



## Development of Innovative Rod Apparatus for Treatment of Long Bones of the Lower Limb in Multiple and Combined Injuries

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**Abstract:** Today, numerous scientific studies are being conducted to improve the diagnosis and treatment of patients with polytraumas. Methods for improving and using minimally invasive approaches and low-traumatic devices for external fixation are being studied, algorithms and markers are being developed to reduce the mortality rate and possible complications. The complex multicomponent reaction of the body to severe mechanical damage is considered as a single whole in the interaction of all the links that make it up. In this regard, the study of the immunology of trauma is an important direction in the study of traumatic disease (TB), and deepening knowledge in this area will significantly improve the effectiveness of medical care for victims, providing the opportunity for earlier correction at the pathogenetic level. The introduction in our country of modern technologies using the basic principles of “Damage control” has improved the results of treatment of victims with polytraumas, however, the frequency of unsatisfactory results of surgical treatment still remains high. The action strategy for the five priority areas of development of the Republic of Uzbekistan for 2017-2021 sets the task of “developing and improving the system of medical and social care.” In accordance with this, the use of new technological solutions for transosseous osteosynthesis and assessment of markers of the systemic inflammatory response of the body (SIRR) in fractures of long bones of the lower extremity with multiple and combined injuries to prevent and reduce the disability of patients and improve their quality of life is one of the pressing problems of traumatology and orthopedics .

**Key words:** polytrauma, extramedullary osteosynthesis, pneumonia, thoracentesis, videothoracoscopy, hemothorax.

**Purpose and objectives of the study.**To develop new designs of external fixation devices and experimentally substantiate them for osteosynthesis of fractures of long bones of the lower extremities with their introduction into clinical practice;

**Object of study**There were 226 patients with fractures of the long bones of the lower extremities with multiple and combined injuries treated at the TMA Multidisciplinary Clinics over the period from 2011. By

2019

**Subject of study:** innovativelow impact technologies for osteosynthesis using external fixation rod devices in patients with fractures of long bones of the lower extremities with multiple and combined injuries, laboratory testing of the device of rod devices for the treatment of long bones of the lower extremities, venous blood for assessing the systemic inflammatory response of the body (SIRO) of patients, assessment bone mineral density.

**Research results.** The choice of surgical methods for treating fractures in the acute and early stages of TB was determined by the severity of the injury of the victims, its location and the nature of the



fractures, and preference was given to the newly designed rod devices developed by ANF. Indications for the use of the developed external fixation rod apparatus 1 and 2 models:

- open bone fractures of the long bones of the lower extremities;
- diaphyseal fractures;
- fractures of the proximal end of the femur type A and B;
- for the purpose of early stabilization of fractures, as an anti-shock measure;
- to facilitate patient care and early activation and rehabilitation;
- Reduces the possibility of developing various hypostatic complications.

With an assessment of the severity of the injury and the severity of the condition of the victims in the dynamics of the acute and subacute periods of TB and from the indicators of hemodynamic stability of patients with dominant injuries with combined injuries, osteosynthesis of fractures of the long bones of the lower extremities was performed after surgical interventions on the dominant injuries of the internal organs of the chest, abdominal organs and skulls. The motivation for performing osteosynthesis of fractures of the lower extremities in the acute and early stages of TB was: to reduce pain on the injured limbs, to prevent ARDS, fatty and thromboembolism, infectious complications and the frequency of deaths arising from TB, to facilitate care for seriously ill patients, and to improve the quality of life casualties and a reduction in bed days.

When deciding on fixation of fractures, the nature of the fracture and the number of damaged segments, the severity of the injury and the severity of the patients' condition were taken into account. In the main group, surgical interventions were performed on 98 patients in the acute and subacute periods of TB and surgical activity in the main group was 87.5%; in total, surgical interventions were performed on 110 segments of the lower extremities. An extremely serious condition was assessed in 14 patients, and due to the severity of the injury and the severity of the condition, as well as concomitant diseases, it was not possible to perform surgical interventions in the acute and early stages of TB.

In the acute period (the first 2 days) of TB, early osteosynthesis of fractures of the long bones of the lower extremities was performed in 79 patients on 85 segments: 41 of them were performed on the femur, 44 on the shin bone. In the early period (from 2 to 14 days) 19 patients, of which 12 were in the femoral segment, 13 in the tibia bones. In the late period (from 14 days to 3 months) there were 10 patients with TB, of which 6 were in the femur, 6 segments were in the tibia bones.

In the acute period of TB, preference was given to an external fixation device and on 41 segments of fractures of the lower extremities the developed rod apparatus of models 1 and 2 was used and on 4 segments the Ilizarov apparatus was used.

