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Temporary osteosynthesis of the tibial bones in repair of multiple and combined injuries

I.Yu. Khodjanov[1], L.A. Amonov[2]✉, F.M. Makhsudov[2]

1 Republican specialized scientific and practical medical center of traumatology and orthopedics, Tashkent, Uzbekistan

2 Navoi branch of republican research center of emergency medicine, Navoi, Uzbekistan

Corresponding author: Laziz Amonovich Amonov, lazizamonov0728@gmail.com

Abstract

Background The incidence of injury worldwide remains high, with a global estimate of 6763 cases per 00,000 population (95 % confidence interval 6412–7147). Trauma to the limbs is a common injury to an individual anatomical area during multiple or combined trauma that accounts for 40 % to 85.2 % of cases. Assessment of the effectiveness of different fixation options and development of treatment algorithms are essential for patients with tibial fractures and multiple (combined) injuries.

The **objective** was to determine how often temporary tibia fixation is applied for patients with multiple and combined injuries.

Material and methods The original literature search was conducted on key resources including Scientific Electronic Library (www.elibrary.ru), the National Library of Medicine (www.pubmed.org), CyberLeninka between 2008 and 2023 using search words and phrases: tibial injuries, osteosynthesis of lower limbs, multiple injuries, combined injuries, temporary osteosynthesis of the tibial bones.

Results and discussion A differentiated approach to the repair of bone fractures resulting from multiple and combined injuries is mostly common with the choice of fixation technique depending on the severity of injury and the severity of the patient's condition. The definitive internal bone fixation is normally used for stable patients, "damage control" strategy is secured for borderline and severe cases using primary temporary external fixation followed by staged surgical intervention. There is no generally accepted strategy for the use of early mobilization of long bone fractures as a component of anti-shock measures in a polytrauma patient.

Conclusion Certain issues remain unresolved, including the use of osteosynthesis for tibial fractures in some cohorts of patients, the optimal time of transition to definitive internal fixation, the possibility of using extrafocal osteosynthesis as a definitive treatment, the optimal configuration and assemblies to be employed. The lack of high-quality randomized controlled trials in this field is an important limitation.

Keywords: bone fixation, multiple injuries, combined injuries, tibia

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INTRODUCTION

The incidence of injury worldwide remains high, with a global estimate of 6,763 cases per 100,000 (95 % confidence interval 6412–7147). In European countries, it varies depending on the region ranging between 9,600–16,100 cases per 100,000, and in Central Asia it is about 10,300 cases per 100,000 [1]. Trauma is one of the main causes of disability in adolescents, young and middle-aged individuals (range, 10–49 years). According to the Global Burden of Disease (GBD) study, transport injuries are a major cause of global disability-adjusted life-years (DALYs) and mortality [2]. The frequency of injuries is higher in male patients [1].

Although there is a decrease in mortality caused by injuries observed in recent decades, the frequency of trauma remains high and is estimated at 738 cases per 100,000 in 2017 [1], while injuries can account for 9 % of the total mortality [3]. The problem of injuries is essential for modern medicine.

Injuries to the limbs are among the most common injuries to individual anatomical areas in the structure of multiple or combined trauma and are observed in 40–85.2 % of patients [4–6]. Moreover, a limb fracture can be a dominant injury in terms of severity in severe combined trauma and polytrauma cases [7]. Long bone fractures are most common among the limb injuries observed in patients with multiple and combined trauma [4, 5]. Tibial bone fractures are one of the most common injuries to the limbs in patients with severe multiple injuries with tibial fractures observed in 12.6 % of patients, and fibula in 5.7 % [6]. Open tibial fractures are registered in 59.5 % of patients with severe injuries and 40.5 % sustain closed fractures [8]. Tibial fractures are common in patients with road traffic injuries (43 % of all limb injuries) [5]. Assessment of the effectiveness of different fixation options and development of treatment algorithms are essential for patients with tibial fractures and multiple (combined) injuries.

