Original Article

Complications of the Use of A.O External Skeletal Fixator in the Treatment of Type – III Open Tibial Fractures

Talat Bashir Khan,[1] **Zakir Ali Shah,**[2] **Naveed Aslam,**[3] **Uzma Arif**[4]

Abstract

Objectives: To determine the complications encountered at our institution during the use of A.O tubular external fixator in the treatment of type-III open tibial fractures.

Place and Duration of Study: From July 2011 to December 2011, at Nawaz Sharif Social Security Teaching Hospital, Lahore (University College Medicine and dentistry).

Subjects and Methods: Thirty cases were included in the study. All the patients between 10 – 59 years of age with type – III open tibial fractures were admitted through emergency department. After complete resuscitation, fracture was stabilized with A.O fixator after adequate debridement under appropriate anaesthesia.

Results: Majority of the patients in study were males. The mean age in study was 31.23 ± 14.151 years. Road traffic accidents were observed to be the major cause of injury in 27 patients (90%). Delayed union was observed in 11 cases (36.67%). Non union was observed in 12 patients (40.0%). The most common post operative complication was pin tract infection. Pin tract infection was observed in 17 patients (56.66%) and pin loosening in 16 patients (53.33%). Out of 130 pin sites in 30 fractures 34 became infected, representing a pin tract infection of 26.15%. Pin loosening was observed in 16 pins (12.31%).

Conclusion: We concluded that External fixator is the best available method of fixation in grade III open tibial fractures with severe soft tissue injuries.

Key Words: External fixator, open fracture, Tibia, Non-union.

Introduction

The management of open tibial fractures remains a challenge for the orthopaedic surgeons. Tibial fractures frequently occur in association with severe damage to the soft tissues due to anatomical pecularities.[1] Its subcutaneous antero medial surface accounts for the high incidence of open fractures.[2] Their treatment, prognosis, and outcome are mainly determined by the mechanism of injury, degree of resulting communition, soft tissue injury and displacement.[3,4]

With mechanization there is increased number of road traffic accidents and industrial injuries. Ethnic and social society disputes along with terrorist activities have lead to increased gunshot and blast injuries in civil life. The incidence of open fractures of tibia and femur are also on increase. In this situation limb

Khan T.B.[1]
Nawaz Sharif Social Security Teaching Hospital, Lahore

Shah Z.A.[2]
Nawaz Sharif Social Security Teaching Hospital, Lahore

Aslam N.[3]
Nawaz Sharif Social Security Teaching Hospital, Lahore

Arif U.[4]
Nawaz Sharif Social Security Teaching Hospital, Lahore

injuries need immediate debridement and stabilization, which can be best provided with external fixators.[8]

Open tibial and femoral fractures are limb threatening and potentially life threatening. To receive the best outcome they require the services of both an experienced orthopaedic trauma surgeon and plastic surgeon with an interest in lower limb trauma.[5] Soft tissue coverage can be provided with split thickness skin graft, fasciocutaneous flap, myocutaneous flap and free tissue transfer.

The open fractures have a higher infection rate than closed fractures and the rate increases with the increasing severity of the soft tissue injury. Open fractures communicate with the outside environment, and the resulting contamination of the wound with micro organisms, coupled with the compromised vascular supply to the region, leads to an increased risk of infection as well as complications in healing. In addition, bone, tendons, nerves and articular cartilage may be exposed and subject to damage.

According to Gustilo and Anderson open fractures are classified into 3 types (type – I, type – II, type – III a, b, c).[6] Type – III open tibial fractures presenting in our hospitals are due to road traffic accidents, firearm and crush injuries. Treatment of open tibial fractures includes stabilization of fracture to facilitate early mobilization and taking care of the soft tissues to achieve healing without infection. Bony stabilization can be done in open fractures in variety of ways such as unreamed intramedullary solid nails, pin plasters and external fixation.[7,8]

Most common method of stabilization for type III open fractures in our hospitals is external fixation using A.O. tubular external fixator. It is technically easy to apply and safe method, less time consuming, requiring minimum instrumentation and least expensive.[9] But it is also associated with certain complications like pin loosening, pin tract infection, delayed union, mal union, non union, joint stiffness, compartment syndrome etc.[10]

The present study is planned to identify the frequency of complications associated with this procedure, so that preventive measures can be taken.

