UNILATERAL 3D EXTERNAL FIXATION IN SERBIAN TRAUMATOLOGY AND ORTHOPAEDICS

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ABSTRACT

Aim Although it may have been criticized and questioned by numerous authors, external fixation holds its place in modern orthopaedics and traumatology. The aim of this paper is to show the applicability of the unilateral 3D external fixation in everyday practice.

Methods For external fixation of the bones, we used unilateral 3D external fixators according to Mitkovic.

Results In the Republic of Serbia, the Mitkovic unilateral 3D external fixation system has been used in over 30,000 cases. The indication field of applicability of this method is wide. External fixation method was mostly used for the treatment of open and closed tibial fractures at all levels, in open femoral fractures as a part of the "staging" protocol and in fractures of the upper limbs. We used external fixation for the treatment of nonunions, malunions, in the treatment of osteitis, septic pseudoarthrosis, angular knee deformities, post-traumatic deformities, for limb lengthening and in replantation surgery.

Conclusion The unilateral external fixator enables 3D biomechanical stability and is suitable for use in everyday traumatology and orthopaedics practice.

Key words: Unilateral 3D External Fixation, Traumatology, Orthopaedics

What´s known?

The external fixation is a well known method with wide application in clinical practice. In the treatment of fractures the external fixation is often used as a temporary method.

What´s new?

Unbilateral 3D external fixation is used as a definitive method of fracture treatment, fracture complications and bone deformities.

1. Introduction

External fixation with the help of an apparatus - the external fixator is a surgical method that holds an important place in modern orthopedics and traumatology. There are numerous diseases and fractures of the locomotor apparatus which can successfully be treated using this method. [1] External fixation can be applied alone or combined with minimally invasive osteosynthesis in numerous conditions in traumatology, especially in intra-articular fractures.[2] All open fractures can successfully be treated by using the external fixation, it can be applied either as a definitive or temporary method in polytrauma, within the protocol "damage control orthopedics (DCO)" .[3] There are conditions where the external fixation is applied after the application of some other internal extramedullary or intramedullary osteosynthesis which was unsuccessful. In nonunions, malunions , in osteitis, replantation surgery, the external fixation finds its application. In post-traumatic bone defects, limb lengthening , the external fixation is successfully applied. In many congenital and acquired deformities, this method also finds its wide application. External fixators according to Mitkovic, enable 3D stability, are easy to use and provide good biomechanical conditions for healing of the fracture. This 3D unilateral external fixator has been widely, biomechanically investigated in AO Insitute in Davos, Switzerland.[4] In the Republic of Serbia, the system for external fixation according to Mitkovic has so far been successfully applied in over 30,000 cases.

2. The History of External Fixation

External fixation has been perfected over the centuries by the progress of science and technical-technological progress of mankind, but its principles have remained the same – bone fixation with the apparatus, the external fixator. Although the first papers on external fixation date back to more than 2400 years ago, the first deliberate beginning of external fixation is attributed to the

famous French professor of surgery J.F. Malgaigne (1806-1865), in 1840. Parkhill and Lambote were responsible for the further development and innovation of external fixators. Clayton Parkhill (1860-1902) was an American anatomist and surgeon, he was also known as an inventor. His external fixator was believed to be useful for nonunion and malunion cases. Further development and progress of external fixation was made possible by Albin Lambotte (1866-1955), a pioneer of modern osteosynthesis. He described his external fixator and its use on the upper and lower limbs. German surgeon Martin Kirschner (1879-1942) described his concept of external fixation in 1909. The eponym Kirschner wire, which is still used today comes from Kirschner, although it was first described in 1932 by Müler. During the 1930s, Otto Stader (1894-1962), an American veterinarian, developed the "Stader splint" external fixator. Its successful results in veterinary medicine were used for the treatment of fractures in humans in 1937 and it was used on soldiers who got injured during the Second World War. At the same time, there were other surgeons who worked in the field of external fixation. Raoul Hoffman (1881-1972) revolutionized the work of many predecessors by developing his external fixator. The famous British orthopedist John Charnley made a great contribution in the field of external fixation. In 1948, he presented the device intended for arthrodesis of the knee and ankle joint. Gavril Abramovich Ilizarov (1921-1992) from Kurgan - Russia started using the original circular external fixator in 1950. It is an interesting fact that the device was constructed to immobilize limb fractures due to the lack of plaster in the Soviet Union at the time. The AO group has developed its own system and its own external fixator in 1977. In 1984, De Bastiani from Verona published papers related to the application of his external fixator, which was later called "Orthofix" .[5] In Nis, external fixation was first applied in 1981, and the first original external fixator according to Mitkovic was applied in 1983 .[1] Since then, external fixators according to

Mitkovic are used in everyday practice in Nis as well as in almost all orthopedic institutions in Serbia.

