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Problems and successes in the combined application of the Ilizarov and Masquelet technologies

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Abstract

Introduction Based on the assessment of the problems and effectiveness in the use of the induced membrane and bone transport techniques, a new technological solution was proposed. It combines the methods of Masquelet and Ilizarov for restorative treatment of patients with bone defects and nonunion. **Materials and methods** The combination of the technologies was successfully applied for filling bone defects in the conditions of active purulent infection and its remission in 24 patients. Patients of the first group (n = 17) had bone defects in the conditions of the osteomyelitic process remission. In the second group of patients (n = 7), the osteomyelitic process was active. The combined technology of bone grafting included segment reconstruction in two stages. At the first stage of treatment, a sanitizing treatment of soft and bone tissues in the area of the defect and nonunion was performed followed by spacer implantation and transosseous fixation of bone fragments with the Ilizarov apparatus. During the second operating session, the spacer was removed, and after osteotomy (corticotomy), the fragment(s) were transported according to Ilizarov. Empirical antibiotic therapy against a wide range of pathogens was started after the verification of the microbial tests of the biomaterial and the determination of sensitivity to antibiotics, the correction of antibiotic therapy was carried out. **Results** The postoperative wounds in the area of the implanted spacers healed by primary intention in the first group. In two patients of the second group (29 %), purulent fistulas were formed by the time the spacers were removed, and the wounds healed by secondary intention. The duration of distraction in the first group was 45.4 ± 9.8 days. Bone transport in the patients of the second group continued 52.8 ± 5.3 days. The duration of fixation of the segments with the device was 195.1 ± 9.9 days in the first group and 181.8 ± 11.4 days in the second group. Discussion At the initial stage of the combination of the Masquelet technique and non-free Ilizarov bone grafting, the risks of the activity of a purulent process remain if the debridement of the infection nidus is not radical, implanted spacers with a prophylactic dose of antibiotics are massive, and the antibiotic therapy is empirical. The formation of an induced membrane with bactericidal activity at the second stage of surgical treatment, the creation of favorable conditions for bone transport, adequate sanitation of the purulent focus, and targeted antibiotic therapy ensure a stable suppression of the activity of the purulent process. **Conclusions** Surgical rehabilitation of patients with segmental infected defects results in bone defect filling with distraction regenerates undergoing complete organotypic restructuring, which eliminates the likelihood of deformities or fractures at the level of newly formed bone areas and reduces the risk of recurrence of the osteomyelitis process.

Keywords: combination, Masquelet, Ilizarov, induced membrane, distraction regenerate

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INTRODUCTION

The history of the use of the Ilizarov non-free bone grafting and the Masquelet technique of induced membrane (IMT) since the 80s of the XX century proves their effectiveness for filling acquired bone defects [1, 2, 3].

The Ilizarov bone transport implies a discrete and controlled transfer of a blood-supplied autograft with a preserved soft tissue cover in the inter-fragmentary gap for filling a bone defect with a newly formed bone tissue [2, 4].

The Masquelet technique involves segment reconstruction in two operating sessions. At the first stage of treatment, a radical sanitizing treatment of soft tissues and necrotic bone is performed, followed by implantation of a polymethyl methacrylate cement spacer into the formed defect. The bone segment is frequently fixed with external fixators. After 6 to 8 weeks, the spacer is removed and the defect is filled with free bone autografts from the iliac crest [3].

It must be recognized that for elimination of bone defects, including in the conditions of purulent infection, no ideal bone-plastic materials and reconstructive surgical interventions that do not have shortcomings have been found.

Supporters of transosseous osteosynthesis recognize certain disadvantages of external fixation, primarily associated with a decrease in the quality of life of patients, long-term and multi-stage treatment, the risk of inflammation of soft tissues in the area of transosseous fixation elements, the development of contractures of adjacent joints [2, 5].

According to the literature, the use of Masquelet technology is limited in elderly patients due to a long and incomplete restructuring of massive implants, risk of pathological fractures, infectious complications, problematic wound healing, including in donor areas, and bone nonunion [3, 6, 7].

Comparative analysis of published treatment results with the use of the Ilizarov bone transport (37 studies, mean defect size 6.9 cm) and outcomes of Masquelet IMT (41 studies, mean defect size 6.32 cm) revealed that the results achieved with the techniques do not have significant differences in restoring the anatomical integrity of the limb, risks of improper union of fragments and infectious complications [8].

