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Variant of bone restoration in humeral nonunion with a free fibular autograft in the conditions of transosseous osteosynthesis

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Abstract

Introduction Failures in surgical rehabilitation of patients with humeral fractures result in the formation of a multicomponent complex of pathological symptoms, including nonunion or bone defect, changes in the shape and length of humeral fragments, development of persistent angiotrophic disorders of the upper limb and contractures of the shoulder and elbow joints. Despite the effectiveness of using metal implants, there are risks in surgical osteosynthesis in complex anatomical and functional lesions.

The **purpose** of the work was to demonstrate a new technology of bone plasty with free fragments of the fibula as a bone-plastic material for restoring the integrity of the humerus in bone nonunion and defects in the conditions of transosseous osteosynthesis and transosseous fixation of the grafts with wires.

Materials and methods A free autograft of the fibula shaped as a cylindrical fragment, which was resected proximally to the ankle joint level at 8.0-9.0-cm distance, was used as a bone plastic material. The fibula graft was fragmented intraoperatively. Fragments were implanted along the periphery of the humerus fragments overlapping of the pseudarthrosis site. Free autografts of the fibula were transosseously fixed with wires. A wire/half-pine Ilizarov apparatus with three external supports was placed to fix the segment.

Discussion The "gold standard" material for bone plasty is autogenous bone. If defects and pseudoarthroses of the humerus are located in the distal metaepiphysis, the application of the fibular cylinder-shaped fragment with intraosseous reinforcement of the humeral bone is technically difficult. Open co-aptation of the humeral fragments with adequate contact between them and application of the optimal autogenous bone-plastic material which overlaps the pseudarthrosis zone to increase the volume of bone mass ensure the restoration of bone regeneration in the pseudarthrosis zone. External fixation is optimal for fixation of bone fragments and grafts.

Conclusion The originality of the developed technology lies in the use of several free bone autografts from the fibula implanted along the periphery of the humeral fragments junction. The area of active osteogenesis is thus created due to the combined effect of open co-aptation of the ends of the humeral fragments with resection of the endplates and bone autogenous grafts that overlap the problematic area. Additional transosseous fixation of bone autografts with wires ensures the stability of free grafts. Controlled fixation of humeral fragments with compression and adequate contact of the fragments is achieved with the Ilizarov apparatus.

Keywords: nonunion, pseudarthrosis, humerus, fibular autografts, transosseous osteosynthesis, Ilizarov, bone plasty material

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INTRODUCTION

The Federal State Statistics Service of the Russian Federation reports that upper limb injuries accounted for 34.6 % to 34.9 % of all skeletal injuries and their consequences in the period from 2020 to 2023. Unfortunately, not all patients with skeletal injuries of the upper limb had satisfactory treatment outcomes. Thus, humeral nonunion and bone defects are detected in 2 up to 30 % of cases following humeral fractures [1]. As a rule, due to failures of surgical rehabilitation, patients develop a multicomponent pathological symptomatic complex, including nonunion or bone defect, changes in the shape and length of humeral fragments, persistent angiotrophic disorders in the upper limb, and contractures of the shoulder and elbow joints [2]. Pathological processes reflect themselves in the architecture of the bone tissue of the humeral fragments, such as their eburnation and atrophy, while the fragments have a mosaic combination of sclerosis and osteoporosis areas throughout [2].

According to the current literature, orthopaedic trauma surgeons prefer dynamic DCP/LCP plates and intramedullary locked osteosynthesis as fixation means. At the same time, while recognizing the effectiveness of internal metal structures, the authors acknowledge the risks of surgical intervention failures and, in some cases, failures of osteosynthesis in complex anatomical and functional injuries of the humerus [1, 3–6].

Purpose The aim of the work was to demonstrate a new technology of bone plasty with free fragments of the fibula as a bone-plastic material for restoring the integrity of the humerus in bone nonunion and defects in the conditions of transosseous osteosynthesis and transosseous fixation of the grafts with wires.

