New technologies

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New technology for humerus reconstruction with a free fibular autologous graft in hypotrophic pseudarthrosis

D.Yu. Borzunov[1,2], D.S. Mokhovikov[3], S.N. Kolchin[3]

[1]Ural State Medical University, Ekaterinburg, Russian Federation
[2]Central City Clinical Hospital, Ekaterinburg, Russian Federation
[3]Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation

Introduction Modern technologies for treating patients with fractures of the humerus using metal structures (various options for free and non-free bone autoplasty, dynamic plates DCP, LCP, intramedullary locked osteosynthesis, external fixation devices) do not always guarantee restoration of the integrity of the segment. Patient's fibula as an autologous osteoplastic material assists in achieving adequate contact of the ends of the fragments, prevents secondary displacement, and creates conditions for bone formation. **Material and methods** We retrospectively evaluated the results of restorative treatment in four patients of the same sex, with the same etiology of pseudoarthrosis, and failure of previous operations in whom a free fibular autograft was used for humerus reconstruction at one medical institution. A new method of humerus reconstruction in hypotrophic pseudoarthrosis patented in the Russian Federation is described in detail. **Results and discussion** Capabilities of any dynamic internal system are limited in time and effects. The external fixation device allows for controlled fixation of the fragments of the humerus and maintains it in the required mode until the consolidation of the fragments. The fibular graft, implanted into the bone marrow cavity in the area of the junction of fragments, plays the role of an interface and additionally reinforces the humerus, preventing secondary displacement that may be caused by compression forces created with the fixator. The autogenous osteoplastic substance formed in interfragmental gap and along the periphery is a substrate for local osteoplastic intervention that stimulates osteogenesis. **Conclusion** A free bone autograft shaped as a cylindrical fibular fragment s implanted into the zone of active angio- and osteogenesis. The coaptation zone of fragments of the humerus is reinforced with an implant intraosseously along its length to eliminate the risk of secondary displacement of the fragments by creating compression with an external fixator. The use of an external fixation device provides contact in the area of the bone wound and maintains compression between the ends of the humerus fragments until bony fusion.
Keywords: humerus, hypotrophic pseudoarthrosis, free bone grafting, autograft, Ilizarov apparatus

INTRODUCTION

The relevance of the problem of treating patients with fractures of the humerus is associated with a high risk of nonunion [1]. Conservative treatment results in two to 10 % of nonunion, and pseudoarthrosis is detected in 30 % of patients after surgical treatment [2]. Repeated and failed surgical interventions lead to pathological symptoms that the injured upper limb may feature and that pose difficulty for further restorative treatment, including nonunion, interfragmental gap, changes in the shape and architectonics of bone tissue of fragments, their eburnation, atrophy, a combination of sclerosis and osteoporosis, cicatricial changes in soft tissues, neurological disorders, and contractures of the adjacent joints. Aseptic pseudarthrosis with atrophic fragments is referred to a special group. According to the proposed surgical protocols, a prerequisite for restoring the integrity of the humerus is careful treatment of the ends of the fragments to create an adequate contact between them, opening of the bone marrow canals for resection of the eburned ends and the use of free allo- and autografts [1, 3]. Bone grafting with iliac wing grafts is preferred; LCP plates are used as metal implants [3]. Additionally, protocols for treating patients with pseudarthrosis of the humerus include cell therapy using osteopotent cells, growth factors and scaffolds. Recognizing the effectiveness of BMP and PRP therapy, the authors, however, do not consider it as an independent option or treatment protocol [1, 4]. Therefore, in order to restore the anatomical and functional integrity of the humerus, it is necessary to perform high-quality, stable and controlled osteosynthesis with adequate coaptation of the ends of the fragments. The use of modern treatment technologies and metal structures for various options with free and non-free bone autoplasty, dynamic plates DCP, LCP, intramedullary locked osteosynthesis, external fixation devices does not always guarantee the restoration of the integrity of the segment.

It is possible to achieve adequate contact of the ends of the fragments, to prevent secondary displacement,

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to create conditions for bone formation with the help of an autologous osteoplastic material using the patient's fibula. The idea of using the fibula for humerus reconstruction is not new; it was described by Wright et al. in a clinical and biomechanical research [5]. Previously, we had some experience and successful use of a free massive fibular graft under the conditions of transosseous osteosynthesis to replace post-resection defects of the humerus in patients with Ewing's sarcoma or humerus lesions due to echinococcosis [6, 7]. There are data in the literature on a fairly wide clinical use of free fibular grafts in patients with pseudarthrosis of the humerus. DCP and LCP plates were used for osteosynthesis of fragments of the humerus [2, 3, 8].