3. EXTERNAL FIXATION OF THE UPPER LIMBS

External fixation of the upper limb is routinely applied as a temporary or definitive method of treatment in many conditions in orthopedics and traumatology (Figure 1).

3.1. External Fixation of the Upper Arm

Surgical treatment for the fractures of the upper arm, which the literature describes are open reduction and internal fixation of the fracture with a plate, MIPO (minimally invasive plate osteosynthesis), intramedullary fixation, external fixation.[6,7] The external fixation can be used as a temporary or definitive method in the treatment of different types of open and closed humerus fractures (upper third, diaphysis, lower third, multifragment, segmental fractures). External fixation is usually used for fractures of the upper arm in polytrauma as a temporary method.[1]

3.2.External Fixation of the Elbow

External fixation in the elbow area involves bridging the elbow with an external fixator. In this case, pins of the external fixator are placed in the humerus (usually 2 pins) and in the forearm (ulna). This fixation method is rigid and can be combined as an addition or support for minimal internal fixation, in severe closed or open multifragment and articular fractures of the distal humerus, in unstable dislocated fractures of the distal humerus, in unstable elbow dislocations. The rigid elbow fixation method can be converted into a dynamic fixation mode which allows movements in the elbow. Prolonged rigid elbow fixation leads to elbow contracture. External elbow fixation can be a temporary or definitive method for treating various conditions, diseases and elbow injuries.[1]

3.3.External Fixation of the Forearm and Wrist

There are numerous cases from clinical practice where the external fixation of open forearm fractures was used either as a temporary or definitive method of treatment. External fixation, depending on the clinical case, can be applied to the radius, ulna or both bones of the forearm. Except for open fractures, external fixation can be used as a definitive method of treatment for different types of closed fractures (multifragment, segmental).[1] The method can be applied to fractures in the proximal third of the forearm, in the diaphyseal region, distal end. As for the distal end of the forearm, external fixation has found its widest application in the treatment of distal radius fracturest. After the closed reduction of the fracture, the external fixator pins are placed in the distal radial fragment, if the fragment is solitary. In case of comminution (intra-articular fracture), the ligamentotaxis method is applied , two external fixator pins are placed in the radius and two in the second metacarpal bone. This fixation method is applied with or without minimal internal fixation, usually with Kirschner wires. Most dorsal fractures (Colles) and volar fractures (Smith) can be treated in this way. Most distal radius fractures are treated non-operatively, using reduction and plaster immobilization. Without going into the propriety of the indication for this treatment method, there are numerous cases of malunion of radius with the occurence of Madelung deformity. Radial deviation, ie Madelung [Otto Wilhelm Madelung (1846-1926)] deformation is not a rare occurrence in clinical practice. External fixation is successfully applied in the treatment of these post-traumatic deformities. The method involves radius corticotomy, correction of the deformity and external fixation or, in cases of radius shortening, radius corticotomy, external fixation and callus distractiond using a distractor on the external fixator.[8]

3.4.External Fixation of the Hand

Many acute traumatic conditions or post-traumatic conditions in fractures of the metacarpal bones, phalanges, conditions of acute or obsolete perilunate dislocations can successfully be treated using the external fixation. A special mini fixator according to Mitkovic, enables external fixation of all hand bones, and it is also used for elongation of metacarpal bones.[9] In everyday clinical practice, we witness different types of hand injuries, closed fractures or open injuries associated with hand bone fractures, tendon injuries and surrounding soft tissue. The hand is an important part of the locomotor apparatus and damage control requires expertise and professionalism. A plastic and orthopedic surgeon teamwork is often necessary in complex hand injuries. Isolated fractures of one or more hand bones, regardless of type and severity, can successfully be treated using external fixation.

