



Original article

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Combined osteosynthesis for tibial shaft fracture treatment

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Abstract

Introduction Widespread use of intramedullary and extramedullary implants, as well as external fixation devices, has demonstrated that current surgical methods are not always successful. **The study aimed** to assess the efficiency of a combination of transosseous osteosynthesis with intramedullary reinforcement using elastic titanium hydroxyapatite-coated rods (HA-rods) in long bone fracture treatment. **Material and methods** Medical records of 40 patients aged from 18 to 55 years with closed diaphyseal tibia fractures of A1-A3 type (AO/ASIF) treated with the Ilizarov transosseous osteosynthesis method combined with intramedullary elastic HA-coated wires were analysed. **Result** Ilizarov fixator removal was performed on average 45.3 ± 14.7 days after surgery. Radiological signs of bone union (immature callus, patterns of periosteal and endosteal stratifications overlapping the fracture line) were visible by week 3 to 4. **Discussion** Combination of the external fixator and intramedullary elastic HA-coated wires overcomes shortcomings of both external and internal means of fixation. External osteosynthesis provides advantages of the Ilizarov method: preservation of blood supply, absence of soft tissue injury, joint function and early weightbearing. Elastic intramedullary wires do not injure a. nutricia and mechanically stimulate endosteal and periosteal bone formation. **Conclusion** The advantages of combined osteosynthesis provide reduction of Ilizarov apparatus fixation time, reduction in the number of wires and half-pins in the frame assembly, stimulation of bone callus formation and prevention of secondary bone fragment displacement.

Keywords: Ilizarov, flexible intramedullary nailing, hydroxyapatite

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INTRODUCTION

The problem of urgent care for patients with injuries of the locomotor system is becoming increasingly important every year due to a growing number of severe injuries and following disability, especially in people of working age [1-4].

Widespread use of intramedullary and extramedullary implants, as well as external fixation devices, has demonstrated that current surgical methods are not always successful. The failure of treatment is related to iatrogenic lesion of surgical intervention, long-lasting duration of external fixation, delayed bone

union, the lack of comfort when using external fixation devices [5, 6].

It is recognized that the use of bioactive implants (elastic titanium rods and degradable intraosseous implants) is a promising approach to solve the problems of bone regeneration reducing the treatment time [7-9].

The study was aimed to assess the efficiency of a combination of transosseous osteosynthesis with intramedullary reinforcement using elastic titanium hydroxyapatite-coated rods (HA-rods) in long bone fracture treatment.

MATERIAL AND METHODS

This retrospective study was conducted at the Ilizarov National Medical Research Center for Traumatology and Orthopaedics (Kurgan, Russia) from April 2015 to December 2020. Medical records of 40 patients aged from 18 to 55 years old with closed tibial shaft fractures of A1-A3 Types (AO/ASIF classification) were analyzed.

The criteria for inclusion in the study were adults of working age operated on with a combined technique. We excluded from the study patients of other ages, open or complicated fractures.

After obtaining institutional review board approval, the data were collected about clinical and radiological

features of fractures, postoperative period, bone healing and functional recovery. Incidence, severity of complications and outcomes were assessed as well.

Surgical technique The surgery was performed under epidural anesthesia in all cases. The standard skeletal traction allowed reducing bone displacements. The intramedullary nailing was performed simultaneously at the time of fixator placement using two bent nails. Two oblique tunnels toward the medullary canal were formed in the metaphysis (proximal or distal, closest to the fracture) using a drill of 4-mm diameter [10]. Bent nails with bioactive coating (HA-coated elastic nails) were

easily inserted through the holes into the medullary canal under fluoroscopic control. We used 1.8-mm diameter titanium alloy nails with hydroxyapatite coating (Orthopediatrics nails modified by Metis Ltd, Tomsk, Russia). The nails were 20-40- μ m thick and had 2-8 % porosity, obtained by the method of anodic oxidation in arc mode [11]. This type of coating is presented by ultraporous system consisting of macro- and micropores from 50-100 nm to 1-2 μ m in diameter.

The intramedullary nailing was followed by application of the Ilizarov fixator (Experimental Plant of Russian Ilizarov Scientific Center "Restorative

traumatology and orthopaedics", Kurgan, Russia) according to the technology of transosseous osteosynthesis. It should be emphasized, that intramedullary nails did not interfere with wires or half-pins of the external fixation device.

Radiography in two standard views was taken before surgery, on the date of surgery, then every 2 weeks until bone union. The radiographs after frame removal were also evaluated.

Statistical analysis was conducted with AtteStat 12.0.5 software. Means and standard deviations were used to describe continuous variables.