In our opinion, a differentiated and rational combination of different approaches and alternative surgical technologies may optimize the treatment process, reduce the duration and stages of osteosynthesis, and decrease the risks of possible complications [9].

We have experience of successful management of congenital pseudarthrosis of the lower leg bones in the combined conditions of an induced membrane and Ilizarov non-free bone grafting. According to our data, the combination of the Masquelet technology and Ilizarov bone transport provides an optimal replacement material amount for compensation of the lost bone mass and reduces the risk of nonunion recurrence in the long-term in patients with congenital pseudarthrosis [10].

The aim of the work was to search for new technological solutions to improve the results of surgical rehabilitation of patients with acquired bone defects in the conditions of active purulent infection and its remission.

MATERIALS ANS METHODS

The work is based on a retrospective and prospective studies of the results of restorative treatment of 24 patients who underwent a combination of Ilizarov and Masquelet bone grafting techniques.

The patients were divided into two groups. The first group of patients (17 cases) had bone defects in the conditions of remission of the osteomyelitic process and was treated in a specialized department of the Federal State Budgetary Institution Ilizarov NMRC for TO. The second group (7 cases) was patients with bone defects and active manifestations of the osteomyelitic process, who were treated at the Central Clinical Hospital No. 23, Yekaterinburg.

All patients were of working age, from 18 to 62 years old, had an acquired etiology of nonunion and defects. Their injuries were sustained one to 7 years (3.7 ± 1.5 years) ago. All patients had previous failed treatments; eight of them (33 %) underwent multiple operations and they could not indicate the exact number of operations and did not have complete medical documentation with them. The anamnesis and reviewing of medical records found out that at different stages of treatment the patients were treated with intramedullary locking nailing, plating, and transosseous osteosynthesis (Table 1). The injuries, repeated and failed surgical interventions, resulted in scars and adhesions of soft tissues to bone fragments.

Table 1

Patients' characteristics

Parameters	Group1		Group 2	
	No	%	No	%
Number of patients	17	100	7	100
Females	3	18	1	14
Males	14	82	6	86
Injury due to traffic accidents	11	65	6	86
Household injury	4	24	1	14
Production site injury	1	5.5	0	0
Postresection defect	1	5.5	0	0
Previous treatment				
Intramedullary locking nails	4	24	5	71
Plating	9	53	0	0
External fixation	10	59	2	29
Clinical and anatomical disorders				
History of osteomyelitis	17	100		
Active inflammation			7	100
Nonunion and defects of tibial bones	11	65	7	100
Defects and nonunion of the femur	4	24	0	0
Defects of the humerus	1	5.5	0	0
Defects of the ulnar shaft	1	5.5	0	0
Defects of class I (< 2 cm)	1	5.5	0	0
Defects of class II (2-5 cm)	1	5.5	0	0
Defects of class III (5-10 cm)	8	47	6	86
Defects of class IV (> 10 cm)	8	47	0	0

The condition in 17 patients was remission of the osteomyelitis process. All patients of the second group had an active inflammatory process with purulent discharge from fistulas and wounds. In active purulent process in patients of the second group, osteomyelitis was classified according to Cierny-Mader as type IV (diffuse osteomyelitis) with damage to the entire diameter of the bone and loss of segment stability [11].

Injuries and failed surgical interventions resulted in nonunion and defects of the tibia in 18 patients (75 %). Defects and nonunion of the femur were revealed in 4 patients. A 7-cm defect in the humerus was verified in one patient, a defect in the diaphysis of the ulna over 5 cm was detected in one patient.

The defects were classified according to Karger C et al. [12]. Class I (< 2 cm) defects were found in one patient, class II (2-5 cm) defects were in 14 clinical cases, class III (5-10 cm) defects were detected in 8 patients. In one patient, a class IV (>10 cm) defect was diagnosed.

According to Shevtsov et al. [13], the nonunion were classified as pseudoarthrosis-defects with anatomical shortening in 14 patients (58 %) and without anatomical shortening in 10 clinical cases (42 %). The anatomical shortening of the segments ranged from 1 to 7 cm (4.6 ± 2.2).

The study used descriptive statistics methods (the mean value and its standard deviation).