4. EXTERNAL FIXATION OF THE PELVIC RING

In pelvic ring fixation, external fixation is mainly used as a temporary method, in polytraumatized patients who have an unstable pelvic ring injury (type B, C), within the "damage control orthopedics (DCO)" protocol (Figure 2A). These are hemodynamically unstable patients in whom it is often necessary to perform pelvic tamponade and external fixation until hemodynamic stability is achieved. The general condition of a patient with a pelvic injury can be hemodynamically stable or unstable, and from a biomechanical aspect the pelvic ring can be biomechanically stable or unstable. The main cause of pelvic bleeding is mainly of venous origin from the presacral plexuses (80% - 90%). In polytrauma, the causes of hemodynamic instability, ie the source of bleeding, should be urgently discovered, urgent surgical measures should be taken to stop the bleeding using massive transfusions, fluid replacement, and urgent pelvic ring external fixation should be performed. After achieving hemodynamic stability, it is necessary to do a definitive stabilization of the unstable pelvic ring. In open pelvic ring injuries, external

fixation method, whether temporary or definitive, has its full indication. In severe open pelvic ring fractures, in addition to external fixation, frequent, repeated wound debridements with antitetanus protection and antibiotic prophylaxis, ie broad-spectrum antibiotic therapy, including antibiotics which are effective against anaerobic bacteria, are necessary. In geriatric patients, external fixation is also indicated. External fixator pins are placed in the iliac crest or supra-acetabularly.[10-12]

5. EXTERNAL FIXATION OF THE LOWER LIMB

External fixation of the lower limbs has its wide application in everyday practice. This method treats different types of open and closed fractures, various congenital and acquired deformities, complications of fracture treatments, such as malunions or nonunions, osteitis, septic pseudoarthrosis, lengthening of the lower leg (Figure 2-5).

5.1.External Fixation of the Proximal part of the Femur

In a significant number of patients with transtrochanteric fractures, with poor general condition in whom surgery is life-threatening, there is a need for short-term intervention that would provide care, early activation and weight bearing on the injured leg. External fixation is a method of choice. Treatment of elderly patients after transtrochanteric fractures is difficult due to a number of conditions that accompany this age, medical and surgical complications, as well as functional limitations that may be present. Due to the complexity, the treatment of elderly patients after hip fractures is multidisciplinary and belongs to the domain of orthogeriatrics. Non-operative treatment binds the patient to the bed, definitely does not give good outcomes and is associated with a high mortality rate. External fixator pins without threads are placed in the femoral head after the closed reduction on the extension table with fluoroscopic check of the pin position in two directions (AP and lateral). The other two pins are placed in the femoral shaft.

The disadvantage of the method can be infection around the pins of the fixator and discomfort while wearing the apparatus. In open transtrochanteric fractures, in fractures caused by projectiles from firearms, external fixation is the method of choice .[13,14] Non-operative methods of treating subtrochanteric fractures do not give good anatomical and functional outcomes. They bind the patient to the bed, and the end outcome of treatment is hip contracture with leg shortening, varising deformity and external rotation .[15] Poor healing is present in 50% of patients, and the nonunion rate and mortality are high. In a certain number of patients with poor general condition in whom surgical intervention is life-threatening, there is a need for external fixation as a less traumatic surgical intervention that is short termed, the apparatus- external fixator is placed by a closed method, and after external fixation early activation is enabled and patient care is easier.

5.2. **External Fixation of the Femoral Shaft**

External fixation of the femoral shaft is used as a temporary or definitive method of treatment. It is usually used as a temporary method for femoral fractures in polytrauma.[16] The conversion into internal fixation should then be done as early as possible, 7 to 10 days after external fixation. Delaying the conversion increases the possibility of infection after the fixation conversion. In case of latter conversion, it is necessary to remove the external fixator and place the skeletal traction until the wounds around the pins of the external fixator heal. Fixation conversion is done only after complete wound healing. In open fractures of III degree according to Gustilo, external fixation is applied routinely, as well as in femoral fractures that are caused by a penetrating or a perforating shot from a firearm. Femoral external fixation has a widest application in war surgery .[17] In the treatment of war wounds, soft tissue debridement is extremely important and should be repeated constantly. The greatest danger of infection around the pins of the external

fixator threatens after the external fixation of the femur. External fixation is used in the treatment of septic pseudoarthrosis.