Patients and Methods

Data Collection Procedure

Thirty patients between 10 – 59 years of age received in emergency with type III open tibial fracture were included in study. Detailed history was taken with particular reference to the mode of injury, time since injury and any associated injury. All patients were examined and resuscitated where needed according to the standard ATLS principles and diagnosis was confirmed with radiographic examination. Baseline investigations including complete blood count blood urea, serum creatinine, PT, APTT, blood sugar and hepatitis B and C screening were done. The wound was examined and fracture was classified according to Gustilo's classification. Distal neurovascular status was checked in the injured extremity and compared with the normal side. Patients were given prophylaxis against tetanus and antibiotics used for type – III fractures were a combination of second generation Cephalosporin and Gentamicin (aminoglycoside). After making a thorough assessment the operative planning was done and the patients were shifted to the operation theatre after informed consent for wound debridement and stabilization of the fracture. Spinal or general anaesthesia was used according to the anaesthetist's discretion. The dressings were removed, and specimens from wound were taken for culture and sensitivity and the limb was thoroughly washed with at least 10 litres of normal saline to remove all dirt and debris etc. The limb was prepared for surgery by painting with pyodine. Then the limb was draped and wound debridement begun by extending the wound to assess the deep soft tissue and bony damage. The necrotic skin, fascia and tendons were excised. The muscle that did not bleed when cut, disintegrated to touch, did not contract or was pale or discoloured, were excised but bigger bone pieces with adequate soft tissue attachment were preserved. Extreme vigilance was kept to save neurovascular structures. After irrigation and debridement, stablization of fracture was done by applying the external fixator. Two unilateral modalities were applied i.e. unilateral uniplaner and unilateral biplaner. Preference was given to apply uniplaner unilateral external fixator. All wounds were left open and debridement was repeated within 48hours. Once the wound became clean, it was closed within 5 – 7 days with delayed primary closure, graft or flap. Usually the patients were discharged once the soft tissue problems were dealt. As soon as the patient was comfortable active joints motions and muscle strengthening exercises were initiated. The patient proceeded with partial weight bearing with crutches bearing increasingly more weight on the injured leg as the fracture consolidated. With the radiological evidence of callus formation the frames were dynamized usually around 3rd month after the application. The patient was then encouraged to bear

more and more weight so that the fracture consolidated and external fixator removal was possible. After removal of the frame the leg was protected with patellar bearing cast and weight bearing continued. When there was solid union on x-rays the cast was removed. The patients were fully informed regarding the anticipated complications, further rehabilitation and follow up. They were taught to take care of the pin tracts by cleaning them with soap and water daily and applying gentle pressure dressings. Each patient was advised periodic outdoor department visits for at least nine months or when the problem was over. On each visit clinical and radiological examination was performed to find out and manage any complication. After 9 months (time to declare non union) all the data was transferred to the proforma and kept for analysis.

Results

A total of 30 patients were included in the study. Out of 30 patients 28 (93.3%) were males and 2 (6.7%) were females (Table 1).

The ages ranged from 10 to 59 years. The youngest patient was 10 years and the oldest was 59 years with a mean age of 31years. Of these 5 (16.5%) patients were in the age group 10 – 19 years, 10 (33.3%) patients were in age groups 20 – 29 years, 7 (23.3%) were found in the age group 30 – 39 years, 3 (10.0%) patients were in age groups 40 – 49 years, 5 (16.7%) were found in the age group 50 – 59 years (Table 2).

The time elapsed between injury and arrival at the hospital varied from 6 — 12 hours. Majority of patients 18 (60.0%) reached within 6 hours and 12 patients (40.0%) reached within 6 – 12 hours (Table 3).

Table 1: Distribution of cases according to Sex Group (n = 30).

Sex	No. of Patients	Percentage
Male	28	93.3
Female	2	6.7
Total	30	100.0

Male – Female Ratio 14:1

Table 2: Distribution of cases according to Age Group (n = 30)

Age	No. of Patients	Percentage
10 – 19	5	16.5
20 – 29	10	33.3
30 – 39	7	23.3
40 – 49	3	10.0
50 – 59	5	16.7
Total	30	100.0

Mean ± SD = 31.23 ± 14.151

Table 3: Distribution of cases according to time of arrival (n = 30)

Time of Arrival	No. of Patients	Percentage
Arrival Within 6 Hours	18	60.0
Arrival Within 6 – 12 Hours	12	40.0
Total	30	100.0

The total duration of hospital stay ranged from 8 to 14 days. The majority of patients 21 (70.0%) stayed in the hospital for 8-14 days while only 9 patients (30.0%) had to stay for 15 – 121 days. The mean stay was 13.20 ± 2.92 days (Table 4).