The **objective** was to determine how often temporary tibia fixation is applied for patients with multiple and combined injuries.

MATERIAL AND METHODS

The original literature search was conducted on key resources including Scientific Electronic Library (www.elibrary.ru), the National Library of Medicine (www.pubmed.org), CyberLeninka between 2008 and 2023 using search words and phrases: tibial injuries, osteosynthesis of lower limbs, multiple injuries, combined injuries, temporary osteosynthesis of the tibial bones. Literature reviews, original articles, and clinical studies were considered. About 700 sources that included the keywords were found. 52 sources were selected for review. Selection criteria included compliance with the topic of the review, consideration of the most relevant approaches in the strategy and treatment of the pathology. The review mainly includes articles by European authors.

RESULTS

Temporary osteosynthesis and its use in modern traumatology

In modern traumatology, osteosynthesis is understood as surgical reduction and alignment of bone fragments until they are completely fused [9]. According to the method of bone fixation, the following variants of osteosynthesis are distinguished [9, 10]:

Internal osteosynthesis:

— extramedullary osteosynthesis using plates, cerclages (not common);

— intramedullary osteosynthesis using screws or nails:

- intramedullary osteosynthesis with reaming;
- intramedullary osteosynthesis with blocking;
- osteosynthesis using implants made of titanium nickelide with shape memory.

Extrafocal osteosynthesis:

— transosseous osteosynthesis using external fixation devices (EFD) (for example, Ilizarov apparatus):

— osteosynthesis with EFD using pins;

— osteosynthesis using wires and pins (hybrid) devices.

Hybrid osteosynthesis using implants and EFD

Nailing can be combined with open reduction of bone fragments or performed as part of a minimally invasive intervention with the reduction performed in a closed manner and the implant be placed through small holes [9]. Osteosynthesis is divided into early (in the first 48–72 hours of injury) and delayed fixation performed at 7–10 days [10], late delayed osteosynthesis (more than 3 weeks). In addition, osteosynthesis can be primary or consist of two stages (conversion osteosynthesis): primary temporary and final. Conversion osteosynthesis is often used for multiple or combined injuries [11, 12].

Extrafocal techniques are employed for temporary osteosynthesis during staged surgical repair of fractures using pins, wires or hybrid EFD. According to the functional principle, EFD are divided into compression, distraction, compression-distraction and hinge-distraction. The EFD designs developed, often bear the author's name [13]. The Ilizarov compression-distraction apparatus is one of the most famous and widely used frames to facilitate bone reduction and fixation, distraction and compression, which promotes regeneration at the site of the bone defect. In addition to the use of the frames for acute fractures as a method of osteosynthesis, compression-distraction devices are used in the treatment of malunited fractures and nonunions, for arthrodesis and distraction of malunited bones [9, 14]. In the literature the title of the Ilizarov method covers the original design of the device and modified versions, including the use of wires and pins and pins only with circular supports, since they are based on the principle developed by G.A. Ilizarov [15].

The advantage with EFD includes the ability to quickly fix bone fragments in fractures of almost any anatomical location, low trauma, low blood loss, which allows for temporary osteosynthesis to be combined with other surgical interventions, which is important for patients with concomitant trauma and polytrauma. Extrafocal osteosynthesis can be performed by several trauma teams in the presence of fractures of different anatomical locations [10, 16]. Although there is controversy in the incidence of infectious complications during the staged treatment of fractures compared with primary intramedullary nailing temporary extrafocal osteosynthesis can be practical for preventing deep infection in open fractures [17, 18]. The availability of equipment for extrafocal osteosynthesis in most trauma hospitals and departments is another advantage with the techniques.

The disadvantages of temporary extrafocal osteosynthesis include the difficulty of optimal reduction in closed fractures, instability and a higher incidence of malunion [19]. With the advantages of using half-pins with EFD for temporary bone fixation, the constructs fail to provide sufficient fixation for ambulation and rehabilitation and cannot be employed for a long term. Also important for when using AVF is Regular checkups of the attending orthopaedic and trauma surgeon is essential for successful fracture consolidation with EFD [16, 17, 20].