5.3. External Fixation of the Knee

One of the indications for urgent and immediate application of external knee fixation is traumatic dislocation of the knee. Knee dislocation is a very severe injury, requiring urgent and immediate reduction and external knee fixation . The knee is usually fixed in a slight flexion with two external fixator pins in the femur and two in the tibia. Antithrombotic prophylaxis and continuous monitoring of vascular status of the limbs is necessary due to possible injury of the popliteal artery. Rigid knee fixation can be transformed latter into dynamic fixation. Temporary bridging external knee fixation is also used in cases of femoral and lower leg fractures on the same side „floating knee“, as well as in intra-articular fractures of the distal femur or proximal tibia. This method of knee fixation is temporary. External knee fixation is successfully applied in cases when it is necessary to perform knee arthrodesis. In cases of infection after knee arthroplasty, after extraction of the endoprosthesis, the knee is fixated with an external fixator .[8]

5.4.External Fixation of the Lower Leg

The lower leg is the part of the lower limb where external fixation has found its greatest application as a definitive method of treating closed, open fractures and numerous bone and joint conditions and diseases. Open fractures caused by explosive devices, penetrating or perforating gunshot wounds from projectiles are treated with frequent surgical debridements and external fixation .[1,8] After external fixation of these open fractures with a primary soft tissue defect, it is necessary to cover the defect as early as possible. In cases of bone defects, it is solved by osteoplasty or sliding graft, after surgical reconstruction of the soft tissue defect. External fixation has been successfully used in the treatment of fractures at all levels of the lower leg

(proximal, diaphysis, distal).[18-20] Most closed fractures of the tibial shaft are reducted by the closed method. In cases when the closed reduction is unsatisfactory, the fracture is reducted by the mini open method. In joint fractures at the level of the knee and ankle, there is a possibility of hybrid fixation according to Mitkovic, which provides good ground for the healing of fractures. Segmental tibial shaft fractures represent a serious problem and their treatment can be accompanied by numerous complications. External fixation of segmental fractures represents an excellent treatment, despite numerous authors favoring intramedullary fixation. The middle fragment is fixed with one or two pins, it does not deperioste, its circulation is not compromised, which enables good ground for latter healing. Possible postoperative deformities are easily corrected in outpatient settings.[21] In tibial shaft fractures that are accompanied by compartment syndrome, external fixation with fasciotomy represents an excellent method of treatment. Septic pseudoarthrosis, defective pseudoarthrosis, nonunions, malunions and numerous other conditions can be solved by applying the method of external fixation.[22] Congenital or acquired knee deformities are also solved by external fixation.[23-26] The limb lengthening of the tibia is performed by external fixation after corticotomy of the fibula and tibia, by distraction osteogenesis using an external fixator. In septic pseudoarthrosis, external fixation is one of the methods of choice. Cleaning and debridement, curettage of the focus of the infection and external fixation are necessary. In defective pseudoarthrosis, external fixation after corticotomy of the tibia and fibula enables bone transfer "sliding" and solving this serious and often unsolvable problem. Bone transfer is performed until full compressive bone contact with the other end of the bone is achieved. In fractures of the distal part of the tibia (tibial pylon), external fixation is applied with great success. Fractures of the tibial pylon can be extra-articular, partially articular or intra-articular (AO, type A, B, C). The method of external fixation is applied

temporarily within the "staging" protocol, which involves temporary bridging external fixation and a definitive open reduction into the internal fixation of the fracture after two to three weeks. Another way of applying the method of external fixation in tibial pylon fractures is definitive external fixation with or without minimal osteosynthesis, as a "one-stage" method .[27-30] Anatomical reduction of the articular surface of the distal tibia and minimal osteosynthesis with screws or Kirschner wires are necessary. This rigid of external fixation can later be transformed into a dynamic one.[31] In many clinical practice cases, tibial pylon fracture reduction can be done by a closed method - ligamentotaxis. In these cases, external fixation is combined with minimally invasive, percutaneous fixation of the fracture.