RESULTS

Forty patients (9 females, 31 males) with a mean age of 29.6 years (range, 18-55 years) were included. Thirty three patients (82.5 %) underwent antegrade intramedullary nailing while seven patients (7.5 %) underwent ante- retrograde nailing (Figure 1). In seventeen cases (42.5 %) bent intramedullary nails enabled complete fracture reduction thus there was no need to insert additional olive wires in fractured bone ends at the level of intermediate external fixator rings. From the first days after the surgery, all patients were encouraged to walk independently with partial then total weight bearing using crutches. A postoperative edema of the injured leg disappeared within 2 to 3 weeks. The postoperative pain related to fracture was moderate and persisted until the end of the second week. It responded to simple nonsteroidal anti-inflammatory drug treatment.

Fourteen days after the surgery, radiographic check revealed that the contours of the fragmental ends were blurred. The endosteal bone callus became visible and well-expressed in the medullary canal parts close to the fracture line and along the intramedullary implant. Periosteal reaction was clearly visible and defined on bone fragments on both views. It was 2.8 ± 0.2 mm thick and 14.7 ± 1.3 mm long. In 24 cases, the periosteal callus was uninterrupted and overlapped the fracture line uniting proximal and distal fracture ends two weeks after the surgery.

After four weeks, radiographs showed signs of bone union: blurred image of fracture ends, a barely visible fracture line, high optical density of uninterrupted periosteal bone in antero-posterior and lateral views. In that period, 32 patients started to walk with 50 % or even full loading on the injured leg without assistive devices.

Two weeks later, bone union was noticed in all cases: the fracture line was barely defined; the image of the periosteal callus was large dense and compact. Weight-bearing walking was not associated with pain. We noticed a satisfactory recovery of ankle range of motion in all cases. Thus, an indication for frame removal was justified and the procedure was performed within the period of 32-62 days (in average, 45.3 ± 14.7 days) after the surgery in all patients without plaster cast immobilization. A month after frame removal, radiographs demonstrated bone callus remodeling with permeability of the medullary canal, anatomical alignment of the segment. There were no cases of intramedullary nail migration. The nails were removed 4 to 7 months after fixator removal in all cases without any difficulties.

Regarding complications, pin site infection observed in 9 cases (22.5 %) were treated successfully by local care in 7 cases. Antibiotics and wire removal were necessary in 2 patients. The preoperative range of motion in the knee or in the ankle joint recovered in all patients by the latest follow-up control. There were no neurological or vascular complications in this series.

Case report Male patient, 47 years old, was admitted with closed spiral shaft fracture of the distal third of the right tibia (Fig. 1 a). The surgery consisted of osteosynthesis of leg bones with the Ilizarov fixator and intramedullary reinforcement of the tibia using HA-coated elastic nails (Fig. 1 b). Radiological signs of bone union were evident by 30th day (Fig. 1 c). Thereby the fixator was removed without subsequent immobilization (Fig. 1 d). The patient was allowed full weight-bearing 2 weeks after frame removal. A follow-up control (1 year and 3 months after frame removal) demonstrated bone callus remodeling and normal radiological parameters of the injured tibia (Fig. 1 e, f).