Table 4: Distribution of cases according to Hospital stay (n = 30)

Days	No. of Patients	Percentage
1 – 7	–	–
8 – 14	21	70.0
15 – 21	9	30.0
Total	30	100

Mean ± SD = 13.20 ± 2.92

Table 5: Distribution of cases according to Anatomical site of fracture (n = 30)

Anatomical Site of Fractures	No. of Patients	Percentage
Proximal 1/3	1	3.3
Middle 1/3	28	93.3
Distal 1/3	1	3.3
Total	30	100.0

Middle 1/3 of tibial shaft was fractured in 28 (93.3%) followed by proximal 1/3 of tibia in 1 (3.3%) and distal 1/3 of tibia in 1 (3.3%) cases (Table 5).

Type – IIIA fracture was observed in 8 (26.7%), Type – IIIB in 19 (63.3), and Type – IIIC in 3 (10.0%) cases (Table 6).

Table 6: Distribution of cases according to Type of fracture to Gustilo classification (n = 30).

Type of Fracture	No. of Patients	Percentage
Type – IIIA	8	26.7
Type – IIIB	19	63.3
Type – IIIC	3	10.0
Total	30	100.0

Road traffic accidents were observed to be the major cause of injury in 27 (90%), followed by firearm injury in 3 cases (10.0%) (Table 7).

Table 7: Distribution of cases according to Mode of Injury (n = 30).

Mode of Injury	No. of Patients	Percentage
Road Traffic Accident	27	90.0
Firearm Injury	3	10.0
Total	30	100.O

Left leg was involved in 18 cases (60.0), followed by right leg in 12 cases (40.0) (Table 8).

Table 8: Distribution of cases according to Side involved (n = 30).

Leg Side	No. of Patients	Percentage
Left	18	60.0
Right	12	40.0
Total	30	100.0

Out of 30 patients, 4 patients (13.33%) were associated with ipsilateral fracture femur and 4 patients (13.33%) with contralateral fracture of tibia (Table 9).

Table 9: Distribution of cases according to Associated skeletal injury (n = 30).

Associated Injury	No. of Patients	Percentage
Fracture Femur Ipsilateral	4	13.33
Fracture Tibia Contralateral	4	13.33
No	22	73.4
Total	30	100.0

Mal alignment was major per operative complication that was seen in 5 (16.66%), followed by Muscle and tendon impalement at the time of surgery 1 (3.3) (Table 10).

Delayed union was observed in 11 cases (36.67%). All these fractures were type III – A and III – B (Table 11) and eventually all went in to union.

Table 10: Distribution of cases according to Per-operative complications (n = 30).

Per Operative Complications	No. of Patients	Percentage
Fracture Through Pins	–	–
Vessel Penetration at the Time of Surgery	–	–
Nerve Impalement	–	–
Muscle and Tendon Impalement	1	3.3
Mal Alignment	5	16.66

Table 11: Distribution of cases according to Post operative complications (n = 30).

Post Operative Complications	No. of Patients	Percentage
Delayed Union	11	36.67
Non Union	12	40.0
Joint Stiffness (Ankle)	7	23.33
Ring Sequestrum	1	3.33
Amputation	3	10.0
Joint Stiffness(Knee)	7	23.33

Non-union was considering as movement at the fracture site on manipulation and no evidence of callus information after 9 months. 12 patients (40.0%) developed this complication. These fractures were highly communited, and severely contaminated (Table 11).

Ankle stiffness was observed in 7 cases (23.33%) and knee stiffness was also seen in 7 cases (23.33%). Pin breakage was seen in only 1case (3.33%) and ring sequestrum in 1case (3.33%). Type – IIIC 3 cases (10.0%) ended in amputation (Table 11).

Table 12: Distribution of cases according to Post operative complications of pins (n = 30).

Pin Related Complications	No. of Patients	Percentage
Pin loosening	16	53.33
Pin Breakage	1	3.33
Pin Tract Infection	17	56.66

Table 13: Frequency of complications related to no. of pins (n = 130).

Pin Related Complications	No. of Pins Out of 130	Percentage
Pin loosening	16	12.31
Pin Breakage	1	0.77
Pin Tract Infection	34	26.15

Table 14: Distribution of cases according to Plastic surgery procedure performed (n = 30).

