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Surgical treatment of bone defects of the extremities after gunshot injuries

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According to various authors, in wartime, injuries to the limbs as a result of combat trauma account for 44 to 70 % of all musculoskeletal injuries. In approximately 80 % of wounded, gunshot bone fractures are characterised by the presence of a bone defect of varying size. Despite certain difficulties and complications in the treatment of bone defects, orthopedic surgeons have quite effective methods of treating this pathology. However, a promising area of treatment is the technology of manufacturing an individual implant using 3D-printing of the scaffolds of existing bone defects and double-plate osteosynthesis with autobone grafting. Objective. To present the possibilities of surgical treatment of wounded with bone defects of the limbs as a result of gunshot wounds. The preliminary results of surgical treatment of 2 wounded with diaphyseal bone defects due to gunshot wounds of the upper and lower extremities, who were treated in the trauma department of the Military Medical Clinical Centre of the Eastern Region in 2022–2024, were analysed. To improve the functional results of treatment, we proposed three stages of rehabilitation treatment and implemented appropriate rehabilitation measures. To replace bone defects, we used the «double-plating» method with autobone grafting and individual implants made by 3D-printing. The results of surgical treatment were evaluated by clinical, radiological and functional data. It was found that fixation with two plates in combination with autogenous bone grafting ensures stable fixation, which helps to consolidate the bone defect and restore the functional capacity of the limb, and the use of individual implants made by 3D-printing allows to replace the lost bone tissue, which leads to the restoration and preservation of the functional state of the damaged limb.

Проаналізовано літературні джерела та виявлено, що в умовах війни ушкодження кінцівок унаслідок бойової травми сягають від 44 до 70 % від усіх травм опорно-рухового апарата. Майже у 80 % поранених вогнепальні переломи кісток характеризуються наявністю кісткового дефекту різної величини. Незважаючи на певні труднощі й ускладнення, під час лікування дефектів кісток в арсеналі ортопедів-травматологів є досить ефективні методики. Наразі перспективним напрямом є технології виготовлення індивідуального імплантата за допомогою 3D-друку каркасів наявних дефектів кісток і накістковий остеосинтез двома пластинами з аутокістковою пластикою. Мета. Навести можливості хірургічного лікування осіб із дефектами кісток кінцівок унаслідок вогнепальних поранень. Подано попередні результати хірургічного лікування 2 військовослужбовців із діафізарними дефектами кісток унаслідок вогнепальних поранень верхньої та нижньої кінцівок, які лікувалися у травматологічному відділенні військово-медичного клінічного центру Східного регіону у період 2022–2024 роки. Для вдосконалення функціональних результатів запропоновано три етапи відновного лікування та впроваджено відповідні реабілітаційні заходи. Для заміщення кісткових дефектів використовували метод «double-plating» з аутокістковою пластикою й індивідуальні імплантати, виготовлені методом 3D-друку. Результати хірургічного лікування оцінювались за клініко-рентгенологічними та функціональними показниками. Встановлено, що фіксація двома пластинами в поєднані з аутогенною кістковою пластикою забезпечує стабільність фіксації, що сприяє консолідації кісткового дефекту та відновленню функціональної спроможності кінцівки, а використання індивідуальних імплантатів, виготовлених методом 3D-друку дозволяє замістити втрачену кісткову тканину, що приводить до відновлення та збереження функціонального стану ушкодженої кінцівки. Ключові слова. Дефекти кісток, індивідуальні імплантати, 3D-друковані каркаси, остеосинтез, вогнепальні поранення, бойова травма, верхня та нижня кінцівки.

Keywords. Bone defects, individual implants, 3D-printed scaffolds, osteosynthesis, gunshot wounds, combat trauma, upper and lower limb

Introduction

According to various authors, in war conditions, limb injuries due to combat trauma reach from 44 to 70 % of all musculoskeletal injuries. Almost 80 % of wounded individuals have gunshot fractures of bones characterized by the presence of a bone defect of various sizes, primary due to the action of a high-energy projectile, or secondary bone resection against the background of the development of an infectious process [1–5].

Despite certain difficulties and complications during the treatment of diaphyseal and metadiaphyseal bone defects, there are quite effective methods of treating this disorder in the arsenal of orthopedic traumatologists. In particular, the use of various bone transplantation techniques (autologous, allogeneic, xenotransplantation and artificial bone transplantation), the Masquelet technique (induced membrane formation), distraction osteogenesis according to G. A. Ilizarov, fibula transplantation (on a vascular pedicle or with a skin flap) and the method of longitudinal osteotomy of the fibula with subsequent transport [6–10]. The listed methods of treating bone defects in patients with gunshot wounds have their indications, complications, disadvantages and advantages and are widely used in modern war conditions [11–15].