MATERIALS AND METHODS

A retrospective evaluation of humeral bone reconstruction with free fibular autografts in the conditions of transosseous osteosynthesis and transosseous fixation of grafts with wires was performed. The novelty of the technology has been confirmed by an application for a patent for the invention "Autotransplantation of the fibula for defects of the diaphysis of long bones" registered with the Federal Institute of Industrial Property (reg. No. 2024137957 dated 17.12.2024).

Technical performance

A free autograft of the fibula shaped as a cylindrical fragment up to 7 cm long which was resected proximally at 8-9 cm from the ankle joint level was used as a bone-plastic material. The resected autograft of the fibula was divided into two cylindrical fragments and fragmented lengthwise into several pieces. Then, the pseudarthrosis site was approached, the endplates of the humerus fragments were resected, and the humerus fragments ends were adapted for contact. To increase the volume of bone mass in the pseudarthrosis and bone defect site for expected increase in the strength properties of the future callus, the prepared previously bone autografts were implanted along the periphery of the pseudarthrosis site, overlapping the humerus fragments junction. To exclude possible autograft migration, they were additionally fixed with transosseous wires inserted into the soft tissues of the humerus along the periphery. After hemostasis control, the wound was sutured tightly layer by layer. To fix the segment, the Ilizarov apparatus was used, consisting of three external supports in the wire/half-pin variant of bone fragment fixation. Considering the transosseous fixation of bone grafts and the end-to-end contact between the fragments of the humerus, we refrained from traditional supporting compression at the junction of the fragments in the postoperative period, and actually switched to a neutral version of transosseous osteosynthesis. After the fragments showed union in radiographs and in clinical consolidation test, the Ilizarov apparatus was dismantled.

Case report

A 38-year-old patient was admitted to the clinic on 23.04.2024. The injury was 19 years old and the patient had undergone multiple failed surgeries. Unfortunately, the patient did not have complete medical reports on the previous stages of treatment.

Nonunion of the patient's left humerus was classified as a pseudarthrosis with a normotrophic type of bone formation according to the Weber & Cech classification [7] and verified as a defect-pseudarthrosis of the left humerus with anatomical shortening of 6 cm according to the classification of Shevtsov et al. [2].

The previous surgeries resulted in numerous pointed and linear scars along and combined contractures of the left shoulder and elbow joints with a sharp limitation of the function of the upper limb. Movements at the level of the left elbow joint were possible mainly due to pathological mobility in the area of the neoarthrosis (Fig. 1).

Fig. 1 Photo and radiographs of the left humerus in two projections at admission to the hospital

At the Samarkand branch of the RSNPMC TO, the patient underwent open co-aptation of the fragments of the left humerus. The ends of the fragments were economically resected, the bone marrow canals were opened, and end contact was achieved between them. Fragments of the fibula were implanted into the pseudarthrosis site of the humerus along the periphery and were additionally fixed with wires. Fixation of the segment was carried out with the Ilizarov apparatus of three supports in a wire/half-pin arrangement (Fig. 2). During the dynamic examination, the patient regularly underwent clinical examinations and X-ray studies, while positive dynamics of graft reorganization and the formation of bone callus in the pseudarthrosis zone of the humerus fragments were observed (Fig. 3).