The use of conservative methods including plaster cast and skeletal traction, is limited for lower limb fractures due to long-term immobilization and a greater risk of associated complications for patients with severe multiple and combined injuries. Conservative methods may fail to provide good bone fixation and are associated with a higher risk of instability and malunion [21]. Conservative methods were recommended for severe cases with ISS greater than 40 and unstable hemodynamics, considering the condition as a relative contraindication to EFD [10]. However, in recent years, the results of studies have shown successful use of EFD in severely injured patients with ISS > 40 [22]. The use of EFD used to repair fractures in patients with severe trauma and unstable hemodynamics is included in the draft of the Russian clinical guidelines for the management of patients with combined trauma and polytrauma, while conservative treatment is secured for extremely unstable patients. The advantages of temporary osteosynthesis using EFD explain facilitate the method to be applied in patients with severe and extremely severe condition, concomitant trauma and polytrauma. Temporary osteosynthesis is well consistent with the principles of “damage control” strategy, discussed below, which are now generally accepted in the treatment of patients with multiple injuries or polytrauma [23, 24].

In recent years, new external fixation systems have been developed to provide more reliable fixation [25] and potentially reduce the incidence of malunion with temporary osteosynthesis. Tibial fractures are a common indication for various types of osteosynthesis. Depending on the location, tibial fractures are divided into fractures of the tibial shaft (isolated or in combination with broken fibular), fractures of the proximal epiphysis (tibial plateau, tibial condyles) and fractures of the distal epiphysis (including pylon fractures). In addition, patellar fractures are sometimes classified as tibia fractures [12]. The 2018 the Orthopedic Trauma Association (OTA) and the AO Foundation provided fracture classification scheme including tibia [12]:

1. Tibial fractures:

- *Proximal end segment (41)*:
  - 41A — extraarticular (A1 — avulsion, A2 — simple metaphyseal, A3 — metaphyseal wedge or multifragmentary);
  - 41B — partial articular (B1 — split, B2 — depression, B3 — split depression);
  - 41C — complete articular (C1 — simple articular, simple metaphyseal, C2 — simple articular, wedge or multifragmentary metaphyseal, C3 — fragmentary or multifragmentary metaphyseal);
- *Diaphyseal segment (42)*:
  - 42A — simple (A1 — spiral, A2 — oblique, A3 — transverse);
  - 42B — wedge (B2 — intact wedge, B3 — fragmentary wedge);
  - 42C — multifragmentry (C2 — intact segmental, C3 — fragmentary segmental);
- *Distal end segment (43)*: classification of subtypes A, B and C is similar to that for proximal end segment fractures.

2. Fibula (4F):

- *Proximal end segment (4F1)*:
  - 4F1A — simple;
  - 4F1B — multifragmentry;

- *Diaphyseal segment (4F2)*:
  - 4F2A — simple;
  - 4F2B — wedge or multifragmentary;
- *Distal end segment (4F3)*: subtypes A and B are similar to those for the diaphyseal segment.

3. Malleolar segment (44):

- *Infrasyndesmotic fibula injury (44A)*:
  - 44A1 — isolated fibula injury;
  - 44A2 — with medial malleolar fracture;
  - 44A3 — with posteromedial fracture;
- *Transsyndesmotic fibula fracture (44B)*:
  - 44B1 — simple fibula fracture;
  - 44B2 — with medial injury;
  - 44B3 — with medial injury and fracture of the posterolateral rim (Volkmann's fragment);
- *Suprasyndesmotic fibula fracture (44C)*:
  - 44C1 — simple diaphyseal fibula fracture;
  - 44C2 — wedge or multifragmentary diaphyseal fibula fracture;
  - 44C3 — proximal fibula injury.