A promising direction is the technology of manufacturing an individual implant using 3D printing of frames of existing bone defects, which, depending on their type, are divided into single-component and composite [16–20].

In general, the treatment of gunshot wounds of the extremities requires a comprehensive approach, including bleeding control, early stabilization of the affected structures, infection control, reconstruction of soft tissues and bones, as well as further rehabilitation and physiotherapy. Choosing the optimal treatment strategy for wounded with gunshot bone defects is a difficult clinical task due to the high risk of complications and duration [21].

Purpose: to present the possibilities of surgical treatment of wounded with bone defects of the extremities due to gunshot wounds.

Material and methods

The preliminary results of the surgical treatment of 2 wounded with diaphyseal bone defects due to gunshot wounds of the upper and lower extremities, who were in the traumatology department of the Military Medical Clinical Center of the Eastern Region in the period 2022–2024, are presented. The study materials were approved by the local Bioethics Committee of the MMCC of the Eastern Region (Protocol No. 3 dated 18.03.2024). Patients involved in the study signed an informed consent. The mechanism of injuries was due to the impact of high-energy weapons.

Indications for surgery: presence of a gunshot wound to the limb, diaphyseal bone defect, healed soft tissue defects in the area of reconstructive and restorative intervention, absence of signs of general and local infection. Contraindications: signs of an infectious process, severe post-traumatic stress disorder, alcoholism and drug addiction.

To determine the nature of the damage, the classification of bone defects proposed by K. D. Tetsworth et al. [22] was used, according to which bone defects were defined as D3B (size from 4 to 8 cm) and D3C (defects larger than 8 cm).

Patients underwent standard general clinical and biochemical blood and urine tests, bacteriological assays, determination of the level of acute-phase proteins in blood, standard radiography, spiral computed tomography (CT), electroneuromyography (ENMG), and ultrasound examination of the vessels of the extremities (US) [21].

To improve the functional results of patients, we proposed three stages of restorative treatment and implemented appropriate rehabilitation measures:

– I — treatment using the principles of Damage control orthopedics. Patients underwent primary and repeated surgical treatments, fasciotomy, administration of extra-focal osteosynthesis devices, VAC therapy, and antibacterial spacers;

– II — conversion of the treatment method was carried out by performing reconstructive and restorative surgical intervention with replacement of bone defects;

– III — treatment in rehabilitation centers of Ukraine.

To replace bone defects, the “double-plating” method with autologous bone grafting [23–25] and individual implants made by 3D printing were used. Titanium alloys were used as orthobiological material [16, 18–20].

Surgical interventions were performed according to the traditional method using standard preoperative preparation of the patient and anesthesia. The choice of the patient’s position on the operating table and surgical access depended on the anatomical localization of the bone defect, the features and tasks of the surgical intervention. For autologous bone grafting, a tricortical graft from the wing of the iliac bone was used, which was harvested according to the standard method in sizes corresponding to the existing bone

defect. In the postoperative period, antibiotic and thromboprophylaxis were performed, analgesic and symptomatic therapy was prescribed, and wound healing was monitored. Typical orthoses were used to immobilize the limb for the appropriate period necessary for adequate bone consolidation and prevention of contracture formation in adjacent joints.

The results of the surgical intervention were evaluated according to clinical, radiological and functional data (time course of bone consolidation, range of motion in the limb joints, degree of muscle atrophy, signs of infectious process, peripheral nerve neuropathy, patient satisfaction with the results).

Results

The patients were men with upper and lower limb injuries due to gunshot wounds. When using the "double-plating" method with autogenous bone grafting, two 3.5 mm bone compression plates were used, located in two perpendicular planes.

Clinical example No. 1

A 30-year-old patient G. was hospitalized to the traumatology department of the MMCC of the Eastern region with a diagnosis of a penetrating gunshot wound of the right shoulder with a gunshot fracture of the right humerus. Post-traumatic neuropathy of the radial nerve (Fig. 1).

As a result of staged surgical treatment, a defect in the humerus diaphysis measuring 4.5 cm was formed. After preoperative preparation, open reduction was performed under general anesthesia, bone-on-bone osteosynthesis with two plates with bone autoplasty of the right humerus (Fig. 2, a, b).