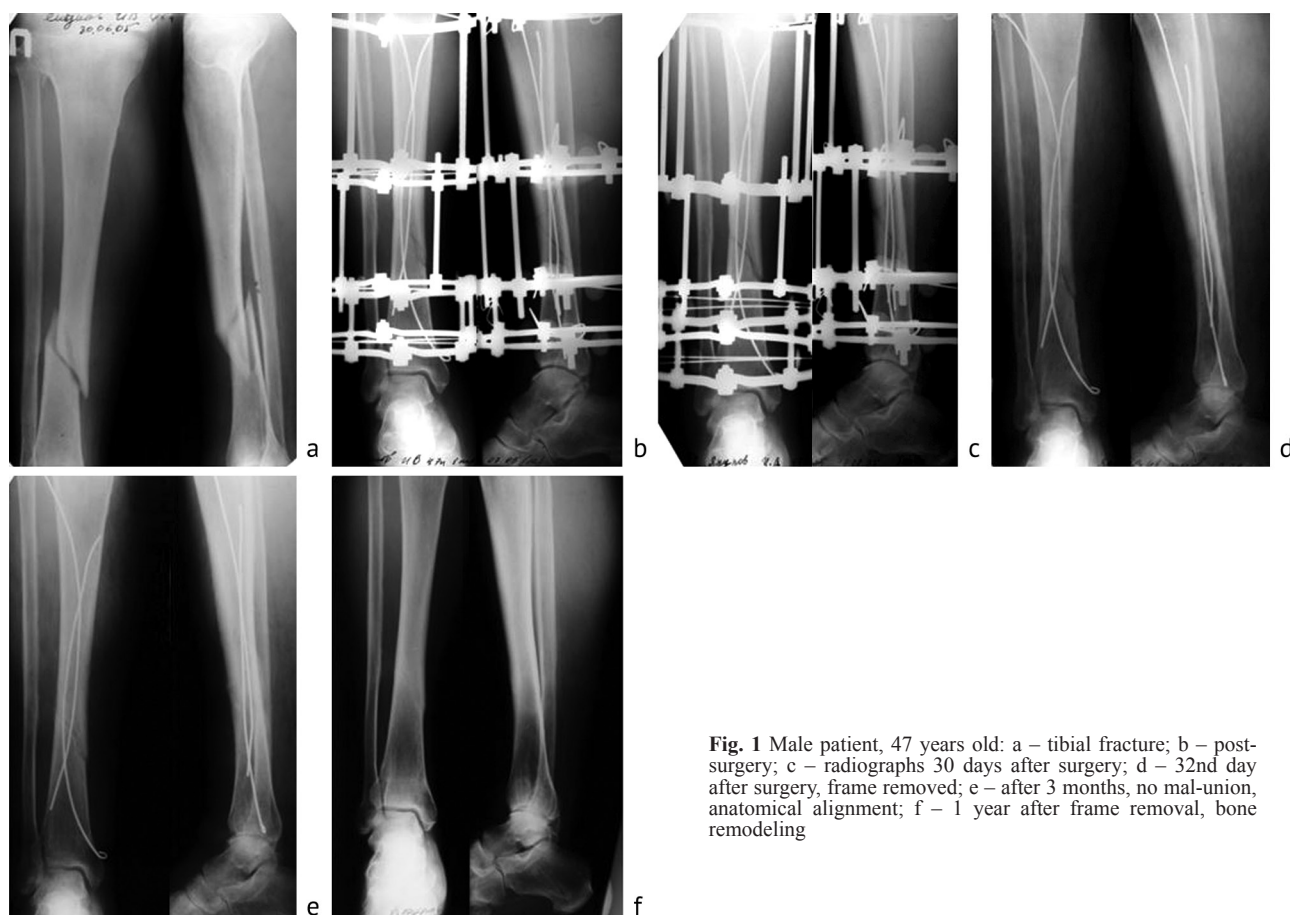


Fig. 1 Male patient, 47 years old: a – tibial fracture; b – post-surgery; c – radiographs 30 days after surgery; d – 32nd day after surgery, frame removed; e – after 3 months, no mal-union, anatomical alignment; f – 1 year after frame removal, bone remodeling

DISCUSSION

Tibial shaft fractures are one of the most common long-bone fractures and their incidence is estimated to occur in 4 percent of the senior population, representing 11.3 to 41.2 % of all skeletal fractures [12, 13]. Despite improvement of surgical methods, we can face delayed bone union and poor outcomes in tibial fractures. Obviously, the results of treatment are conditioned by both the fracture pattern and the method of treatment [14-17].

The extramedullary osteosynthesis can require large approach resulting in increased blood loss and additional lesion of surrounding the fracture soft tissues, worsens the blood supply to the fracture zone [14-16]. The main disadvantage of intramedullary osteosynthesis is significant damaging to intramedullary circulation, destruction of the bone marrow and endosteum. It potentially decreases bone regeneration [16, 17].

Ilizarov external fixation method is recognized for surgical treatment of tibial fractures. But its application is associated with long wearing (3 to 9 months) of external frame and related to this fact high incidence of pin-site infection. It remains uncomfortable for patients [18-20].

The combination of the external frame and HA-coated intramedullary elastic nails reduces inconveniences of both external and internal devices. External osteosynthesis provides all advantages of the Ilizarov method: preservation of circulation, little soft tissue damage, early joint function and weight-bearing [19-21]. Elastic intramedullary nailing does not injure a. nutricia and mechanically stimulates endosteal and periosteal bone formation [22]. We suppose that HA-coating enables biological support for bone union [23]. Morphological experimental studies performed at the Ilizarov Medical Research Institute of Traumatology and Orthopedics revealed bone tissue structure around intramedullary nails and along their entire length, which persists until the end of the experiment and ensures complete stability of bone fragments [24]. Thin elastic nails do not interfere with spongy bone tissue in the medullary canal. Bundles of osteoid collagen fibers are firmly fixed to the rough, nanostructured surface of the nails coating and connected to the endosteal surface of the bone improving stability of bone fragments. This coating of a nanostructured highly porous

hydroxyapatite layer provides high biocompatibility and osteointegration of implants into the surrounding bone preventing the development of fibrous connective tissue [25, 26]. Our small series demonstrated that this

combination of stability of bone fragment fixation and biological bone regeneration stimulation enables satisfactory outcomes of tibial fracture repair along with reduced external fixation time.

CONCLUSION

The results of the study revealed effectiveness of external fixation associated with elastic HA-coated intramedullary nailing. It is assumed that this combined technique ensures mechanical and biological favorable

environment for bone union. The outcomes allow recommending this minimally invasive technique for treatment of tibial shaft fractures which are considered as having compromised bone regeneration.

Conflict of interest Authors declare no conflict of interest.

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Contribution of the authors:

Klyshnikov KA – retrospective analysis of clinical material, assessment of treatment results.

Sazonova NV – assessment of traumatism in the Russian Federation, level of disability due to fractures of the tibia.

Popkov AV – development of technology for combined osteosynthesis, surgical treatment of patients.