Plastic Surgery	No. of Cases	Percentage
Fasciocutaneous flap	10	33.3
Split thickness skin graft	7	23.3
None	13	43.3
Total	30	100.0

The most common post operative complication was pin tract infection. Pin tract infection was seen in 17 patients (56.66%) and pin loosening in 16 patients (53.33%).(Table 12) Out of 130 pin sites in 30 fractures 34 became infected, representing a pin tract infection of 26.15%. Pin loosening was observed in 16 pins (12.31%) (Table 13).

Plastic surgery procedures performed were Fasciocutaneous flap in 10 cases (33.3%), and split thickness skin graft in 7cases (23.3%), rest of the patients were managed with secondary closure (Table 14).

Discussion

The external fixator in open tibial fractures not only solves the difficult problem of soft tissue injuries but at the same time provides a reasonable fixation for the bone to heal. With the AO external fixator it is possible to adhere to safe and effective external fixation techniques, avoid damage to vital structures and to provide wound access.[11]

The total number of patients in this study was 30. The mean age observed in our patients was 31.23 ± 14.151 years. These results were closer to the study done by Khan, Khan and Qadir at Peshawer and another study by McQueen, Christie and Court Brown.[12,13,22] This is the age group which is most active in any society and spend their time in outdoor activity.

The maximum number of patients in my study was males 93.3%. These results were similar with the study conducted by Khan, Khan and Qadir at Peshawer and Awais, Shahid, Ali and Adil at emergency department of Jinnah Hospital Lahore, Whose study also showed male predominance (93.33%).[12,14]

This distribution can be explained as in our socio-economic set up males spend more active life and remain out doors more often for daily activities to earn their living and also in outdoor sports while females stay mostly at homes and are less involved in outdoor chores and sports.

Road traffic accidents were the major cause of injury in study. This is in accordance with the study published by Gururaj in J Coll Physician Surg Pak in 2004. According to which one million people were killed on road during 2000 (75.0%) died in the developing countries of the world, about half of them in Asia.[15]

The main reasons for the increased number of road traffic injuries are increase in the number of motor vehicles, poor enforcement of traffic safety regulations, poor quality of roads and vehicles and inadequate public health infrastructures.[16,17]

In present study 21 (70.0%) patients had hospital stay for 8-14 days, and 9 patients (30.0%) patients had the hospital stay for 15 – 21 days with Mean 13.20 ± 2.92 days. This matches with the study done by Padhi NR and Padhi P which showed similar results.[18] Hos-

pital stay was more in type IIIB fractures for management of wound in our study. Plastic surgery procedures performed were Fasciocutaneous flap in 10 cases (33.3%), and split thickness skin graft in 7cases (23.3%), rest of the patients were managed with secondary closure.

Mal alignment was major per operative complication that was seen in 5 (16.66%), followed by Muscle and tendon impalement at the time of surgery 1 (3.3). Mal alignment was corrected by re adjusting fixator.

The left leg was involved in 18 cases (60.0%) and the right in 12 cases (40.0%). These results match to the study done by Khan, Khan and Qadir.[12]

As there were 19 type III – B fractures as a result of road traffic accidents, so great attention was given to the care of soft tissue injuries. The average healing time was 20 weeks. This healing time is well comparable with the results published in the litera-ture.[19,20,21, 22,24,27] In a study conducted by Padhi NR and Padhi P average time of healing was 25.7% weeks in type III fracture, which is slightly higher than our study.[18]

Court – Brown et al examined two types of fixator in the treatment of type III open tibial fractures, demonstrating no difference between a uniplanar and a multiplanar device. Study revealed union in 36.7 weeks[30] which was also higher than our study.

The average duration of application of external fixator was 3 months in our study, followed by patellar bearing cast and weight bearing as tolerated.

The most common complication was pin tract infection. Pin tract infection was superficial in most of the cases and was easily controlled with standard management. Loosening of pin has been considered the pre-disposing factor for pin tract infection.[23] We managed to prevent pin tract infections by low velocity drilling and keeping the pin sites sterile by application of pyodine soaked sterile gauze. We also educated the patient to maintain the sterility at the pin sites.