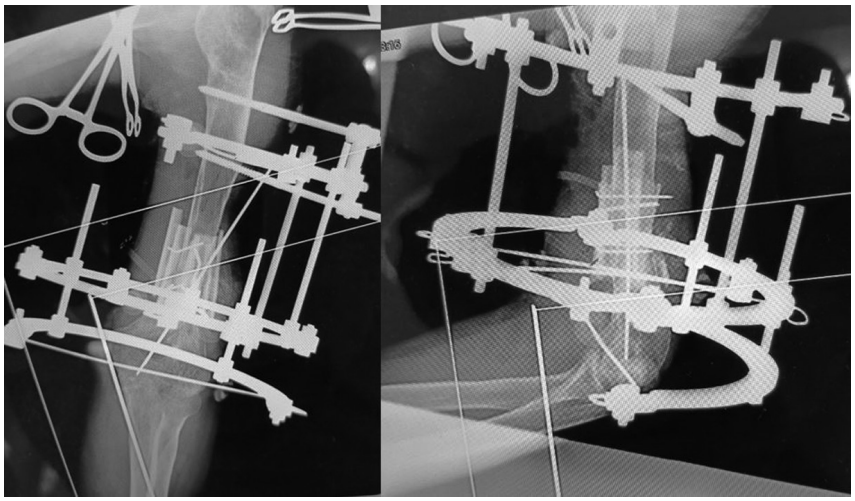
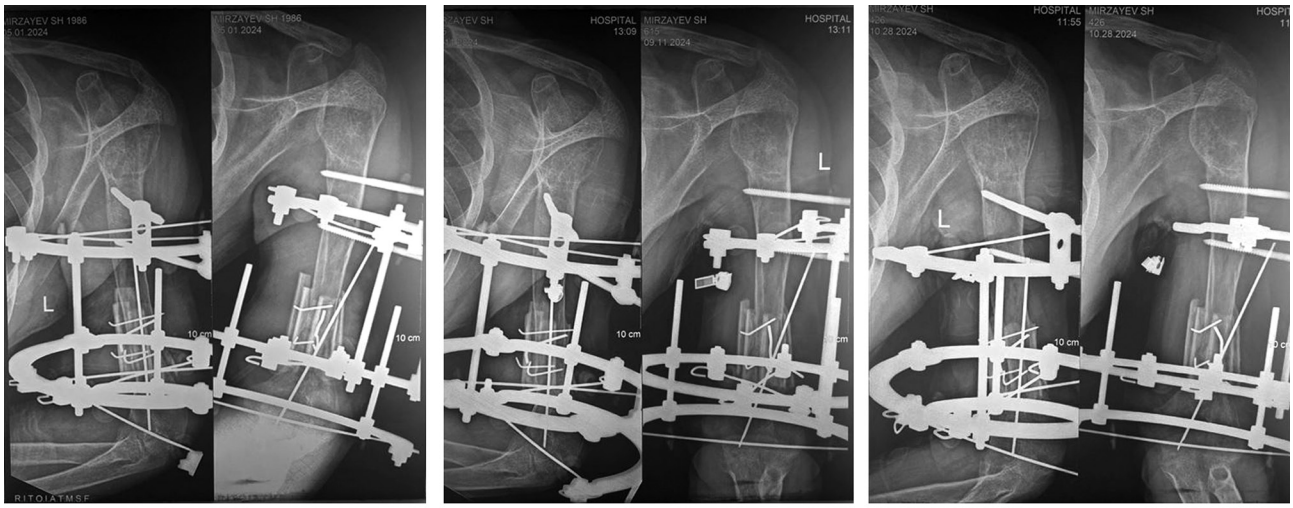


Fig. 2 Intraoperative radiographs of the left humerus in two projections taken on 26.04.2024



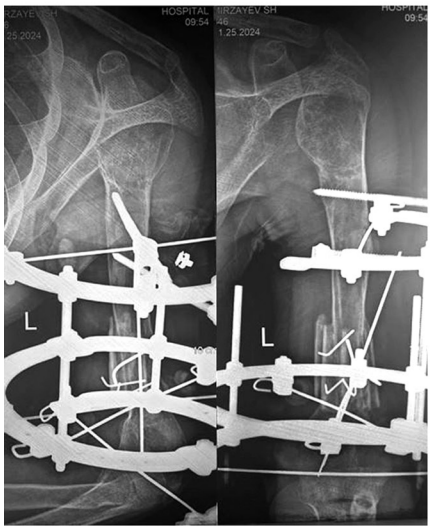


Fig. 3 Radiographic dynamic checks of the left humerus consolidation condition: (a) 16.08.2024; (b) 11.09.2024; (c) 28.10.2024; (d) 25.11.2024

The radiographic control and clinical consolidation test showed bone union and augmented bone mass at the pseudarthrosis level. Free autografts of the fibula were undergoing remodeling, lysis and signs of osteonecrosis of bone tissue were absent. The Ilizarov apparatus was dismantled (Fig. 4). Three months after dismantling the apparatus, the treatment result was preserved, remodeling of newly formed bone tissue was complete (Fig. 5).