The **aim** of the work is to present a new technology of a free fibular graft under the conditions of transosseous osteosynthesis to restore the integrity of the humerus in patients with hypotrophic pseudarthrosis in the absence of active purulent infection.

MATERIAL AND METHODS

We retrospectively evaluated the results of restorative treatment in four patients with the use of a free fibular autograft for humerus reconstruction.

All patients were treated in the same department of the Ilizarov Centre in the period from 2016 to 2018. All were females, aged from 23 to 67 years, who had a post-traumatic etiology of pseudarthrosis. Two of them had road accidents, and two patients had a domestic trauma. All patients had previously been unsuccessfully operated on once or twice.

Patients were admitted for treatment with implanted intramedullary interlocking nails; the distal pavilion of the nail was dynamized in one patient. The metal implants were unstable. In two patients, in addition to locked nails, plating was used and failed. According to the anamnesis, the duration of nonunion ranged from one to seven years.

Nonunions were classified as atrophic (non-viable) according to the classification of Weber T.W. and Cech O. [9]. According to the classification of V.I. Shevtsov et al. [10], the nonunions of the humerus were of defect-pseudarthrosis types with anatomical shortening (two patients) and without anatomical shortening of the humerus (two patients). Anatomical shortening of the humerus was 2 and 5 cm, respectively in two patients. Two patients had persistent combined contractures of the shoulder and elbow joints with severe limitation of the range of motion and function of the upper limb.

For the reconstruction of the humerus, a free fibular autograft, sized 8 (n = 3) to 10 cm (n = 1), was used. Reamers with a diameter of 10 and 11 mm were used for reaming the medullary canal and the area of pseudarthrosis.

Fixation of the humerus with the Ilizarov apparatus continued for three to four months until consolidation of the fragments.

Technical performance was patented in RF as the method of humerus reconstruction in hypotrophic pseudarthrosis [11]).The intramedullary nail was removed according to the standard protocol, after which, using reamers, a canal was formed, the diameter of which exceeded the graft diameter by 1.0 mm. The autograft was taken from the diaphysis of the fibula, 9 cm proximal to the level of the ankle joint. The autograft length was 8–10 cm. Plates if they were present were removed. After hemostasis, the wound was sutured in layers. The large tubercle was palpated, m. supraspinatus was found and the middle portion of the tendon was devided along its fibers. An awl with a T-shaped handle was used to open the medullary canal of the humerus. The largest transverse dimension of the autograft was measured. A reamer equal in diameter to the largest transverse size of the autograft passed into the medullary canal and widened it. The area of pseudoarthrosis was opened closely, the endplates at the ends of the humerus fragments were destroyed, and the ends of the fragments were adapted. Under control of the image intensifier, the distal and proximal humeral fragments were coapted with the restoration of the segment axis so that the medullary canal of the proximal fragment was a continuation of the medullary canal of the distal fragment. An external fixation device was used to reduce the fragments. Holding the fragments in the achieved position, the reamer passed through the medullary canal of the distal fragment to a depth of at least 10 mm and no more than to the level of the metaphysis. The autograft was implanted closely and antegrade into the medullary canal of the humerus, bridging intramedullary the pseudoarthrosis zone. In the formed canal, the autograft was placed so that one end of it was located in the proximal fragment, and the other in the distal fragment. The autograft was inserted into the medullary canal tightly; if necessary, it was hammered in without rotational movements. At the same time, a counter-support was created for the contralateral elbow joint to avoid diastasis between bone fragments. Thus, the bone fragments of the humerus were stabilized with an autograft serving as a bone pin. Compression efforts at the junction of the fragments were maintained with an external fixation apparatus until consolidation of pseudoarthrosis was achieved. Compression was performed along the axis of the fragments by 0.75–1.0 mm every 10–14 days. After fusion of the fragments, the apparatus was dismantled.