RESULTS

Combination of the Ilizarov and Masquelet bone grafting technologies included the reconstruction of the segment in two operating sessions. At the first stage of treatment, a radical sanitizing treatment of soft tissues and bones in the area of the defect and pseudarthrosis was performed followed by fixation of the segment with the Ilizarov apparatus. The assembly of the apparatus implied the possibility, after the removal of the spacer, of performing osteotomies (corticotomies) of fragments to manage the post-resection defect by lengthening of the fragments. Biomaterials were taken from the zone of the formed defect and compromised tissues. Empirical antibiotic therapy against a wide range of pathogens was initiated, including methicillin-resistant strains of staphylococci. After verifying the microbial cultures of the biomaterial and determining the characteristics of antibiotic sensitivity, the antibiotic therapy was corrected.

A polymethyl methacrylate cement spacer was implanted into the interfragmentary gap. The spacers were of a cylindrical shape and extended in the interfragmentary gap that measured from 3 to 6 cm long (4.2 ± 1.1). One prophylactic dose of gentamicin or vancomycin was added (Fig. 1).

One clinical case with a subtotal tibial defect received a 13 cm spacer into the interfragmentary diastasis.

The conventional use of Masquelet bone grafting involves the removal of the cement spacer after 6 to 8 weeks and the filling of the interfragmentary diastasis with a spongy autograft [14].

The duration of spacer implantation ranged from 26 to 51 days (39.0 ± 7.7). In two cases, the delay in the second stage of treatment was 2 to 3 months. Different terms in the implementation of the second stage of treatment were due to the fact that there were patients on outpatient basis from various regions of the Russian Federation and organizational difficulties associated, among other things, with COVID-19. At the same time, according to the literature, the secretion of membrane-induced growth factors is longer, with peak values being reached between weeks 4 and 6 after spacer implantation [15].

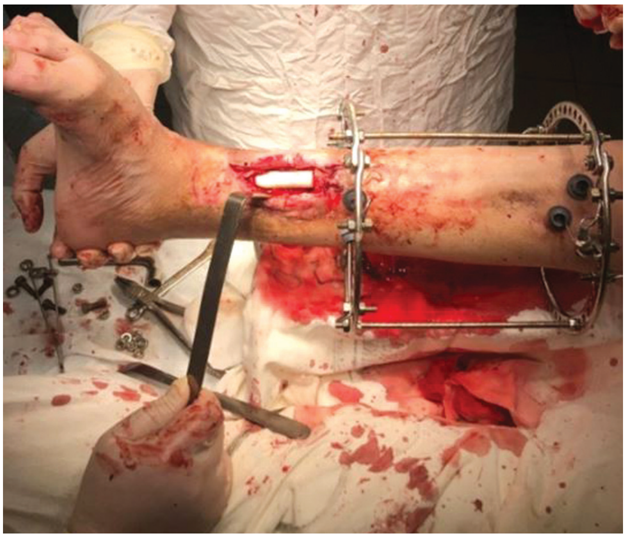

Fig. 1 Intra-operative photo of the tibia and an implanted spacer in the gap

The wounds in the area of implanted spacers healed by primary intention in all group 1 patients. Purulent fistulas were formed by the time the spacers were removed in two patients of group 2 (29 %), and the wounds healed by secondary intention.

Clinical case from group 1

Female patients, 60 years old, had subtotal defect of the tibia that was replaced with a 13-cm spacer. The limb was fixed with the Ilizarov apparatus. The wound healed with secondary intention, there was little purulent discharge (Fig. 2).