The choice of using a metal structure depended on the level and nature of the fractures of the segment, as well as on the severity of the injury and the severity of the condition of the victims: BIOS was used for fractures of the upper, middle third, fractures of the femur and tibia bones of the upper third, middle and lower third and according to the nature of the fracture for transverse and oblique fractures. Extramedullary osteosynthesis has been used for fractures of the distal end of the femur, proximal end and distal end of the tibia, as well as for comminuted fractures with rotational dislocations. Ilizarov wires were used for open fractures of the lower third with transition to the articular surface of the distal femur and tibia with extensive wounds. The Ilizarov apparatus was used for open fractures of the tibia. Model 1 and 2 rod devices were used depending on the damaged segment, as well as the severity and condition of the victims: since model 2 rod apparatus was used for fractures of the proximal end, model 1 rod device was used for open fractures of the shin bones and severe conditions of patients as temporary fixation or final osteosynthesis.



Osteosynthesis with a rod apparatus of the femur and tibia bones was performed in patients with shock of degree II or III and, according to the severity of the injury, ISS - 20 points or more with relative hemodynamic stability.

Patients with fractures of the proximal end of the femur underwent osteosynthesis with a developed rod apparatus for the purpose of early activation and prevention of complications (hypodynamic pneumonia, bedsores, cardiovascular failure, etc.), especially in older patients.

According to the "Damage control orthopedics" principle, patients with dominant injuries of damage to internal organs and systems were preceded by appropriate infusion therapy, the purpose of which was to replenish the volume of circulating blood and stabilize hemodynamic parameters, anesthetize the area of fractures of the limb bones and immobilize the damaged segments with temporary splints.

These victims only underwent surgical intervention for vital indications on damaged internal organs. According to the "Damage control orthopedics" principle, patients with dominant chest injuries in the intensive care unit were subjected to thoracentesis by thoracic surgeons for the purpose of diagnostic and therapeutic tactics. Of these, 2 (1.78%) patients underwent videothoracoscopy with elimination of hemothorax and coagulation of bleeding vessels on the 3rd day after injury. For dominant abdominal injuries, laparotomy was performed with suturing of damaged parenchymal and hollow organs (liver, spleen, intestinal loops). In 1 (0.89%) patient with damage to the brachial plexus, after stabilization of the general condition, surgical intervention on the brachial plexus was performed together with a neurosurgeon. The injured limbs were temporarily fixed with plaster casts. In 6 (5.36%) patients, due to the severity of the injury and secondary complications (sepsis, ARDS), surgical treatment of injured lower extremities was contraindicated; it was continued conservatively with fixation with plaster casts. Of these, 4 (3.56%) patients had a fatal outcome in the acute and early stages of TB (of which 2 patients had a fracture of the femur and 2 patients had a fracture of the femur and shin bones). Osteosynthesis of lower limb bone fractures was performed after injury on day 14 in 2 (1.78%) patients (BIOS of the femur and tibia). 6 (5.35%) patients, after resolution of pulmonary complications at 3 months, underwent extramedullary osteosynthesis with a plate - (segment 4 of the tibia, segment 2 of the femur); and in 2 (3.56%) patients, an improperly healing fracture of the femur and a healed fracture of the tibia were observed and an operation was performed to block intramedullary osteosynthesis of the femur.

In addition to osteosynthesis of fractures of the long bones of the lower extremities in 108 patients, 42 surgical interventions were performed for combined fractures: clavicle fracture - in 4 patients, humerus fracture - in 8 patients, forearm bone fracture - 12, calcaneal bone fracture - 4, patella fracture - 2, pelvic fracture - 12 patients.

In the control group, surgical interventions were performed on 72 patients in the acute and early stages of TB and surgical activity in the main group was 63.2%; in total, surgical interventions were performed on 78 segments of the lower extremities. Of the 114 patients, 28 patients, due to the severity of the injury and the severity of the condition, as well as concomitant diseases, were not given the opportunity to undergo surgical interventions in the acute and early period of TB, and surgical interventions were performed in the late period of TB.