5.5.External Fixation of the Ankle Joint

Temporary or definitive external fixation of the ankle joint is used in the treatment of open or closed, unstable intra-articular fractures of the tibial pylon. Open or closed dislocated ankle fractures at the level of the distal tibia, dislocation or maleolar dislocated fractures can be treated using the method of external fixation. Distraction external fixation of the ankle joint is also used during diagnostic-therapeutic arthroscopies of the ankle joint. In open or closed subtalar dislocations, dislocated talar fractures, talar fractures associated with maleolus fractures, navicular bone, distal tibia, and other local bone structures, external fixation has been successfully used for years.[32-35]

5.6.External Fixation of the Foot

Many foot fractures, severe foot injuries, congenital or acquired deformities can be treated with great success by the method of external fixation . For this purpose, there is a specially designed external foot fixator according to Mitković, or a classic external fixator can be used for various

traumatic conditions or for external bridging fixation, in tibial pylon fractures, subtalar dislocations and talar fractures.[8]

6. Complications after the External Fixation

Each orthopedic-surgical method has its complications. Complications that an orthopedic surgeon may face after the use of external fixation are infection around the pins, osteolysis around the pins and loosening of the external fixator pins, pin breakage, injuries of blood vessels and nerves, joint contracture, delayed fracture healing, nonunions, post-traumatic deformities, limb shortening, refractures, compartment syndrome. One of the main disadvantages of using th external fixation method is the necessity of wrapping around the pins in order to prevent infection (pin site infection) and the discomfort of the patient while wearing the external fixator. Infection is the main cause of osteolysis around the external fixator pins and in these cases it is necessary to remove the pin, perform surgical debridement and curettage, and place the new pin in a healthy site, proximal or distal to the osteolysis site, taking into account the proximity of the osteolysis .[36-38] Improper placement of the pins and overloading of the external fixator during wearing the apparatus can lead to loss of fixation or pin breakage. Good knowledge of the anatomy of the limbs and the experience enable the surgeon to avoid neurovascular complications when placing the pins of the external fixator. Although rare, these complications have been described in the literature. Due to the proximity and contact of the external fixator pins with blood vessels, the literature describes the formation of pseudoaneurysms on arterial blood vessels.[39] After the pin extraction, heavy bleeding can occur, and arteriography usually shows the presence of a pseudoaneurysm, most often on the lower leg. The complication is rare and requires the intervention of a vascular surgeon. In order to avoid complications such as angulation and refracture, the authors recommend that after the radiographic and clinical

assessment of the fracture healing, only the frame of the apparatus be removed, and that the pins stay for a few more weeks. The patient is allowed full weight bearing on the injured limb, and an X-ray is made two weeks after removing the external fixator frame. In case the patient feels pain and that angulation has occurred, it can easily be manually corrected by returning back the external fixator frame. The external fixator should then be worn for a little more, until the fracture is completely healed. The external fixator according to Mitkovic enables control of biomechanical conditions during the fracture healing process by enabling dynamization which is achieved by unlocking (unscrewing) the screws on the fixator frame, compressing and re-tightening the screws, or leaving them unscrewed. Malunions or nonunions most often occur as a consequence of a badly reducted fracture initially, incorrect placement of the apparatus, pins and poorly dictated postoperative flow, usually late weight bearing. The process of fracture healing is not only affected by the way the fracture is fixated, but also the fracture healing depends on numerous local and systemic factors that we do not have an impact on. What is expected of us is strict adherence to the principles of external fixation and enabling biomechanically optimal conditions for fracture healing. Many of the complications can be solved by re-applying the external fixation . Also, many of the complications that have occured after the application of some other method of treatment can be resolved by external fixation method. Joint contractures after external fixation are avoided by early rehabilitation, placing the external fixator pins with the knee in flexion, when it comes to external fixation of the femur. During external fixation of the lower leg fracture, ankle contracture with the position of the foot in plantar flexion (equinus) is possible. Prevention of contracture consists of early rehabilitation and placement of a foot holder which is connected to the fixator and serves the patient to pull the foot in dorsiflexion. When it comes to compartment syndrome, based on the author's clinical

experience, it occurs as a consequence of trauma, and unlikely as a consequence of external fixation. Treatment of compartment syndrome consists of urgent fasciotomies and external fixation of the fracture. Compartment syndrome is an urgent condition and requires urgent and immediate decompression, ie fasciotomy, in order to prevent the occurrence of permanent and irreversible, ischemic consequences for the injured limb.[40-41] Clinical examination and continuous monitoring of the patient and injured kimb, loosening of plaster immobilization, high elevation of the limb, local cooling, monitoring of the neurovascular status of the injured limb, is of great importance in order to recognize the early compartment syndrome symptoms. Early recognition of the symptoms and early fasciotomy are the most important factors for establishing normal limb circulation.[42] Timely intervention prevents the consequences of acute compartment syndrome, which can lead to permanent and severe functional damage and contractures, but also to limb amputation, due to long-term ischemia.