In spite of all this pin tract infection was seen in 17 patients (56.66%), which may be attributed to the poor compliance of the patients to take care of the sites. The pin tract infection in our study was 56.66% which is comparable to the Asian studies.[22,24,25]

In a study by Ghaloo MA pin tract infection was seen 45%.[22]

Another study conducted by Thakur AJ, Patankar J. showed pin tract infection 45.2%.[24]

In a study conducted by Khan, Khan and Qadir at Peshawer pin tract infection was most common complication (47.4%), which was also due to poor compliance of patients.[12]

The study done by Hay S. M, Rickman M and Saleh M. in Europe showed less incidence of pin tract infection 10.4%.[26] Which is due to proper follow up of patient in review clinics and their compliance.

Chan et al analyzed the results of 60 type III open tibial fractures revealed pin complication in 100%.[29]

Court – Brown et al study revealed pin complication in 35%.[30]

Pin loosening was observed in 16 patients (53.33%) in 16 pins out of 130 pins in our study, all loose pins were removed and placed in different sites.

Non-union was observed in 12 cases (40.0%) and that was in Gustilo type III – B and fractures were highly communited. This can be compared with literature like Johnson, Burns and Hayda.[28]

In a study conducted by Ghaloo MA non union was observed in 4 patients (11.1%).[22]

Chan et al study revealed non union in 60%.[29]

The decrease incidence of non-union in our study was early soft tissue cover and early weight bearing.

The problem of delayed union occurred in 11 cases (36.67%). Our all cases with delayed union eventually went into union. The delayed union in our study is comparable to those mentioned in the literature.[22]

Mal – union was not observed in any case because of initial good reduction; however mal union is mentioned in literature.

Chan et al study revealed mal union in 41.5%.[29]

Court – Brown et al study revealed mal union in 50%.[30]

Ankle stiffness was present in 7 cases (23.33%), and knee stiffness also in 7 cases (23.33%), which was due to lack of proper follow-up clinic visits, lack of physiotherapy and only verbal instructions to the patient for home. Functional deficit was minimal and no patient requested for further corrective surgery.

Study conducted by Thakur AJ, Patankar J. showed Ankle stiffness in 10.9%.[24] which is lower than our study.

Another study conducted by Khan, Khan and Qadir at Peshawer revealed Ankle stiffness in 12 cases (40%).[12] which is higher than our study.

Amputation was done in 3 cases (10.0%) which were type – IIIc and presented after 11 hours of trauma with vascular injury and initially treated at some other hospitals, which is comparable to study done in Serbia.[33]

In recent years, there has been considerable interest in circular external fixation using multiple small wires. Ilizarov device has been used for the primary treatment of tibial fractures.[31]

Tucker et al reported on the treatment of 26 tibial fractures, six of which were closed. None of the fractures had bone loss. The average union time was 25.6 weeks, and they stated that only one patient did not have an excellent or good result. Approximately 10% of the wires showed evidence of sepsis, and 19.2% had a mal union.[32] Surgeons suggested that the results they achieved were comparable with those obtained with much simpler frames.

Conclusion

1. All open fractures should be considered as surgical emergencies and require an aggressive approach which include copious irrigation, adequate surgical debridement and high doses of antibiotics.
2. External fixator is the best available option for all open tibial fractures with severe soft tissue injuries (Type III b, c) and may be adopted in the management of such fractures. This method of fractures stabilization is versatile, cost effective, satisfactory and reliable.
3. AO external fixator is easy to apply as compare to ilizarov external fixator.