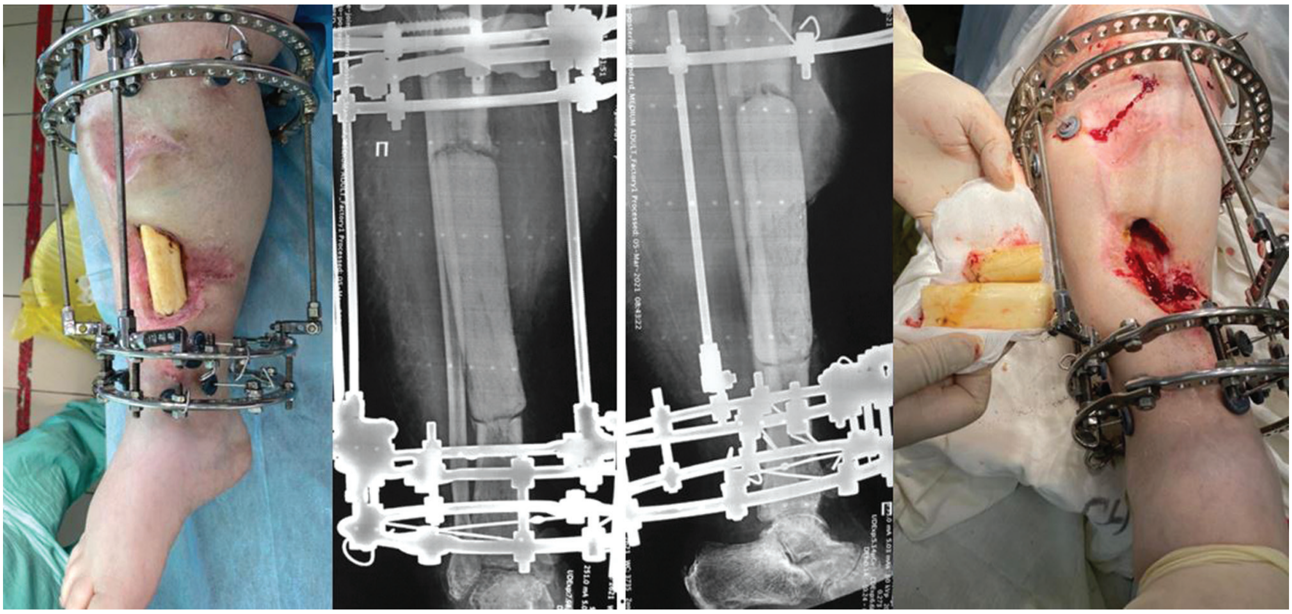

Fig. 2 Photos and radiographs of female patient M before implantation and after removal of the spacer

After removing the spacer, antibiotic therapy was prescribed according to the culture tests and the sensitivity of the microflora to antibiotics. It was supposed to fill the subtotal defect of the tibia by formation of polyfocal distraction regenerates and lengthening of the opposite fragments. The defect was replaced by polyfocal lengthening of fragments [16]. After performing osteotomies of the opposite fragments, distraction was started on the 10th day; the rate of distraction was 0.75 mm for lengthening of the proximal fragment and 0.5 mm per day for lengthening of the distal one. The patient currently continues treatment (Fig. 3).

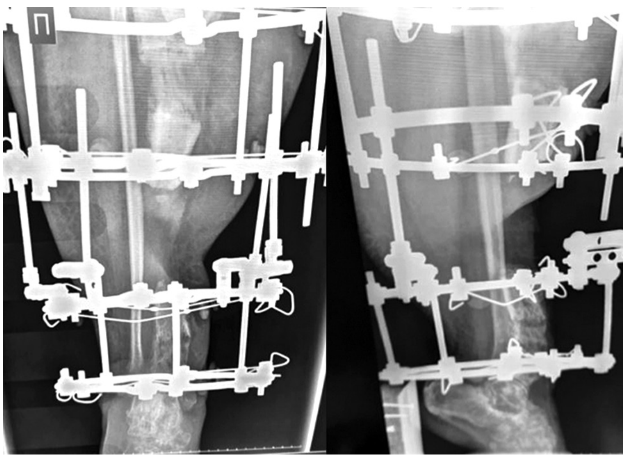

Fig. 3 Radiographs of the patient's M tibia in the course of treatment

In another patient of group 2, the postoperative wound healed by primary intention but the sinus was formed by week 6 after the implantation of the spacer. The culture tests from the wound detected *S. Aureus* (MRSA) and *Enterobacter spp*. After removal of the spacer and repeated radical debridement, the postoperative wound healed by primary intention, while the membrane was not damaged. The tibial defect was repaired by lengthening the proximal fragment.

The duration of distraction for the transport of the fragments in group 1 was 45.4 ± 9.8 days. The transport of fragments in group 2 was performed within 52.8 ± 5.3 days. By the time of docking with the opposite fragments, the endplates were not formed. Howevr, after the removal of the spacers, the ends of the fragments were additionally sparingly, and in the presence of fistulas in two clinical cases, additionally radically processed. The absence of endplates enabled to perform closed reduction and adaptation of the end sections of bone fragments. At the junction of the fragments, compression was maintained until consolidation of the fragments was achieved. Manipulation to maintain compression between the ends of the fragments was performed by 1.0 mm once in 10-14 days. The duration of fixation of the segments with the device was 195.1 ± 9.9 days in group 1. In group 2, the fixation period took 181.8 ± 11.4 days. In all patients who completed the treatment, the restoration of the integrity and support of the damaged segment was achieved. At follow-up visits, residual anatomical shortening from one to 6.0 cm was detected in three patients (3.3 ± 1.8 cm).