According to modern concepts, fracture fixation should be provided for patients with multiple and combined injuries on the first day of injury. The strategy with primary internal fixation or staged interventions (temporary external osteosynthesis and subsequent delayed definitive procedure) must be chosen individually, and unreasonable refusal of early definitive osteosynthesis in stable patients and long-term surgical interventions in unstable and borderline patients should be avoided. Dynamic assessment of clinical and laboratory parameters is essential for the timing of surgical intervention [26, 27]. However, there is a lack of research regarding the effectiveness of the approaches in patients with certain fracture sites [28].

The use of temporary osteosynthesis for tibia fractures and multiple and combined injuries

Conservative methods of fracture fixation including plaster cast are a good method for low-energy closed fractures of the tibia [29], but are associated with a high risk of complications in patients with multiple and combined trauma including hypostatic pneumonia, thromboembolic complications and bedsores. Long-term use of conservative techniques can lead to a higher risk of muscle atrophy and joint contractures, and inadequate circulation can result in a greater risk of nonunion, which is generally higher in polytrauma patients [30]. The use of internal osteosynthesis in patients with multiple and combined injuries can be limited because of the severe condition and the risk of “secondary impact” during long-term surgical interventions. External osteosynthesis with EFD is an option for this cohort of patients [16, 31, 27].

EFD is commonly used for tibia fractures is due to the anatomy, superficial location and the absence of muscles on 1/3 of the surface of the tibia. Extrafocal osteosynthesis may have additional advantages compared to internal techniques taking into account the relatively poor development of soft tissues and the high risk of open fractures due to the anatomical localization of the tibial bones. Wires and half-pins can be practical for tibia placement due to muscles of small thickness [21].

There is a paucity of data to compare the effectiveness of EFD and internal hardware with regard to external fixation as the definitive treatment. The results of treatment are difficult to interpret because many studies report patients with no differentiation of multiple, associated injuries, isolated fractures. Evidence regarding functional benefits of EFD or internal osteosynthesis and risk of complications remains controversial. A retrospective descriptive study showed a lower overall complication rate with use of transosseous osteosynthesis in patients with tibial fractures, as compared with conservative treatment, extramedullary and intramedullary osteosynthesis [32]. Major complications with transosseous osteosynthesis included bone displacement and osteomyelitis. External fixation can be associated with deformity at the level of a consolidated fracture, displacement of bone fragments and contractures of the ankle joint. Nailing can result in bone displacement and weak consolidation. Bone displacement, deformity at the level of a consolidated fracture and knee contracture were common complications observed in patients who received conservative treatment [32]. Good outcomes were reported in patients with complex fractures of the tibia treated with extrafocal osteosynthesis who developed local infection and broken wires [33]. Similar results were reported with EFD and circular supports used to treat patients with open tibial fractures and severely compromised soft tissues (Gustilo grade III). Good functional outcomes were reported with the use of the Ilizarov apparatus in patients with fractures of the proximal tibia [34].

Artemyev et al. reported the use of wires and half-pins of EFD for patients with open fractures of the tibial diaphysis (Gustilo grades I–II) complicated with pin tract infection (42.1 %) and delayed healing (1.8 %). The study included patients with isolated (75.4 %) and multiple and combined fractures. The authors first applied a temporary assembly using half-pins added with wires and half-pins for definitive phase without preliminary dismantling of the half-pin frame to reduce the length of surgical interventions. The use of half-pin devices as temporary fixation for short periods of transportation can be redundant and temporary transport immobilization followed by primary Ilizarov fixation can be more practical [15].

A higher rate of complications was reported in an earlier study of Ilizarov fixation of closed diaphyseal fractures of the tibia: 59 % of patients reported difficulties using the frame, 6 % developed pin tract infection, and 5 % had malunion of the fracture. The authors reported a lower incidence of knee pain with Ilizarov fixation [34]. A number of studies and meta-analyses have shown a higher incidence of infectious complications with EFD compared to IM nailing in patients with isolated open fractures of the tibial shaft and in polytrauma [35, 36, 37]. A meta-analysis suggested a higher incidence of fracture healing failures with EFD as compared with intramedullary osteosynthesis [36].