The postoperative period was uneventful, the sutures were removed on the 14th day after the intervention, the wound healed with primary tension. He underwent follow-up observation in the department 2 months after the operation. During the examination, there was a postoperative scar without any abnormalities, atrophy of the muscles of the right upper limb of 1.5 cm, positive time course of muscle strength recovery and areas of innervation of the radial nerve, the amplitude of movements in the adjacent joints was physiological. Control radiography 2 (Fig. 3, a) and 12 months (Fig. 3, b) after the operation showed positive bone consolidation. When using individual implants made by the 3D printing method, titanium alloys were used as an orthobiological material.

Clinical example No. 2

A 31-year-old patient A., hospitalized to the traumatology department of the MMCC of the Eastern region with a diagnosis of gunshot shrapnel penetrating wound of the right tibia at the border of the middle and lower third with damage to the tibial artery. After staged surgical treatment, a defect in the diaphysis of the right tibia measuring 9.68 cm was formed (Fig. 4).

After preoperative preparation under general anesthesia, open reduction was performed, intramedullary osteosynthesis with a rod, and an individual titanium implant with bone autoplasty of the defect of the right tibia was installed (Fig. 5).

The postoperative period was uneventful, the sutures were removed on the 14th day after the intervention, the wound healed with primary tension. He underwent a follow-up observation in the department 3 months after the operation. During the examination, the postoperative scar area was unremarkable, there was 2 cm of muscle atrophy of the right lower limb, positive time course of muscle strength recovery, and the amplitude of movements in the adjacent joints was physiological. Control radiography 3 (Fig. 6, a) and 12 months (Fig. 6, b) after the operation showed positive bone consolidation.

Discussion

The use of two plates is aimed at creating additional stabilization of the fracture fragments, both during primary fixation and surgical treatment of false joints [23–25]. In our study, two compression plates were used for rigid fixation of a bone autograft against the background of a bone defect resulting from a gunshot wound. In our opinion, the proposed fixation has certain advantages over traditional fixation methods due to:

– fixation stability. The installation of two plates in perpendicular planes provides a greater density of attachment of the bone autograft areas. This allows for better stabilization of the damaged bone segment, promotes physiological consolidation of the bone in the "bone-autograft" area, which is the key to early

Fig. 1. Photoprint of the radiograph of patient G. with a gunshot fracture of the right humerus

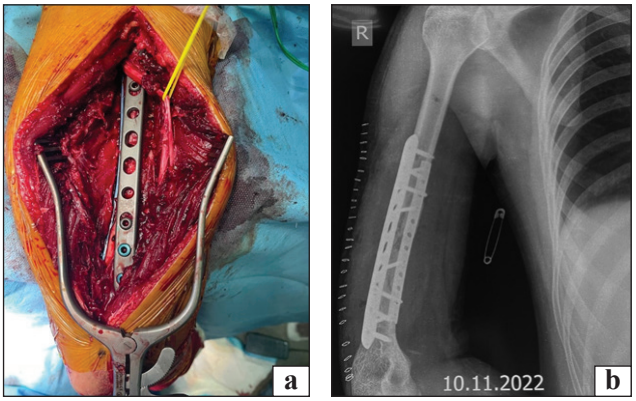

Fig. 2. Appearance of the surgical wound during the intervention (a) and photoprint of the radiograph of the right humerus after the operation (b)

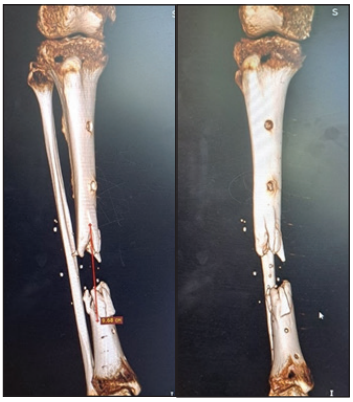

Fig. 4. Photoprints of SCCT images at the stage of preoperative planning in patient A. with a defect of the diaphysis of the right tibia