Fig. 4 Photos and radiographs of the left humerus in two projections upon the dismantling of the Ilizarov fixator and removal of transosseous wires on14.01.2025

Fig. 5 Radiographs of the left humerus in two projections at a 3-months follow-up after Ilizarov apparatus removal on 14.04.2025

DISCUSIION

We believe that external fixation can be considered as an alternative variant of osteosynthesis in complex clinical situations. Obviously, this idea is not new. According to our data, the possibility and effectiveness of transosseous osteosynthesis in the treatment of patients with pseudarthrosis and defects of the humerus were first described in the dissertation research of V.I. Shevtsov [8]. Despite the long history of successful use of transosseous osteosynthesis in the treatment of patients with defects and pseudarthrosis of the humerus, there is no reason to claim that this fixation option is widespread and popular. Most publications devoted to this problem were written by researchers of the Ilizarov Center [2, 9–11].

However, recent publications by the authors from Uzbekistan report on the successful use of transosseous osteosynthesis to correct deformities and manage pseudarthrosis of the humerus [12–15]. The choice of osteosynthesis and fixation of humeral fragments is not the only problem in the surgical rehabilitation of patients with defects and nonunion of the humerus. To restore the integrity of the humerus, open co-aptation of the ends of the fragments is required for a tight contact between them, opening the bone marrow canals and application of bone-plastic materials, mainly allo- and autografts in the case of bone defects [1, 16].

It is known that the “gold standard” of bone-plastic material is autogenous bone, while the use of fibula as the most accessible autograft has been recognized effective and popular [4, 17–20]. Certainly, researchers would prefer to use a vascularized fibula with restored arteriovenous bypass [21–27]. However, this technology is complex, two-stage, requires the use of microsurgical techniques, creates problems in the donor site, the replant itself has risks of thrombosis of arteriovenous shunts, and in a number of clinical situations the operation is technically impossible [28–31].

According to our data, the fibula was first used for humeral reconstruction with intramedullary fixation of the graft by Wright et al. [4]. In the literature, one can find publications on the successful use of a free non-vascularized fibula in patients with pseudarthrosis of the humerus, and the authors of those reports preferred plates with angular stability for fixation of fragments [16, 17, 20].

An experience of successful management of atrophic defects of the humerus was published: a free autograft of the fibula was implanted into the bone marrow canal of the humerus, fixation of fragments and maintenance of compression were carried out with the Ilizarov apparatus [32]; the novelty of the developed technology was confirmed by a Russian patent [33].

However, in a number of clinical situations, intraosseous implantation as an option for a post-traumatic defect in the distal humerus and intramedullary canal reaming in the intercondylar zone of the humerus are impossible due to the anatomical features of the humerus and the risks of iatrogenic fractures during canal formation. Therefore, when defects and pseudoarthroses of the humerus are located in the distal metaepiphysis, the use of the fibula in the cylinder-fragment design with intraosseous reinforcement of the humerus is technically impossible with the previously proposed technology [32, 33].

Based on the literature data on the search and development of new innovative bone-plastic materials, it should be noted that to date, autografts, which have no risks of negative immune responses and are capable of complete organotypic restructuring, are still optimal in terms of osteoinductive and osteoconductive properties [32, 34]. The key disadvantage of bone autografts is the limited volumes of this bone-plastic material [35]. At the same time, in a number of complex clinical situations with bone defects of the upper limbs, significant volumes of implantation material are not required. Rational use of available donor material can provide the necessary volumes of lost bone tissue.