7. Conclusion

We live in a time when bone and joint trauma is on the rise. Today's injuries are not as they used to be, isolated, simple. Injuries are often multiple or are an integral part of polytrauma. The modern way of life also contributes the increase of mass injuries, which can occur as a consequence of natural disasters, wars or major traffic accidents in transport and can be severe and life-threatening. In the last ten years, we have witnessed great progress in orthopedics and traumatology, which is reflected in new surgical, minimally invasive methods of treatment and new implants. Although external fixation is not a new method, its significance and applicability in the world is evident. External fixation is successfully used in acute-isolated trauma, multiple trauma or polytrauma, whether it is used for temporary or definitive fixation of bone tissue. The suitability of this system is its simplicity in handling, ease of application, possibility of latter

corrections, dictation of biomechanical conditions for fracture healing, possibility of minimally invasive surgery and additional surgical procedures.

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Figure legend:

Figure 1 (A-E). External fixation of the upper arm. A(a-f)- External fixation of the upper arm after traumatic arm amputation; B (a-h). External elbow fixation to support minimal fixation of the open intra-articular distal humerus fracture; C(a-g)- External forearm fixation after semi-amputation with fracture of both bones of the forearm, lesion n. ulnaris, n. median, lesion of the ulnar artery; D (a-c). External fixation of the wrist with minimal fixation of the styloid process of the radius in wrist dislocation and styloid process fracture; E(a-e). External fixation after third metacarpal bone corticotomy due to callus distraction in the treatment of post-traumatic metacarpal bone shortening.

Figure 2(A-F). External fixation of the lower limb. A- External fixation of the pelvic ring in polytrauma; B (a, b)- External fixation of a transtrochanteric fracture caused by a projectile from a forearm; C(a-d). External fixation of an open femoral fracture; D(a-f). External fixation of the knee and tibia after an open intra-articular fracture of the proximal tibia Gustilo IIIC and a closed distal third tibial fracture; E (a-j)- External fixation of the open fracture Gustilo IIIB of the distal tibial end; F(a-e)- Clinical appearance after external fixation of the tibial shaft fracture. The external fixator enables early mobilization of the patient and weight bearing on the operated leg.

Figure 3. External fixation of the tibial shaft, distal part of the tibia and ankle joint „bridging“ external fixation. A(a-h)- Radiographic images before and after external fixation of the lower leg diaphysis fracture, during treatment and after removal of the external fixator; B(a-f). External fixation of the tibial pylon (AO type C). The initial rigid bridging external fixation easily turns into dynamic after a few weeks; C(a-e). External fixation and minimal osteosynthesis after a dislocated talar fracture (Hawkins type III) associated with a distal tibial fracture; D(a-h)- Clinical and radiographic case presentation of the lower leg infection after plating of distal tibia. The plate was removed, debridement, curettage and hybrid external fixation were done; E(a-e).

Compartment syndrome after closed tibial diaphysis fracture. After external fixation of the tibia, an urgent fasciotomy was performed. Secondary wound closure and skin covering were done 7 days after the injury.

Figure 4(A,B). Treatment of angular knee deformities with hemi-corticotomy and hemicallotasis using unilateral 3D external fixator. A(a-d)- Distal femoral hemi- corticotomy in „valgus“ knee gradual correction of deformities; B(a-d)- Proximal tibial hemi-corticotomy in „varus“ knee gradual correction of deformities.

Figure 5(A,B). External fixation in bone lengthening. A (a,b)- External fixation in lower leg lengthening; B(a,b)-External fixation in the treatment of congenital shortening of the fourth metatarsal bone (Brachymetatarsia).

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All authors read and approved the final version of the manuscript. SM wrote the manuscript. MM and VB conceived the design of the study and collected the data, MM and MB contributed to the critical revision of the manuscript.

Conflict of Interest

The authors Sasa Milenkovic, Milan Mitkovic, Marko Bumbasirevic and Vojislav Bumbasirevic declare that they have no conflict of interest. The author Milorad Mitkovic has at this moment agreement with Ortocon Ltd, Nis, Serbia, producer of the external fixators , on temporary assignment to the use of patent.

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Ethical approval

This study was approved by the appropriate ethics committee.

Informed consent

Informed consent was not necessary for this study and thus not requested from our patients.