In the acute period (the first 2 days) of TB, early osteosynthesis of fractures of the long bones of the lower extremities was performed in 22 patients on 28 segments, mainly for open fractures: 5 of them were performed on the femur, 6 fractures of the proximal end of the femur, 17 bones of the tibia. In the early period (from 2 to 14 days) to 50 patients, of which the femoral segment was 28, the tibia bones were 30 segments. In the late period (from 14 days to 3 months or more) TB surgical intervention was performed on 28 patients (5 (6.1%) patients underwent surgical intervention 3 months after the injury), of which 25 were performed on the femoral segment, on the tibia bones - 9 segments. Osteosynthesis of long bone fractures was performed on 100 patients using various types of metal osteosynthesis: BIOS on 38(31.7%)segments, extramedullary osteosynthesis with a plate - 36(thirty %), Ilizarov knitting needles 25(20.8%)segments, intramedullary osteosynthesis with a pin



– 14(11.7%) and the Ilizarov apparatus was applied on 7(5.8%) segments. For fractures of the diaphyseal part of the femur at the level of the upper and middle third, osteosynthesis was performed with a tetrahedral intramedullary pin; at the level of the lower third, locking intramedullary osteosynthesis or an extramedullary plate was used.

For fractures of the proximal end of the femur, an extramedullary Bakicharov plate, a ChM plate and Ilizarov wires were used for osteosynthesis.

For patients with a dominant chest injury in the intensive care unit, a thoracic surgeon performed thoracentesis for diagnostic and therapeutic purposes. 7 patients were diagnosed with ongoing bleeding, which was an indication for videothoracoscopy with elimination of hemothorax. Laparotomy was performed from the abdominal cavity with suturing of the parenchymal organ. In 7 patients with dominant injuries of the abdominal organs, after relative stabilization, emergency diagnostic and therapeutic laparoscopy and laparotomy were performed within 6 hours from the moment of admission to the clinic. With the dominant brain grass, craniotomy was performed with removal of the subdural hematoma; in 4 patients, craniotomy was performed with removal of the hematoma.

During treatment, mortality was observed in 12 (10.5%) patients, the reasons for this were the following complications: acute blood loss in 4 patients, acute myocardial infarction in 1 patient; fat embolism – 3; sepsis – 2; MODS - in 2 patients and in addition in 7 (6.1%) patients, due to the severity of the injury and concomitant diseases, fractures of the long bones were fixed with plaster casts and surgical interventions were performed 3 months after the injury in 5 patients: BIOS of the femur - 2 patients and tibia in 1 patient, in 1 patient - BIOS of fractures of the femurs and tibia bones, in 1 patient - extramedullary osteosynthesis of fractures of the tibia. In 2 patients (fracture of the femur and pelvic bones), due to the severity of the injury and concomitant pathology, treatment of the injured limbs was continued conservatively.

In addition to osteosynthesis of fractures of the long bones of the lower extremities in 108 patients, 35 surgical interventions were performed for combined fractures: clavicle fracture - in 3 patients, humerus fracture - in 6 patients, forearm bone fracture - 14, calcaneal bone fracture - 2, bone fracture pelvis - 10 patients.

To assess the effectiveness of treatment of patients with multiple and combined injuries based on an assessment of the severity of the injury and according to the principle "Damage control orthopedics", also of the method of osteosynthesis of fractures of long bones of the lower extremities, a comparative analysis of the immediate and long-term results was carried out.

To assess the immediate results, we studied the rates of observed complications, mortality, length of hospital stay, readmission of patients and the functional status of patients as assessed by E.R. Mattis (1988) in the long term after treatment. Studying and assessing the functional state of damaged limbs is an indicator of the quality of treatment in patients.

Long-term treatment results were analyzed in 164 (78%) patients. The victims of the main groups consisted of 80 patients (follow-up period was from 1 to 2 years) and 84 patients made up the control group (follow-up period was from 1 to 3 years).

Among the observed complications in the main group of patients, wound suppuration was noted – in 1.85% of cases, in the control group – 14%, hypostatic pneumonia was observed in 3.7%, against – 12% in the control group, development of bedsores of the sacral, calcaneal and scapular areas were observed in the main group – in 0.9% of cases, against – 13%, inflammation of the soft tissues around the rods was observed in – 7.4%, in the control group – 4%, secondary wound healing was observed in 1.85%, against – 13% in the control group, delayed consolidation of fractures in the main group – 6.5%, in the control group – 20%, contracture of adjacent joints – in 7.4%, against – 26%, deep vein thrombosis – 0.9%, against – 37%, serious complications, such as thromboembolism and fat embolism, were noted fat embolism in the main group - 1.85%, in the control group - 3%, when



analyzing this result, tactical errors were revealed: surgical intervention was performed in the acute period with poor correction of central venous pressure and blood rheology, osteomyelitis in the main group was observed in 0.9%, in the control group - 3%, lysis of the femoral neck, pseudarthrosis - 3.7%, against - 7% in the control group. Acute anemia, ARDS, sepsis, postoperative wound hematoma, migration and fracture of metal structures, aseptic necrosis of the femoral head were not observed in the main group, in the control group observed - 15% of cases, which required blood transfusion of the same blood group, 1%; 4%; 6%, 12% and 4% of cases respectively. In our opinion, surgical interventions in the acute period of TB, timely active correction of anemia, and early activation of patients did not allow the above complications to arise.

Also, in order to study the effectiveness of treatment, we used average number of bed days inpatient treatment: in the main group  $-10.6 \pm 2.7$  days, in the control group  $-15.5 \pm 3.56$  days ( $P > 0.05$ ).

We also studied the immediate results of treatment depending on the method of osteosynthesis for multiple fractures of the long bones of the lower extremities in patients.

During osteosynthesis of fractures of the proximal end of the femur, migration and fracture of Ilizarov wires were observed in 7 cases, of which 2

In cases, the wire was removed from the anterior abdominal wall (due to wire fracture and migration). In 1 patient, 45 days after osteosynthesis with a bundle of wires, migration of the wires occurred, which was complicated by perforation of the bladder; together with the urologist, the patient underwent emergency surgery to remove the migrated wire with the application of a Petzer catheter.

Readmission to hospital was observed in 3 cases due to the above complications.

During osteosynthesis with a bone plate, a fracture of the metal structure was observed in 5 patients: (of these, 2 patients had osteosynthesis with a Bakicharov and AO plate, 3 patients had osteosynthesis with a ChM plate), while in 2 cases reosteosynthesis was performed with an intramedullary pin with blocking, and 3 patients refused from surgical treatment and we continued conservative treatment and achieved healing of the fracture with varus deformity. Due to the application of a coxite plaster cast, secondary contractures of the hip and knee joints were noted in 15 cases.

For osteosynthesis with a rod apparatus, 2 models. Complications were noted during the outpatient period. Suppuration of the soft tissues around the rods was observed in 3 cases and was relieved by local use of antibiotics: in 1 patient, after 1.5 months, it became necessary to remove the rod apparatus, but fusion of the femoral neck with varus deformity occurred. Limitation of the range of motion in the hip and knee joints compared to the healthy limb (no more than  $10^\circ$ ) was observed in 5 cases. 2 patients had a fracture of the femoral head 31B1.3 according to the classification of AO/ASIF (2018). After 6 months, they dismantled the rod apparatus, after which lysis of the femoral neck occurred, intermittent pain in the hip joint appeared, the patients were recommended to walk with the help of crutches with a moderate load on the limb. In the dynamics, the control X-ray image showed fusion of the femoral head with a shortening of 2.0 cm. Repeated hospitalization was observed in 1 case, the reason for this was, from the anamnesis, the patient was repeatedly injured in a fall, after which severe pain appeared in the injured limb: on MSCT the position of the bone fragments and the stability of the rod apparatus were unchanged; after a clinical and x-ray examination, sciatic nerve neuralgia was diagnosed, a novocaine blockade was performed and a course of physiotherapy and pain were successfully relieved. The device was dismantled after a clinical and radiological examination: in the absence of pain and swelling on the injured limb, an easy and confident gait and the presence of radiological signs of fracture consolidation.

During osteosynthesis of fractures of the femur and shin bones, the following complications were observed: with the developed rod apparatus model 1 inflammation of the soft tissues around the rods was noted in 3 (2.7%) cases and delayed fracture consolidation - V2 cases (1.85%). All complications were stopped by sanitary dressings and/or antibacterial therapy and stimulation of reparative



regeneration with medications (myocalcium, vigantol). During osteosynthesis with a bone plate hematoma postoperative wound – at 6(6%) patients due to insufficient hemostasis during surgery and re-hospitalization was observed in 3 cases due to the above complications. During BIOS osteosynthesis, migration and fracture of the locking screws were observed in 4 patients, contracture of the knee joints in 5 patients, delayed consolidation of the fracture in 3 patients, migration of a tetrahedral intramedullary pin in 1 patient, the reason for this was incorrect measurement of the length of the femur, after which the distal end was injured femur and migration of the intramedullary pin through the knee joint occurred. The patient was re-hospitalized 4 months later and an operation was performed to remove the intramedullary pin from the femur with reosteosynthesis of the BIOS of the femur. And after 8 months, complete fusion of the femur was observed.