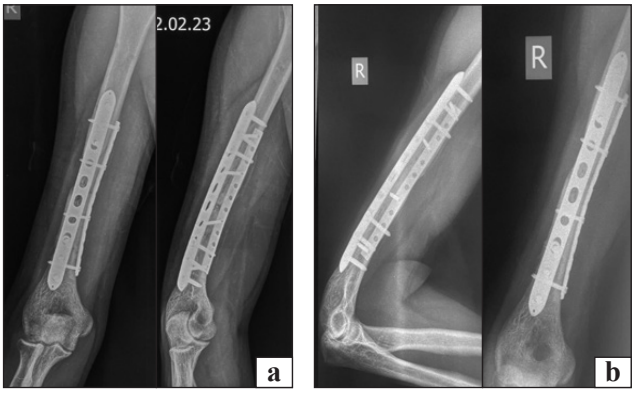

Fig. 3. Photoprints of radiographs of patient G. 2 (a) and 12 (b) months after open reduction, bone-on-bone osteosynthesis with two plates with bone autoplasty of the right humerus

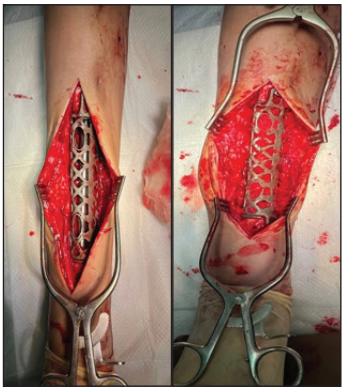

Fig. 5. Appearance of the surgical wound during open reduction, intramedullary osteosynthesis with a rod and installation of an individual titanium implant with bone autoplasty of the defect of the right tibia

dosed loads and prevention of the development of delayed union and false joint;

– uniform load distribution. Osteosynthesis with two plates allows for a more uniform distribution of the load on the bone, reduces stress on individual bone areas and avoids the occurrence of stress areas, which prevents the development of complications such as destruction of the metal structure;

– regenerative potential. Gunshot fractures have a longer consolidation period than closed ones and are more often complicated by delayed union, development of a false joint and infectious complications. Therefore, the use of autologous bone grafting allows not only to repair the bone defect, but also serves as a source of bone regeneration.

A significant limitation to the use of two bone plates for bone defects due to gunshot fractures is certainly infection. Therefore, the key to the safe use of this method is careful selection of patients for surgical intervention.

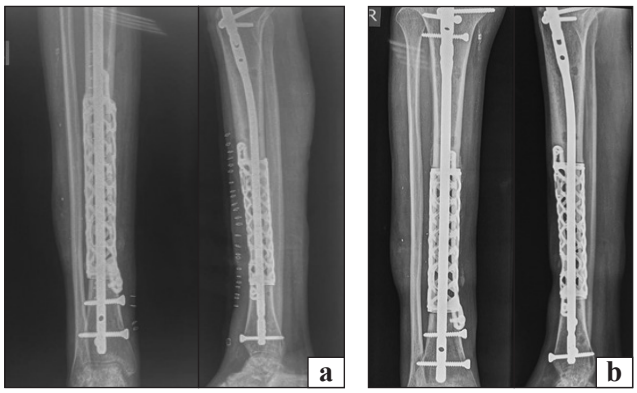

Fig. 6. Photoprints of radiographs of patient A. 3 (a) and 12 (b) months after open reduction, intramedullary osteosynthesis with a rod and installation of an individual titanium implant with bone autoplasty of the defect of the right tibia

The use of individual implants manufactured by 3D printing has recently become increasingly popular. Thus, in recent decades, the issue of the influence of scaffolds (frameworks) on osteogenesis and osteointegration has been actively studied. Today,

scaffolds are obtained from natural and synthetic bioceramics, biopolymers, metal biomaterials or their alloys, as well as various composite biomaterials. The literature provides a comprehensive overview of the composition, mechanical and biological properties, 3D printing technology, advantages and applications of various single-component scaffolds, which are used in particular in orthopedics and traumatology for the repair of bone defects using 3D printing [16, 19, 20]. From our point of view, it is advisable to use individual implants made by 3D printing from titanium alloys for the repair of bone defects caused by gunshot wounds.

Conclusions

Bone defects due to gunshot wounds are an important problem of modern military traumatology.

Fixation with two plates in combination with autogenous bone grafting provides stability of fixation, which contributes to the consolidation of the bone defect and restoration of the functional capacity of the limb.

The use of individual implants manufactured by 3D printing for bone defects due to gunshot wounds allows replacing lost bone tissue, which leads to the restoration and preservation of the functional state of the damaged limb.

Conflict of interest. The authors declare the absence of a conflict of interest.

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SURGICAL TREATMENT OF BONE DEFECTS OF THE EXTREMITIES AFTER GUNSHOT INJURIES

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