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Management of posttraumatic long bone defects in the national orthopedic practice (literature review)

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We present present-day trends in the compensation of post-traumatic defects of long bones according to the Russian literature sources. The relevance of the problem due to the growth in the number of injuries in general and in the severity of trauma is highlighted. The basic directions in the solution of the problem of compensation of bone defects are shown. The merits and shortcomings of the available techniques as well as modern implantation materials based on hydroxyapatite, bioceramics and titanium alloys are analyzed. It has been pointed out that interdisciplinary interaction with the involvement of experts in the field of tissue engineering technologies, physicians, biologists, physicists, industry specialists and a sufficient financial support is needed to create optimal implants.
Keywords: long bone, defect, implant, Ilizarov apparatus, osteoinduction, osteoconduction, hydroxyapatite, titanium, bioceramics, bone plasty

Bone defect management is one of the priority issues in the medical, social and economic spheres in the Russian Federation [1, 2, 3, 4]. The pathology can be caused by fractures, cystic formations, tumors, false joints, infectious lesions and other conditions associated with the need for bone resection [3].

But above all, the relevance of the issue is related to the growth of high-energy trauma in the recent years and a large number of affected individuals with the consequences of polytrauma [5, 6, 7, 8].

At present, there are four directions in the reconstructive surgery of long bone defects: free bone grafting, management of defects with osteosubstituting and osteoinductive materials, non-free bone transport according to G.A. Ilizarov and combined methods.

Orthopedic traumatologists prefer the Ilizarov non-free bone plasty and vascularized or free autologous grafting in the defect, as the most effective and alternative methods [4].

The idea of bone defect compensation, proposed by GA. Ilizarov, opened a new page in osteoplastic surgery [9, 10, 11]. The method is based on the creation of compression-distraction forces at the site of bone fragments contact and dosed transport of an autologous non-free graft into the defect. The defect fills in by formation of distraction regenerate, which undergoes complete and organotypic restructuring over time and the recovers limb segment anatomy [12, 13].

Despite the obvious merits, many specialists are ambivalent about using the Ilizarov method in their practice. This is explained by long duration and multi-stage inpatient treatment, complexity and difficulty of osteosynthesis performance. In addition, continuous monitoring is necessary throughout the period of treatment and rehabilitation, which is often quite difficult due to remoteness of patients' residences from specialized medical institutions.

There are also a number of local problems that arise during and after treatment (decrease in the quality of life of patients, to a certain extent, as a result of the need for dressings, inconvenience in performing hygiene procedures, etc.) [14, 15, 16].

To reduce the hardware treatment period, an option was proposed and tested experimentally to use a combination of methods of locked intramedullary and external osteosynthesis with the Ilizarov apparatus. This technology has proven to be very efficient in clinical practice [17].

It was shown in a number of studies that the index of transosseous osteosynthesis in long bone defect management with the technology of combined osteosynthesis was equal to the index of distraction, 10.2 ± 0.78 days / cm; however, according to other authors, in the same situation, the period of hardware

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fixation corresponded to 160 ± 29.8 days. Despite the fact that there is no acceleration of the process of organotypic rearrangement of distraction regenerate, there is a decrease in hospital stay and improvement of quality of life [17, 18].

In turn, the use of free autologous grafting with arteriovenous shunting is difficult to perform and requires high-tech equipment. The use of this technique is limited by the volume of the donor material. There is also a high risk of complications such as hematomas with further development of purulent-inflammatory process, damage to blood vessels and nerves, thrombosis of arteriovenous anastomosis, resorption of the graft, the risk of fracture in the donor zone, and cosmetic defect. Also, this type of plasty is associated with a high risk of nonunion and pathological fractures of the replants due to delayed osteo- and angiogenesis [15].

A worthy alternative to auto- and allografts are artificial substitutes of bone tissue. Their non-biological origin significantly reduces the risk of infection transmission, as well as the occurrence of undesirable immune responses.

Currently, the experts in the field of traumatology and orthopedics have been actively searching in this direction. Implantation materials applied up-to-date feature various properties.