Based on this concept, we considered the possibilities of managing humeral bone defects with free autografts from the fibula as quite sufficient and rational. The patient’s case presented as a clinical example had a pseudarthrosis of the humerus localized in the distal metaphysis, had combined persistent contractures of the adjacent joints, and pronounced pathological mobility of bone fragments. Given the features of the pathological anatomical and functional changes in the patient's upper limb, the use of dynamic DCP/ LCP plates or intramedullary locking fixators was questionable, since these instruments have limitations in strength and time of action.

According to the literature, the main cause of nonunion and failures after reconstructive interventions is the lack of rigid and stable fixation of the humerus fragments [5, 6, 36, 37]. Adequate contact between the ends of the fragments is necessary to achieve union [38]. Open co-aptation of the humerus with adequate contact between the fragments and the use of optimal autogenous bone-plastic material ensures bone regeneration in the pseudarthrosis site. In our opinion, with this type of bone grafting, external fixation devices have undeniable advantages in fixing humerus fragments and bone grafts. An enhanced volume of bone mass in the pseudarthrosis zone resulting

from bone remodeling in the adaptation zone of the fragment ends and organotypic restructuring of free autografts allows us to recommend this technology for restoring the integrity of the humerus not only in normotrophic pseudarthrosis but also in atrophic nonunion.

CONCLUSION

The originality of technology lies in the use of several free bone autografts formed from the resected fibula fragment and implanted along the periphery of the humeral fragments junction. Currently, despite the active search and development of innovative bone grafting materials, the most effective and generally accepted method is the use of autografts, with the fibula used as the "gold standard" for bone grafting. The area of active osteogenesis is created due to the combined effect of open co-aptation of the ends of the humeral fragments with resection of the endplates and bone autogenous grafts that overlap the problematic area. Additional transosseous fixation of bone autografts with wires ensures the stability of free grafts. Controlled fixation of humeral fragments with compression and adequate contact of the fragments is achieved with the Ilizarov apparatus.