Case report Patient T., 53 years old, was admitted with complaints of pain in the left shoulder area, pathological micromobility of fragments. Diagnosis: hypotrophic pseudarthrosis of the left humerus, condition after locked intramedullary osteosynthesis; chronic autoimmune thyroiditis. Fractures of the right clavicle and left humerus were obtained in an accident a year before. Surgical treatment was performed at her residence hospital with LIO of the left humerus and osteosynthesis of the right clavicle. No fusion of the left humerus was achieved. Clinical examination found linear normotrophic scars along the left humerus area, not adhered to the underlying tissues and bone fragments. No shortening or atrophy of the soft tissues of the left humerus was found. Movement in the shoulder joint: abduction 70°, flexion 80°, extension 25°, with muscle strength 3 points. Movement of the elbow joint: flexion 40°, extension 180°, painless, with muscle strength 4–5 points. Abnormal mobility of fragments of the humerus in the middle third of the diaphysis was detected, the manipulation was painful. No neurovascular disorders were detected (Fig. 1, a).

Removal of the intramedullary fixator was performed first followed by closed reaming of the pseudarthrosis zone, antegrade implantation of a free autograft cylinder-shaped fibular fragment. The fragment was harvested from the diaphysis of the fibula. The graft was shaped as a cylindrical bone pin. From the proximal end of the humerus, from the side of the head, the insertion hole was formed. A canal was formed in the humerus, which corresponded in size and geometrically was a continuation of the medullary canal of the humerus. The bone marrow canal was opened with a reamer (diameter 10 mm), equal in diameter to the largest transverse size of the autograft, and the bone marrow canal was entered. The medullary canal was expanded and the zone of pseudarthrosis was reached. The area of pseudoarthrosis was exposed in a closed way, the endplates at the fragments of the humerus were destroyed, the ends of the fragments were adapted with the formation of osteoplastic material localized along the periphery of the adaptation zone of the fragments. Using the Ilizarov apparatus, the proximal and distal fragments of the humerus were reduced to the anatomically correct position; the bone marrow canal of the proximal fragment was a continuation of the medullary canal of the distal fragment. Holding the fragments in the achieved position, a reamer passed along the medullary canal of the distal fragment to a depth of 10 mm. The autograft was inserted antegrade into the medullary canal of the humerus formed, bridging the intramedullary pseudoarthrosis zone. The segment was fixed with the Ilizarov apparatus. In the postoperative period, dosed compression of the pseudarthrosis zone was performed by 0.75–1 mm every 10–14 days (Fig. 1 b). Three months later, bone union in the area of pseudarthrosis was visualized, and the Ilizarov apparatus was dismantled (Fig. 1 c).