DISCUSSION

The Masquelet technology creates favorable conditions for tissue regeneration, including distraction osteogenesis. There is evidence that the membrane formed around the spacer is adequately supplied with blood, is rich in mesenchymal stem and epithelial-like cells, fibroblasts, myofibroblasts, and produces growth factors (VEGF, TGF-beta 1) and morphogenetic proteins BMP-2 and BMP-7 [17-19].

According to the literature, the induced membrane has antimicrobial activity, which is associated with the presence of antioxidant chemicals locally secreted with growth factors that can cause degradation of the DNA of microorganisms, leading to cytolysis. The presence of certain peptides can also cause a bacteriostatic effect by inhibiting cell division. Another proposed mechanism is the presence of local peptides that can inhibit the secretion of bacterial biofilm and therefore prevent the adhesion of microorganisms to surrounding surfaces [20].

Previously, we presented the results of successful treatment of 10 patients with lower leg defects in the absence of active infection using a combination of the Masquelet technology and Ilizarov non-free bone grafting. We did not observe an exacerbation of the purulent process in any of the cases. We chose radical debridement of a potential focus of infection as the main task. We used the time interval between surgical sessions to verify the microbial agents in the harvested biomaterial and to select the targeted antibiotic therapy [21].

However, according to the literature, elimination of the antibiotic from a polymethyl methacrylate cement spacer into the surrounding tissues does not exceed 10 % of the initial dose [22].

According to Masquelet A.C., the induced membrane technology is not a treatment for bone infection. It is a misconception that the use of a spacer saturated with antibiotics is able to completely suppress infection without thorough debridement [23].

Authoritative authors opine that persistent suppression of purulent infection is ensured by radical surgical debridement of the focus and local creation of an antibiotic depot in compromised tissues [8, 24].

Probably, in our study, the healing of postoperative wounds by secondary intention and the formation of fistulas with purulent discharge in the area of implanted spacers in two clinical cases of the second group was associated with a non-radical surgical debridement of the purulent nidus, an insufficient dose of antibiotic, and the massive implanted spacer.

The literature reports that the use of Masquelet bone grafting as monotechnology is unable to arrest the purulent process in 8.09-8.8 % of clinical cases [8, 25].

Our results are quite consistent with the literature data. At the first stage of the combined use of technologies in the conditions of active purulent infection, it was not possible to stop the purulent process in two patients. Removing the spacer, re-debriding the infection nidus, and conducting etiotropic antibiotic therapy achieved remission of the purulent process. It should be noted that the combination of Ilizarov and Masquelet technologies provides favorable conditions for distraction osteogenesis. The transport of a non-free bone autograft is carried out without technical problems through a tunnel, the walls of which are an induced membrane, through previously compromised tissues, that have been surgically debrided prior to fragment transport [26].

We did not detect any exacerbation of the osteomyelitic process in our groups of patients at the stages of fragment lengthening and subsequent fixation. However, according to our preliminary data, non-radical sanitation of the focus, implantation of massive spacers with a prophylactic dose of antibiotics does not guarantee stable suppression of purulent infection.

CONCLUSION

At the initial stage of using the combination of the Masquelet technique and Ilizarov non-free bone grafting, the risks of purulent process activity remain if surgical debridement of the infection nidus is not radical, implantation spacers with a prophylactic dose of antibiotics are massive, and antibiotic therapy is empirical. At the stages of transosseous osteosynthesis, there are low risks of inflammation of soft tissues in the area of transosseous elements. In our patients, infection of soft tissues in the area of the pins, which would have required their removal and elimination of the focus of pin osteomyelitis, was not encountered. Ilizarov bone transport is carried out in the conditions favorable for histogenesis. There is a biologically active capsule around the transported non-free autograft and the newly formed bone tissue, the basis of which is an induced membrane with osteoinductive and bactericidal properties. The formation of an induced membrane

(IMT) with bactericidal activity at the second stage of surgical treatment, the creation of favorable conditions for the lengthening of fragments, adequate sanation of the purulent focus, and targeted antibiotic therapy ensure a stable suppression of the purulent process activity. Surgical rehabilitation of patients with segmental infected defects resulted in filling of bone defects with distraction regenerates undergoing a complete organotypic restructuring. It eliminates the likelihood of deformities or fractures at the level of newly formed bone areas and reduces the risk of recurrence of the osteomyelitic process.

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