Outcomes of patients with severe tibial shaft fractures treated with external ring fixation were compared with those treated with internal fixation in a recent randomized trial (n = 254). Patients in the external fixation group were significantly more likely to have complications such as bone malalignment or rejection of the construct, while the incidence of other complications (deep infections, likelihood of amputation, nonunion or malunion, soft tissue problems), and the healing time were comparable [38].

Liu et al. reported a statistically higher incidence of superficial infections and malunion with external fixation as compared to intramedullary osteosynthesis in patients with open fractures of the tibia. Rejection of the construct was significantly greater with IM nailing. No statistically significant differences were reported for deep infections, the timing of fusion and nonunion rate [39]. Similar results were presented in a meta-analysis comparing the outcomes of ORIF and external fixation in patients with open pylon fractures: superficial infections, nonunion, osteoarthritis, and the need for bone grafting were statistically significantly more common in the external fixation group, and no differences were observed in the incidence of deep infectious complications and functional outcomes [40].

However, caution should be exercised in transferring the results of studies involving patients with isolated fractures to patients with multiple and associated injuries, since concomitant injuries have an impact on fracture healing [41]. In this regard, the outcomes of different fixation methods may differ in patients with isolated and multiple (combined) injuries. In a retrospective analysis Bondarenko et al. suggested that the lowest complication rate was observed in patients with tibial fractures treated with ORIF or IM nailing at the second stage of treatment, and EFD was useful for patients with severe open fractures [42]. Extrafocal osteosynthesis as temporary fixation could not be recommended for patients with less severe injuries in a stable condition [43].

Gasser et al. reported the results of a retrospective study of 210 patients with diaphyseal fractures of the tibia or femur (a total of 244 fractures) as part of multiple trauma (ISS 16 or more) or with severe soft tissue damage (open fractures grade II and higher according to the Gustilo classification). The authors compared outcomes using three fracture treatment strategies: ETC (primary intramedullary osteosynthesis), DCO (staged intervention including temporary external fixation followed by definitive osteosynthesis with an intramedullary screw) and external fixation as definitive osteosynthesis [43], and showed a statistically significantly higher complication rate in the definitive external fixation group (69 % of fractures) compared with DCO and ETC (23 % and 20 %, respectively). The differences persisted when adjusting for severity of condition at admission, which was higher in the definitive and DCO groups. Major complications included failure in consolidation or function of the fixation system, delayed fusion or nonunion, and infectious complications. Based on the results of the study, it was concluded that external fixation could be used as a temporary technique in patients with diaphyseal fractures of the long bones of the lower limbs to be followed by internal fixation after stabilizing the patient's condition [43].

There are limitations of the above studies including the retrospective nature and small sample sizes, as conducting randomized trials in these patient populations poses significant challenges [44, 45]. Special registers and analysis of the accumulated data can be practical to obtain more objective data. For example, results from the multicenter FROST registry (Fracture-Related Outcome Study for operatively treated Tibia shaft fractures) are currently awaited, which could potentially increase understanding of complication rates across modalities used to repair tibial fractures [46].

An optimal configuration and assembly of EFD for osteosynthesis of long bone fixation in patients with multiple and combined injuries or polytrauma are an open question. They must provide reliable bone fixation, and the ability to quickly apply the device is important for patients in serious condition. In the study by Alsmadi et al. it was noted that in patients with severe trauma (ISS more than 40), the use of single-plane half-pin EFD can be associated with a higher risk of complications (pin tract infection, migration of half-pins and formation of bedsores) as compared to two- and multi-plane devices, which may occur due to insufficient stabilization of the fracture. The differences were not found in patients with less severe injury (ISS less than 40) [22].