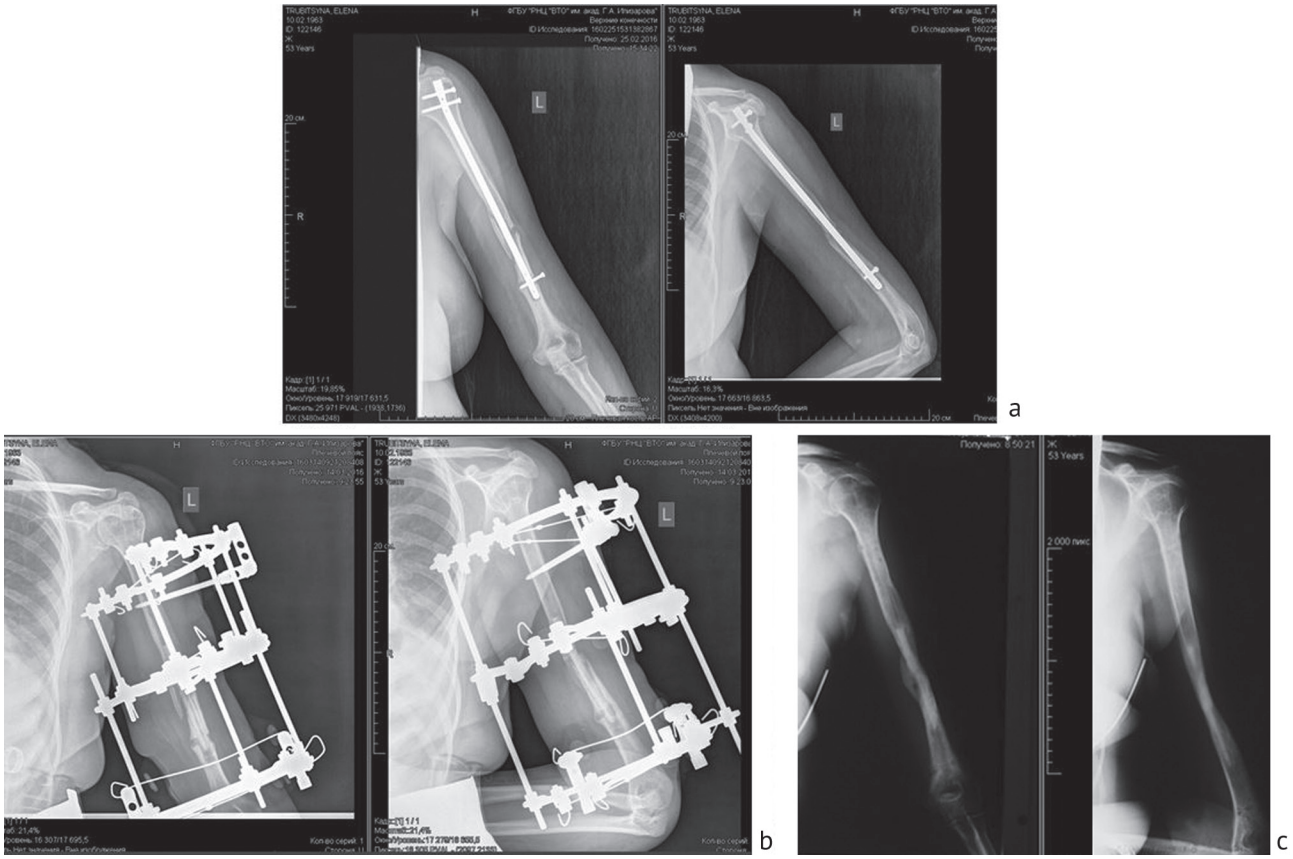

Fig. 1 Radiographs of the humerus in patient T: *a* – before treatment; *b* – in the course of treatment; *c* – three months' follow-up

DISCUSSION

According to a number of reports, the absence of rigid and stable fixation of fragments of the humerus is one of the key reasons for nonunion after reconstructive interventions [12–15]. A prerequisite for achieving consolidation is adequate contact between the ends of the fragments and compression throughout the entire nonunion zone [16]. In our opinion, the capabilities of any dynamic immersion system (intramedullary or extramedullary) are limited in time and impact. The advantages of external fixation in these issues are obvious and undeniable. The external fixation device provides controlled fixation of the fragments of the humerus and maintains it in the required mode until consolidation of the fragments.

At the same time, there are certain shortcomings of transosseous osteosynthesis, associated, first of all, with an impairment in the quality of life of patients, risk of soft tissues inflammation in the area of transosseous fixation elements, possible contractures of adjacent joints, etc. [17, 18]. But these shortcomings, if reduction in the duration of treatment, adherence to the epidemiological regime and full rehabilitation of patients are achieved, are justified and surmountable. There is an idea of stabilizing fragments, including in a lengthening procedure, by combining external fixation and intramedullary reinforcement with wires [19]. However, it is generally accepted that the most optimal osteoplastic material is autogenous bone. The fibular graft, implanted into the bone marrow cavity in the area of fragments junction and co-apted, plays the role of a bar and additionally reinforces the humerus, preventing secondary displacement when compression forces are created by the device. Closed reaming of the medullary canal results in additional autogenous osteoplastic material in the interfragmental gap and along the periphery of the nonunion zone that stimulates osteogenesis.

Reaming of the medullary canal and the pseudarthrosis zone in revision interventions is considered by some authors as a mechanism that triggers a cascade of angiogenesis processes, remodeling of the vasculature of the segment under reconstruction, and ensures bone fusion [20].

The products of reaming have osteogenic potency [21, 22], fill the interfragmental gap, which along with restoration of angiogenesis, increased periosteal blood supply and remodeling of the vascular network [20, 23] eliminates the need for an open revision of the nonunion zone [24, 25] and decreases the invasiveness.

CONCLUSION

The essence of this new technology is as follows. A free bone autologous fibular graft shaped as a cylindrical fragment is implanted into the zone of active angio- and osteogenesis. The zone of coaptation of fragments of the humerus is reinforced with an intramedullary implant along its length to exclude secondary displacement of the fragments when compression with an external fixation device is applied. The external fixation device provides adequate contact in the area of the bone wound and maintains compression between the ends of the humerus fragments until bony fusion.

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Information about the authors:

1. Dmitry Yu. Borzunov, M.D., Ph.D.,
Ural State Medical University, Ekaterinburg, Russian Federation,
Central City Clinical Hospital, Ekaterinburg, Russian Federation,
Email: borzunov@bk.ru
2. Denis S. Mokhovikov, M.D., Ph.D.,
Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation
3. Sergey N. Kolchin, M.D., Ph.D.,
Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation