outcome, the way we treated the patients and the treatment complications. The patients' quality of life after the treatment was examined with EuroQol-5d scoring system.

The surgical technique and treatment methods

M20 is unilateral fixator using pins that we placed in the tibia in "safe zones" [11]. It is very important to set the correct position of M20 with convergent pins, placed at an angle of at least 60 degrees. The fixator body must be placed between fixator pins in the axis of the tibial diaphysis. Only in this way M20 shows its exceptional biomechanical properties [9]. The proper position of the M20 is shown in Figure 1.

We placed pins before the closed or open reduction of bone fragments and after that we placed the rest of the fixator construction. We used 4 pins, but depending on the weight of the patient, the type of fracture, the degree of comminution and the estimated length of the carrying the fixator we can place more than 4 pins. In the zone of fractures in open reduction minimal osteosynthesis can be done. In a few cases, when TSF included involvement of the distal tibia we made a combined construction: dynamic EF of the ankle joint and standard EF for TSF, for additional stabilization [12], shown in Figure 2.

In similar fractures (TSF with the fracture of the proximal tibia) we did EF combined with internal fixation, shown in Figure 3.

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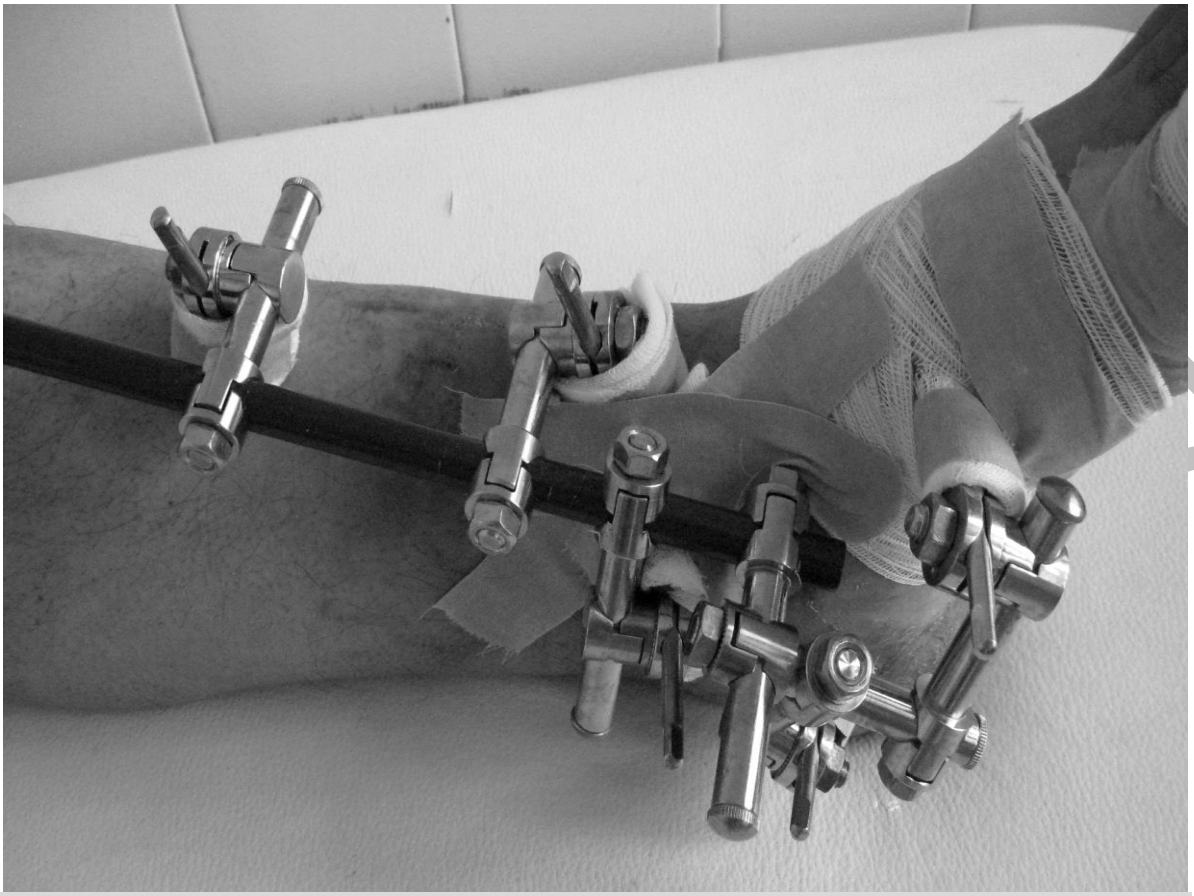

Figures 1–14. CLICK TO SEE ALL 14 FIGURES.

In cases of closed TSF we always use closed reduction of bone fragments and EF after obtaining adequate position of bone fragments. In several cases with an inadequate position of the bone fragments after closed reduction, we did open reduction with a minimally invasive approach. After two weeks we allowed the partial reliance on the injured leg. Pin site is carried out after 3–4 days.

In cases of open TSF, we used the following protocol [8]: early surgery (within 6 hours of injury if it is possible), profuse irrigation of the wound, foreign bodies extraction, hemostasis, debridment of soft tissues, EF, (neurovascular procedure if it's necessary) and drainage. We used the following combination of antibiotics: cephalosporins of the third and fourth generation and aminoglycosides. In the cases of heavily infected wounds we used metronidazole as the third antibiotic. Anti-tetanus prophylaxis was given to all the patients with open fractures according to the protocol. After that, each patient was again carefully examined and the further course of treatment or the need for new surgery determined.

We used EF in children after the careful assessment of their age, weight, type of fracture and the need for surgical treatment [13]. We placed fixator pins outside the zone of the epiphysis and the other part of the treatment is similar to treatments done to adults.

We used Fraxiparine for thromboprophylaxis according to the protocol in all the patients except children.

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RESULTS

Gender structure of our patients was as follows: males 67(67%) and females 33(33%). The classification of our patients according to our age is given in Table 1. Our youngest patient was 10 years old and the oldest 71 yrs. Based on this, we can say that in our study adult men in their thirties and forties were the most frequently injured.

Table 1. Classification of our patients by age.

Patient age	n (%)
2nd decade	10
3rd decade	16
4th decade	26
5th decade	23
6th decade	13
>60 years	12

We treated 4 children with TSF, aged 10, 12 and 13. For two children, it was open fractures type I GA, one child AO type B and one child with bilateral TSF (Figure 4.).

The most common cause of injury was indirect force (falling on the leg with twisting of the foot or the whole lower part of a leg) in 59%, followed by the action of direct force, such was traffic traumatism in 22%, hitting the lower leg 17% and gunshot injuries in 2%.

TSF was closed in 76 patients (A AO 57,4%, B AO 25,4% and C AO 17,1%). The patients were surgically treated on average within 2.5 days of hospitalization, and after 4 hours in the earliest cases (in patients with threatening compartmant syndrome and polytraumatised patients in ``damage control`` surgery) and no later than 9 days (the patient with heart problem). In 64(84.21%) of the patients we achieved a satisfactory position of bone fragments using closed fracture reduction, even in fractures with great bone comminution, shown in Figure 5. In other cases we did the open reduction of fractures and EF, using a minimally invasive approach. In 4 cases we used minimal internal osteosynthesis (screw, wire or hemicortical pin). Hemicortical pin for additional stabilization is shown in Figure 6.

Our study included 34 patients with open TSF. The largest number of patients was with small damage of skin and soft tissue: I GA in 17 cases (50%) and II GA in 11 cases (32,35%). 6(17,64%) patients were with the severe soft tissue damage of III GA (1 IIIa GA, 3 IIIb and 2 IIIc). All the patients with open TSF were surgically treated within 6 hours of hospitalization. We used the above listed combination of antibiotics. The antibiotics were given immediately after admission to hospital and before the surgery. We continued to administer antibiotics in type I GA patients up to 72 hours after the operation. To type II GA and III GA patients antibiotics were given at least 7 or 14 days, depending on when the sterile microbiological findings were obtained.

All the patients with III GA open fractures had a daily wound care and periodic debridments if it was necessary. In 2 patients Tiersch transplant skin graft was made.

In one patient multiple injuries of a. tibialis posterior were found. After a careful wound care, repeated debridements, subsequent secondary sutures and Tiersch skin transplant we achieved a satisfactory result. The patient is shown in Figures 7–8.

In another case, a patient with an open IIIc GA TSF on the right leg and II GA open fracture of the left ankle joint of type was hospitalized with signs of severe traumatic shock due to severe bleeding and signs of serious violations of the blood vessels in the upper part of a lower leg, shown on

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Figures 9-10. He was injured in a car accident and spent nearly two hours stuck under the truck. After initial reanimation we did a surgical procedure of ``damage control``, an urgent bilateral EF. Reanimation of the patient lasted several hours and included 5 units of blood transfusion in addition to other procedures. Because of serious injuries of blood vessels in the upper part of right lower leg the patient was sent to the relevant tertiary institution after receiving the overall status that allowed the transport of the patient. Despite the surgical procedures on blood vessels, the amputation of the right leg above the knee was done in the end.

We had two patients with gunshot injuries of lower legs. In both cases we achieved excellent results. One of them is shown in Figures 11–12. In this patient, we combined a classic surgical treatment with hyperbaric oxygen therapy which proved to be a good combination for a faster healing of wounds.

The average time for fractures union was 18,4 weeks (11–32 weeks). We achieved a bone union in 93% of patients. The decision to remove the fixator was made on the basis of clinical and radiographic findings and the length of treatment. We conducted a simple test shown in Figure 13. in patients that seemed to have adequate healing. We removed the fixator and kept pins in the bone, allowed full reliance on the injured leg and followed the clinical and radiographic findings after a few days. If the clinical and radiographic findings were normal we removed the pins. We continued with the EF treatment in patients who felt pain in the region of the fracture or where there were changes in radiographic findings. After the removal of EF we applied plaster to four patients in order to protect the resulting union. These were our oldest patients.

Table 2 shows the complications of soft tissue in closed fractures. The most common complication was epidermolysis bullosa. We removed blisters and dried the spots with an antibiotic spray. The minor injuries to the skin (dermabrasions and less postcontusion skin necrosis) were treated carefully. In two patients that were threatened with a compartment syndrome we made an emergency fasciotomy of a lower leg.

Table 2. Soft tissue complications in closed TSF.

Complication	n(%)
Epidermolysis bullosa	8
Dermoabrasion	4
Less skin necrosis	2
Threatening compartment syndrome	2

The most common complication in our study was related to the pin-tract infection (PTI) in 14(14%) patients (Table 3). Although the literature cited multiple classification systems related to the problem of PTI [14], we used the simple classification on minor and major infections, described by Ward in 1984. In all the patients with problems related to pin site (pain, swelling, secretion, erythema, itching, etc.) we did a microbiological analysis of pin insertion using the swab, then we manually tested the pin stability and did an x-ray examination. The patients with minor infections were treated with daily pin site care and antibiotic therapy (positive microbiological analysis) and a

Table 3. The presence of complications during treatment.

Complication	n(%)
Minor pin infection	10
Major pin infection	4
Nonunions	6
ARDS	1
Osteitis	2
Amputation	1

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careful assessment of the pin stability. The patients with major infections were treated in hospital. In patients with positive microbiological analysis, the signs of pins instability and radiographic signs of bone osteolysis around the pins we removed pins and placed them in a different location.

Nonunion was found in 6 (6%) patients (2 in closed TSF, 4 in open TSF), shown in Table 3. For the treatment of nonunions, the Ilizarov EF was applied in 2 (2%) patients, whereas the Mitkovic EF with compression-distraction device was used in 4 (4%) patients, shown in Figure 14. In all the patients we achieved bone healing.

The EQ-5D (EuroQol) questionnaire was used to assess these patients at the end of treatment. Excellent result was achieved in 82% of the patients.

In our study we did not have patients with deep venous thrombosis (DVT) and injuries of neurovascular bundles while placing pins. Also, we did not have any mechanical damage to the M20 construction, in terms of bending or fracture of structure.

DISCUSSION

TSF are common injuries that remain challenging to treat because of the wide spectrum of fracture patterns and soft-tissue injuries. Understanding the indications for surgical and nonsurgical treatment of these fractures is essential for good outcomes, Schmidt et al. [15].

There are still controversial discussions on TSF treatment. Operative treatment can be performed with several different implants. Intramedullary nailing (IMN) with a huge biomechanical stability seems to be the implant of choice. The use of EF is still the implant of choice in the first line treatment of multiple traumas according to the damage control principles, Bode et al. [16].

EF with M20 fixator of TSF is a simple and effective method to enable the safe healing of fractures, early mobilization of the patients, early weight-bearing, as well as early rehabilitation, Milenković et al. [17].

The previous three citations describe the dilemma we had during our research. Can EF be used as a universal method of treatment in patients with TSF and how to properly select patients for surgical treatment? Currently, the data of using IMN as a method of choice in treating TSF are dominant. The role of EF is mainly reduced to a temporarily osteosynthesis, in polytraumatised patients in the procedure of ``damage control`` and the treatment of open TSF. Using of IMN described in the literature even in the most serious III GA open fractures. [18].

In our institution, the Mitkovic EF has been in use since 1998. and 375 patients have been surgically treated with the TSF so far. In the beginning, we treated patients with high bone comminution and open TSF. Functional results of treatment of such fractures were excellent and we expanded the list of indications for surgery in patients with unstable closed fractures as well as patients who had ``indicators of fracture instability``. EF is particularly suitable for the treatment of segmental TSF and other high bone comminution (gunshot injuries, traffic traumatism etc.). According to McMahon [19] IMN has the fastest time to fracture union in segmental TSF, however

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there are concerns regarding an increased deep infection rate in open segmental TSF. In this subgroup, the data suggest that the EF provides the most satisfactory results. In our fifteen-year use of M20 fixator for TSF we never had a mechanical damage to the M20 structure. In patients who had no problem with the PTI, a remarkable biomechanical stability of Mitkovic EF enabled long-term use of fixators, but good stability is guaranteed only with and adequately positioned fixator and the proper pins site care. Only in this way Mitkovic EF shows its exceptional biomechanical properties [9].

Gender structure (M 67% F and 33%) and injuries most common in the fourth and fifth decades of life correspond to the data in the literature [1].The most common cause of injury was the effects of indirect forces in 59% of patients, then the effect of direct force in 41%. The distribution of fractures classified in AO system followed the cause of injury (AO type A 54%, B 27% and C 19%), and corresponded to the intensity distribution of forces.

EF was used in four children on the basis of a careful assessment of the child's age, weight and type of fracture. Children adapted very quickly to the method of treatment and functional results of the treatment were excellent. According to Kinney et al. [20] the initial treatment outcomes between operative fixation and closed reduction of displaced tibia fractures in adolescents are similar, but patients must be counseled about the high failure rates with closed reduction. Marengo [21] describes in a study which covers 106 adolescents that the average patient age at the time of injury is 13.5±1.3 years (range 11.3–16.1). The mean patient weight is 57 ± 8 kg. This study demonstrates that the use of ESIN for displaced TSF in children and adolescents weighing 50 kg (110 lb) or more, or older than 13 years of age, is not contraindicated.

Average healing time of 18.4 weeks and achieving a bone union in 93% of the cases is in accordance with the data in the literature.

Distribution of complications (Table 3) is similar to the data in the literature. Beltios [3] published similar information. In our study the most common complication was PTI (14%). Ramos [22] published similar pin site problems. Proper identification of PTI and a quick response is of the utmost importance, because pin instability is the instability of the whole EF [14].

Tibial nonunions are estimated to constitute 2–10% of all tibial fractures. The incidence is greater with high-energy injuries and open fractures, Mino [23]. In our series, we had 6% of nonunions which does not deviate from the data in the literature. In all the patients we achieved bone healing and good functional results.

There was a significant positive correlation in patients with TSF between functional outcomes and the EQ-5D score, Dickson [24]. In our study an excellent result was achieved in 82% of the patients (Euroqol 5D) but the level decreased with the severity of injury (fasciotomy, grade IIIB / IIIC open fracture and amputation). Giannoudis [25] states that patients with these injuries still report long-term problems with their health-related quality of life, though to varying degrees.

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CONCLUSION

The method of treatment TSF using a properly placed Mitkovic EF can be used to treat even the most serious fractures because it provides optimum biomechanical conditions for bone healing and excellent stability of osteosynthesis. Closed reposition of TSF and EF is a method of treatment and provides exceptional results. EF has a precious role because it is used in treatment of open TSF. A combination of early surgery, profuse wound irrigation, removal of all foreign bodies, debridement of avital tissues, fracture stabilization using the external EF, early reconstruction of soft tissue defects, antibiotic and tetanus prophylaxis is a method of choice in open TSF treatment, even in type III GA, the most complex open TSF. This method of TSF treatment gives excellent functional results, and allows for the possibility of early rehabilitation in a very short period of time after surgery, particularly in patients with closed TSF and which are performed by closed reduction of fragments. The patients were generally tolerant to long-term treatments using EF. In our study, the quality of life of patients described by EuroQol 5d scoring system proved to be excellent in 82% of the cases. We believe that early surgical treatment is of extreme importance in patients with TSF. The average healing time of 18.4 weeks and bone union in 93% of the cases is in accordance with the data in the literature. In this study we showed the number, type and method of treatment of complications and our data do not deviate from the data in the literature. In a larger number of patients (14%) pin site problems, can be considered as a regular attendant problems related to EF in the region of the lower leg during prolonged wearing of EF. Proper identification of pin site problems, adequate response and treatment are of utmost importance.

REFERENCES

1. Russell TA. Fractures of the tibial diaphysis. In: Levine MA, editor. Orthopaedic knowledge update trauma. Rosemont (IL): American Academy of Orthopaedic Surgeons; 1996. p. 171–79.
2. Grubor P, Grubor M, Tanjga R, Mitković MM. Dilemmas in the treatment of tibial diaphyseal fractures. Acta Chir Iugosl. 2013; 60(2): 33–9.
3. Beltsios M, Savvidou O, Kovanis J, Alexandropoulos P, Papagelopoulos P. External fixation as a primary and definitive treatment for tibial diaphyseal fractures. Strategies Trauma Limb Reconstr. 2009; 4(2): 81–7.
4. El-Sayed M, Atef A. Management of simple (types A and B) closed tibial shaft fractures using percutaneous lag-screw fixation and Ilizarov external fixation in adults. Int Orthop. 2012; 36(10): 2133–8.
5. Popkov AV, Kononovich NA, Gorbach EN, Tverdokhlebov SI, Irianov YM, Popkov DA. Bone healing by using Ilizarov external fixation combined with flexible intramedullary nailing versus Ilizarov external fixation alone in the repair of tibial shaft fractures: experimental study. Scientific World Journal. 2014; 2014: 239791.
6. Sigurdsen U, Reikeras O, Utvag SE. The Effect of timing of conversion from external fixation to secondary intramedullary nailing in experimental tibial fractures. J Orthop Res. 2011; 29(1): 126–30.
7. Golubović ZS, Stojiljković PM, Mitković MB, Macukanović-Golubović LD, Bumbasirević MZ, Lesić AR, et al. Treatment of unstable closed tibial shaft fractures by external fixation. Acta Chir Iugosl. 2007; 54(2): 83–9.
8. Golubović Z, Stojiljković P, Macukanović-Golubović L, Milić D, Milenković S, Kadija M, et al. External fixation in the treatment of open tibial shaft fractures. Vojnosanit Pregl. 2008; 65(5): 343–8.
9. Grubor P, Grubor M. Results of application of external fixation with different types of fixators. Srp Arh Celok Lek. 2012; 140(5-6): 332–8.

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10. Golubović I, Vukašinović Z, Stojiljković P, Golubović Z, Stamenić S, Najman S. Open segmental fractures of the tibia treated by external fixation. Srp Arh Celok Lek. 2012; 140(11–12): 732–7.
11. Mitković M, Bumbasirević M, Golubović Z, Mićić I, Mladenović D, Milenković S, et al. New concept in external fixation. Acta Chir Iugosl. 2005; 52(2): 107–11.
12. Božović A, Mitković MB, Grbić R, Vasić A, Jaksić L, Petrović D, et al. Stability and quality of osteosynthesis in treatment of tibial pylon fractures with dynamic external fixation type Mitkovic. Acta Chir Iugosl. 2013; 60(2): 93–8.
13. Humphrey JA, Gillani S, Barry MJ. The role of external fixators in paediatric trauma. Acta Orthop Belg. 2015; 81(3): 363–7.
14. Kazmers NH, Fragomen AT, Rozbruch SR. Prevention of pin site infectionin external fixation: a review of the literature. Strategies Trauma Limb Reconstr. 2016; 11(2): 75–85.
15. Schmidt AH, Finkemeier CG, Tornetta P 3rd. Treatment of closed tibial fractures. Instr Course Lect. 2003; 52: 607–22.
16. Bode G, Strohm PC, Südkamp NP, Hammer TO. Tibial shaft fractures - management and treatment options. A review of the current literature. Acta Chir Orthop Traumatol Cech. 2012; 79(6): 499–505.
17. Milenković S, Mitković M, Radenković M. External skeletal fixation of the tibial shaft fractures.Vojnosanit Pregl. 2005; 62(1): 11–5.
18. Giovannini F, de Palma L, Panfighi A, Marinelli M. Intramedulary nailing versus external fixation in Gustilo type III open tibial shaft fractures: a meta-analysis of randomised controlled trials. Strategies Trauma Limb Reconstr. 2016; 11(1): 1–4.
19. McMahon SE, Little ZE, Smith TO, Trompeter A, Hing CB. The management of segmental tibial shaft fractures: A systematic review. Injury. 2016; 47(3): 568–73.
20. Kinney MC, Nagle D, Bastrom T, Linn MS, Schwartz AK, Pennock AT. Operative Versus Conservative Management of Displaced Tibial Shaft Fracture in Adolescents. J Pediatr Orthop. 2016; 36(7): 661–6.
21. Marengo L, Paonessa M, Andreacchio A, Dimeglio A, Potenza A, Canavese F. Displaced tibia shaft fractures in children treated by elastic stable intramedullary nailing: results and complications in children weighing 50 kg (110 lb) or more. Eur J Orthop Surg Traumatol. 2016; 26(3): 311–7.
22. Ramos T, Eriksson BI, Karlsson J, Nistor L. Ilizarov external fixation or locked intramedullary nailing in diaphyseal tibial fractures: a randomized, prospective study of 58 consecutive patients. Arch Orthop Trauma Surg. 2014; 134(6): 793–802.
23. Minoo P, McCarthy JJ, Herzenberg J. Tibial nonunions. Available from: http://emedicine. medscape.com/ article/1252306-overview
24. Dickson DR, Moulder E, Hadland Y, Giannoudis PV, Sharma HK. Grade 3 open tibial shaft fractures treated with a circular frame, functional outcome and systematic review of literature. Injury. 2015; 46(4): 751–8.
25. Giannoudis PV, Harwood PJ, Kontakis G, Allami M, Macdonald D, Kay SP, et al. Long-term quality of life in trauma patients following the full spectrum of tibial injury (fasciotomy, closed fracture, grade IIIB/IIIC open fracture and amputation). Injury. 2009; 40(2): 213–9.

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