References

1. Neubauer T, Bayer GS, Wagner M. Open fractures and infection. Chir Orthop Traumatol Cech. 2006; 73: 301-12.
2. Acharya S, Ratra GS, Jain B. Management of open fractures. J orthopaedics 2007; 4e18. Available from: http://www.jortho.org/2007/4/1/e18.
3. Mashru RP, Herman MJ, Pizzutillo PD. Tibial shaft fractures in children and adolescents. J Am Acad Orthop Surg 2005; 13: 345-52.
4. Bedi A, le TT, Karunakar MA. Surgical treatment of non-articular distal tibia fractures. J Am Acad Orthop Surg 2006; 14: 406-16.
5. Naique SB, Pearse M, Nanchahal J. Management of severe open tibial fractures. J Bone Joint Surg Br 2006; 88: 351-57.
6. Stewart DG, Kay KM, Skaggs DL. Open fracture in children. Principles of evaluation and management. J Bone Joint Surg Am 2005; 87: 2784-98.
7. Giannoudis PV, Papakostidis C, Roberts C. A review of the management of open fractures of the tibia and femur. J Bone and Joint Surg 2006; 88: 281-9.
8. Carmack DB. Conversion from external fixation to definitive fixation: Periarticular Injuries. J Am Acad Orthop Surg 2006; 14: 128-30.
9. Sen C, Kocaogen M, Eralp L, Gulsen M, Cinar M. Bifocal compression – destruction in the acute treatment of grade III open tibial fractures with bone and soft tissue loss: a report of 24 cases. J Orthop Trauma 2004; 18: 150-7.
10. Park HJ, Uchino M, Nakamura M, Ueno M, Kojima Y, Itoman M, et al. Immediate interlocking nailing versus external fixation followed by delayed interlocking nailing for Gustilo type-IIIb Open tibial fractures. J Orthop Surg 2007; 15: 131-6.
11. Ricardo J. Pacheco. The role of external fixation in trauma. Trauma 2004; 6: 143-60.
12. Khan MA, Khan SW, Qadir RI. Role of external fixator in the management of type II and III open tibial fracture. J Postgrad Med Inst 2004; 18: 12-7.
13. McQueen MM, Christie J, Court – Brown CM. Compartment pressures after intramedullary nailing of the tibia. J Bone Joint Surg Br 1990; 72: 395-7.
14. Awais SM, Shahid R, Ali M, Adil O, Shah AA. Emergency treatment of trauma victims: a study of 1000 patients at emergency department of Jinnah Hospital, Lahore. J Pak Orth Assoc 2000; 2: 23-9.
15. Gururaj G. Alcohol and road traffic injuries in South Asia: a challenge for prevention. J Coll Physicians Surg Pak 2004; 14: 713-8.
16. Peden M, Toroyan T. Road traffic injuries in South Asia: national and organisational policy responses. J Coll Physicians Surg Pak. 2004; 14: 722-5.
17. Rehman AF. The burden of road traffic injuries in South Asia: a commentary. J Coll Physicians Surg Pak 2004; 14: 707-8.
18. Padhi NR and Padhi P. Use of external fixators for open tibial injuries in the rural third world: panacea of the poor? Injury. 2007; 38: 150-9.
19. Iqbal M, Jamil A. Treatment of open fractures by locally manufactured external fixator. Pak J Med Res. 1998; 37: 121-3.
20. Steinfield PH, Cobelli NJ, Sadler AH, Szporn MN. Open tibial fractures treated by anterior half pin frame fixation. Clin Orthop 1988; 228: 208-14.
21. Anustopolous G, Asssima KA, Exarcholl E, Pentazo PT. lpsilateral fractures of femur and tibia. Injury 1992; 23: 439-41.
22. Ghaloo MA. Evaluation of role of external fixator in the management of open fractures. J Pak Orth Assoc 1997; 9: 29-35.
23. Magyar G, Toksvig – Larsen S, Moroni A. Hydroxyapatite coating of threaded pins enhances fixation. J Bone Joint Surg Br 1997; 79: 487-9.
24. Thakur AJ, Patankar J. Open tibial fractures. Treatment by uniplanar external fixation and early bone grafting. J Bone Joint Surg Br 1991; 73: 448-51.
25. Anand T, Joy JP. Open tibia fractures. J Bone Joint Surg Br 1991; 73: 448-51.
26. Hay SM, Rickman M, Saleh M. Fracture of the tibial diaphysis treated by external fixation and the axial alignment grid. Injury 1997; 28: 437-43.

27. Lawyer RB Jr, Lubbers LM. Use of the Hoffmann apparatus in the treatment of unstable tibial fractures. J Bone Joint Surg Am 1980; 62: 1264-73.
28. Johnson EN, Burns TC, Hayda RA, Hospenthal DR, Murray CK. Infectious complications of open type III tibial fractures among combat casualties. Clin Infect Dis 2007; 45: 409-15.
29. Chan KM, Leung YK, Cheng JCY, et al. The management of type III open tibial fractures. Injury 1984; 16: 157-65.
30. Court – Brown CM, Wheelwright EF, Christie J, et al. External fixation for type III open tibial fractures. J Bone Joint Surg Br 1990; 72: 801-4.
31. Schwartsman V, Martin SM, Ronquist RA, et al. Tibial fractures. The Ilizarov alternative. Clin Orthop 1992; 278: 207-16.
32. Tucker HL, Kendra JC, Kinnebrew TE. Management of unstable open and closed tibial fractures using the Ilizarov method. Clin Orthop 1992; 280: 125-3.
33. External fixation in the treatment of open tibial shaft fractures. Vojnosanit Pregl 2008; 65: 343-8.