A decrease in the incidence of pin tract infection, formation of joint contractures was detected with use of the original design of a transosseous single-plane external fixation device [47]. Hybrid half-pin distraction-reduction constructs consisting of rings or half-rings connected by rods can be used for temporary osteosynthesis; however, further research is needed to evaluate their advantages and disadvantages in clinical practice [48, 49, 50]. Good results have been shown using EFD with sectors, bars and half-pins to repair fractures of long bones of the lower limbs [50].

The optimal time for conversion to definitive internal fixation in patients with tibial fractures as part of multiple and combined injuries is debatable at the moment. Research results remain conflicting. A recent study showed no statistically significant differences in complications (superficial or deep infection and nonunion) in patients who underwent definitive osteosynthesis at 7 days, at 7–13 days, or at 14 or more days, although the latter group had a longer surgical intervention to convert to definitive fixation [51].

Another study showed a statistically higher occurrence of infectious complications in patients with open tibial fractures repaired with external fixation for ⩽ 14 days compared with external technique used for the first 14 days or 15–28 days of injury with a relatively small number of patients with severe soft tissue injuries (Gustilo type III) being a limitation of the study [20].

DISCUSSION

Literature review has shown that there is no generally accepted strategy among the professional community for early mobilization of long bone fractures used as an anti-shock measure in polytrauma patients. The statistical data on errors, complications and treatment outcomes vary significantly and sometimes contradict each other, which indicates the complexity and multifactorial nature of the process that can have a decisive influence on the final clinical and functional outcome.

Internal and external fixation techniques are commonly used for the condition. The internal surgical intervention is produced according to the “do it and forget it” principle. The procedure cannot be produced for polytrauma patients due to the lack of necessary equipment or conditions for its implementation, the presence of fractures complicated by compromized soft tissues, neurovascular structures, infection which are common for polytrauma. The factors significantly limit indications for the use of the techniques. Another limitation with the techniques is the impossibility of creating optimal conditions for reparative osteogenesis while the patient is in bed and the difficulty of manipulating bone fragments if needed.

The transosseous osteosynthesis method, which can be performed in any modifications, does not have these disadvantages; it can be easily supplemented in a minimally traumatic form at the initial stages to solve a specific clinical problem. The advantages include the ability to create optimal conditions for bone consolidation during early functional loading and the ability to reduce the bone, which can be performed at a suitable time. The Ilizarov apparatus can be applied for all cases where internal fixation fails.

Therefore, the cases that cannot be treated with internal techniques on the “set and forget” principle, the Ilizarov fixation can be used as a temporary modification and the most universal and adaptable method of transosseous osteosynthesis, that can be supplemented to expand its functionality.

CONCLUSION

With high prevalence of tibial fractures in patients with multiple and combined injuries, the choice of optimal treatment remains an important issue. Currently, the most common is a differentiated approach is employed for repair of fractures in this cohort of patients with the choice of osteosynthesis technique being based on severity of patient’s condition and severity of injury. Stable patients benefit from early definitive internal fixation; borderline and severe cases are treated with “damage control” strategy where temporary external fixation is initially performed to be followed by a staged surgical procedure. However, certain issues regarding the use of extrafocal osteosynthesis for tibia fractures in patients with multiple and combined injuries, including the optimal timing for transition to definitive internal fixation, the possibility of using extrafocal osteosynthesis as a method of final fixation, optimal configuration and assembly remain open. The lack of data from high-quality randomized controlled trials in this area is an important limitation.

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Information about the authors:

Iskandar Yu. Khodzhanov — Doctor of Medical Sciences, Professor, Head of Department, prof.khodjanov@mail.ru, https://orcid.org/0000-0001-9420-3623;

Laziz A. Amonov — Resident doctor, lazizamonov0728@gmail.com, https://orcid.org/0009-0008-4553-8046;

Farrukh M. Makhsudov — Head of Department, maxsudov707F@gmail.com.