The consolidation of fractures was assessed by clinical and radiological studies. The average time for fusion of bone fragments during osteosynthesis of fractures of the proximal end of the femur with a rod apparatus of model 2 was  $142.4 \pm 19.7$  days, with osteosynthesis with wires –  $161.3 \pm 27$  days and with osteosynthesis with an extra bone plate –  $149.4 \pm 19.2$ , ( $P < 0.05$ ). The average time for fusion of bone fragments during osteosynthesis of shin bone fractures with the rod apparatus of model 1 was  $148.1 \pm 18.7$  days, during osteosynthesis with various metal structures it was  $159.5 \pm 20.9$  days ( $P < 0.05$ ). The average duration of fixation with the external fixation device developed depended on the appearance of signs of consolidation and on the nature of the fracture. For type “A” fractures, the average fixation period was 12-14 weeks, for types “B” and “C” – 14-16 weeks.

When studying long-term results in the compared groups, the following results were obtained: in the main group, good results were established in 75 (89.3%) patients, satisfactory results in 6 (7.1%), unsatisfactory results in 3 (3.6%) patients. In the control group, good results were found in 67 (84%), satisfactory – in 5 (6%), unsatisfactory – in 8 (10%) cases.

Taking into account the summary indicators of the functional state in points by E.R. Mattis [1988] obtained a significant ( $P < 0.05$ ) difference between the comparison groups. In the main group, the average score was  $91.1 \pm 4.4$ , while in the control group it was  $88 \pm 4.1$  points.

BMD indicators remained within normal values and recovered 1.8 times more at 4 months compared with traditional treatment methods, and ultrasound Densitometry showed that early loading of damaged segments, improves quality of bone tissue and after 12 months, 83.3% of patients had BMD values approaching normal values for a healthy limb. Early static load on the injured limb is the prevention of osteoporosis.

The leading causes of death in the acute period of TB were shock and blood loss - 12.5%, in the early period of TB - mainly fat embolism - 25%, followed by ARDS and acute myocardial infarction, 12.5% each, in the late period of TB - MODS and sepsis at 12.5%.

In conclusion, it should be noted that assessing the severity of the injury and the severity of the patient's condition and markers of the dynamics of changes in the SVOA, taking into account the principles of “Damage control orthopedics”, when choosing tactics for the treatment of musculoskeletal injuries in patients with combined and multiple injuries, ensures early restoration of all injuries, activation of patients and is more appropriate in comparison with wait-and-see tactics, which is confirmed by a decrease in the number of complications. When choosing the timing and volume of surgical treatment, an assessment of the severity of the injury and the severity of the patient's condition and the requirements “Damage control orthopedics”, as well as conducting massive intensive therapy with a preference for the use of low-traumatic external fixation devices.

The use of rod devices in patients with multiple and combined injuries makes it possible to achieve stabilization of the general condition of patients and provides the opportunity for early development of movements in adjacent joints. With the help of a rod apparatus, all types of displacement of bone fragments are eliminated, rigid fixation is ensured during the period of fusion, while the function of the joints is preserved, and this is of great importance in practical application in traumatology and orthopedics. The additional inclusion of Polyoxidonium in the complex of treatment measures for



polytrauma leads to the restoration of the balance of cytokines, especially in cases of a tendency to develop SIRS.

### Conclusions:

1. The developed devices of a new design, models 1 and 2, operate in a stable mode, the axial tension is  $P = 18$  kgf and  $R_{upr} = 17$  kgf and the compressive load is  $P = 21.5$  kgf and  $R_{upr} = 32$  kgf, respectively, when the load is removed, the system is restored to its original position, without deformation.
2. It has been experimentally proven that the developed devices of the new
3. Designs provide conditions for stable fixation “fixator-bone” and are stable when used in practical applications.
4. Assessing the severity of the injury and the severity of the condition in the dynamics of the study of SVOO markers and taking into account “damage control orthopedics” in victims during the treatment of fractures of long bones of the lower extremities allows to minimize the degree of surgical aggression and improves the general condition of patients in comparison with traditional methods of treatment, which is confirmed by a reduction in the mortality rate from 10.5% to 3.57% ( $P < 0.05$ ).
5. During osteosynthesis with new structures ANF of fractures of long bones of the lower extremities BMD indicators are maintained within standard values in comparison with the use of osteosynthesis with various metal structures.
6. Carrying out osteosynthesis of fractures of long bones of the lower extremities in patients with polytraumas in the early period of TB can improve the immediate results of treatment, reduce the number of complications by 3.2 times, reduce average number of bed days for an average of 4.9 days.
7. In the long-term period, when treating fractures of the long bones of the lower extremities of patients using an assessment of the severity of the injury, the severity of the condition and the dynamics of SVOO markers, taking into account “Damage control orthopedics”, it is possible to achieve good and satisfactory functional results in comparison with traditional methods from 88.0 points to 91, 1 point.

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