Some of them have high mechanical strength, thus providing a reinforcing effect on the implant-bone site, and, as a rule, are non-biodegradable. Others, on the other hand, are biodegradable, sufficiently plastic and are designed to fill in bone cavities of complex shape and varying volume [19, 20]. Both should be biocompatible with bone and surrounding tissues, have osteoconductive and osteoinductive properties, be a matrix for vascular ingrowth or induce angiogenesis. Materials should not exert a toxic effect on the surrounding tissues, or on the body as a whole [21].

Implants with high strength characteristics, withstanding high mechanical loads, have been introduced in traumatology and orthopedics. As a rule, these are non-biodegradable materials: ceramics, metals, carbon-based and composite or polymeric materials [22, 23, 24, 25, 26].

Depending on their effect on the reparative ability of bone tissue, there are:

• Biotolerant materials: stainless steel, chrome-cobalt alloy. Such materials are separated from surrounding tissues in the body by a powerful fibrous capsule and do not have any effect on the term of consolidation [27];

• Bioinert materials: titanium, zirconium, gold, corundum ceramics, glassy carbon, titanium nickelide, tantalum, niobium, aluminum oxide, which do not affect the period of defect management. However, the reparative processes associated with the formation of bone tissue occurs on the surface of the implant material without the formation of a fibrous capsule [27, 28, 29];

• Bioactive materials: implants coated with hydroxyapatite (HA), tricalcium phosphate ceramics, and similar compounds. The stimulating substance ensures the interaction of the implant with surrounding tissues and accelerates the processes of bone formation. The substrate plays the role of a scaffold and determines the mechanical properties of the implant [26, 27, 29,30].

Titanium is currently the most bioinert material. Porous titanium, due to its high hardness, cavitation, corrosion and erosion resistance, non-magnetization, biochemical and biomechanical compatibility with the human body is often used as an endofixator and as a three-dimensional matrix for the formation of osteogenic tissue [31, 32, 33]. At the same time, low osseointegrative function requires covering the surface of implants made of such material with bioactive substances. Most often, hydroxyapatite is used for this purpose, which promotes the formation of collagen and elastin fibers, effects the differentiation of cell elements in the osteogenic direction [34, 35, 36].

The use of various composite materials containing hydroxyapatite showed efficacy in bone defect management under experimental conditions. The authors noted that restoration of bone integrity with the formation of a continuous cortical plate occurs, on average, at 90 days [37, 38, 39, 40, 41, 42].

However, other researchers who experimented on similar defects by the methods without the use of additional materials, managed to achieve bone restoration within the same period (92.7 days, fixation index 22.1 ± 0.8 days / cm) [43, 44].

The use of a matrix with multipotent mesenchymal cells [45], as well as three-dimensional grafts (osteogenic cells, hydroxyapatite, proteoglycan)

[46] can provide reduction in the timing of bone support area formation in the defect zone. However, the production of such materials requires complex expensive equipment.

Summarizing all of the above, it can be concluded that the existing technologies for bone defects management with the Ilizarov methods of non-free bone grafting is associated with a long (about a year) osteosynthesis in external apparatus, the complexity of the biomechanical process and a significant number of complications.

The shortcoming of composite and cell-based implants is their insufficient mechanical strength, despite good osteoinductive properties and the possibility of filling defects of a complex shape.

The use of implant materials based on bioinert metals and their alloys, carbon and bioceramics, allows achieving mechanical strength in the defect zone. But their widespread use is difficult due to the inability to cover the defects of complex configuration and the lack of sufficient induction properties. The latter is solved by covering the implantation materials with bioactive substances.

The novel technologies related to 3D prototyping and providing a personalized approach (additive technologies) which allow creating implants that possess all the necessary properties for defect filling have been under investigation recently. These technologies should be aimed in the future at ensuring fast and high-quality manufacturing of biologically active implants for a specific patient.

Generally, the creation of a new generation of implants that meet all the necessary requirements is possible only with a comprehensive interdisciplinary approach that would involve experts in the field of tissue engineering technologies, doctors, biologists, physicists, industry specialists and with a sufficient financial support.

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