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REFERENCES

1. Campochiaro G, Baudi P, Gialdini M, et al. Humeral shaft non-union after intramedullary nailing. *Musculoskelet Surg*. 2017;101(2):189-193. doi: 10.1007/s12306-017-0468-x.
2. Shevtsov VI, Makushin VD, Kuftyrev LM, Soldatov YP. *Pseudoarthroses, bone defects of the upper limb and contractures of the elbow joint (basic technologies of treatment with the Ilizarov apparatus)*. Kurgan: Trans-Urals Publ.; 2001:407. (In Russ.)
3. Pantalone A, Vanni D, Guelfi M, et al. From plate to nail: a case-report of proximal humerus non-union. *Injury*. 2015;46(Suppl 7):S48-50. doi: 10.1016/S0020-1383(15)30046-2.
4. Wright TW, Miller GJ, Vander Griend RA, et al. Reconstruction of the humerus with an intramedullary fibular graft. A clinical and biomechanical study. *J Bone Joint Surg Br*. 1993;75(5):804-807. doi: 10.1302/0301-620X.75B5.8376445.
5. Ring D, Jupiter JB, Quintero J, et al. Atrophic ununited diaphyseal fractures of the humerus with a bony defect: treatment by wave-plate osteosynthesis. *J Bone Joint Surg Br*. 2000;82(6):867-871. doi: 10.1302/0301-620x.82b6.10124.
6. Rubel IF, Kloen P, Campbell D, et al. Open reduction and internal fixation of humeral nonunions: a biomechanical and clinical study. *J Bone Joint Surg Am*. 2002;84(8):1315-1322. doi: 10.2106/00004623-200208000-00004.
7. Weber TW, Cech O. *Pseudarthrosis: pathophysiology, biomechanics, therapy, results*. New York: Grune and Stratton Publ.; 1976:323.
8. Shevtsov VI. *Closed Ilizarov compression-distraction osteosynthesis in the treatment of false joints of the humerus*. *Kand. Dis*. Kurgan; 2001:407. (In Russ.)
9. Shevtsov VI, Sveshnikov AA, Nosova LN, Shaposhnikova GV. Replacing diaphyseal defects of the humerus by lengthening one or both fragments according to Ilizarov method. *Traumatology and Orthopedics of Russia*. 1995;5:63-64. (In Russ.)
10. Shaposhnikova GV. *Treatment of patients with humerus defects by the Ilizarov percutaneous osteosynthesis method*. Kand Dis. Kurgan; 1996:209. (In Russ.)
11. Shevtsov VI, Shaposhnikova GV. Anatomo-functional rehabilitation of patients with humerus defects according to Ilizarov method. *Genij Ortopedii*. 1996;(2-3):73. (In Russ.)
12. Subanbekov E. Rationale for the study of the problem of post-traumatic deformations of the supracondylar and supracondylar fractures of the humerus in children. *Synergy of sciences*. 2018;(21):325–334. (In Russ.) URL: https://synergy-journal.ru/archive/article1973.
13. Davirov ShM, Urinboev PU. Repair of an open forearm fracture and extensive bony loss (case report). *Genij Ortopedii*. 2021;27(1):87-91. doi: 10.18019/1028-4427-2021-27-1-87-91.
14. Davirov ShM, Urinboev PU. Repair of open humerus fracture and extensive bone defect using bone grafting (case report). *Genij Ortopedii*. 2022;28(1):91-96. doi: 10.18019/1028-4427-2022-28-1-91-96.
15. Urinboev PU, Davirov ShM, Urinbaev IP. Surgical treatment of nonunion of the lateral humeral condyle in children using combined methods of bone grafting and the Ilizarov fixation. *Genij Ortopedii*. 2024;30(1):46-58. doi: 10.18019/1028-4427-2024-30-1-46-58.
16. Babhulkar S, Babhulkar S, Vasudev A. Recalcitrant aseptic atrophic non-union of the shaft of the humerus after failure of surgical treatment: management by excision of non-union, bone grafting and stabilization by LCP in different modes. *Injury*. 2017;48(Suppl 2):S33-S43. doi: 10.1016/S0020-1383(17)30492-8.
17. Kashayi-Chowdojirao S, Vallurupalli A, Chilakamarri VK, et al. Role of autologous non-vascularised intramedullary fibular strut graft in humeral shaft nonunions following failed plating. *J Clin Orthop Trauma*. 2017;8(Suppl 2):S21-S30. doi: 10.1016/j.jcot.2016.12.006.

18. Balaev II, Kuftyrev LM, Borzunov DY, Zlobin AV. Transosseous osteosynthesis in treatment of a patient with humeral Ewing sarcoma. *Genij Ortopedii*. 2004;(2):63-65. (In Russ.)
19. Borzunov DYu, Mitrofanov AI, Mokhovikov DS, et al. A rare case of humeral shaft echinococcal involvement. *Genij Ortopedii*. 2014;(2):64-68. (In Russ.)
20. Crosby LA, Norris BL, Dao KD, McGuire MH. Humeral shaft nonunions treated with fibular allograft and compression plating. *Am J Orthop (Belle Mead NJ)*. 2000;29(1):45-47.
21. Golyana SI, Tikhonenko TI, Galkina NS, Grankin DYu. Microsurgical autologous ffbula transfer as an optimal method for closure of extensive bone defects in children with neuroffbromatosis. *Genij Ortopedii*. 2023;29(4):368-375. doi: 10.18019/1028-4427-2023-29-4-368-375.
22. Bumbasirevic M, Stevanovic M, Bumbasirevic V, et al. Free vascularised fibular grafts in orthopaedics. *Int Orthop*. 2014;38(6):1277-1282. doi: 10.1007/s00264-014-2281-6.
23. Van Den Heuvel SCM, Winters HAH, Ultee KH, et al. Combined massive allograft and intramedullary vascularized fibula transfer: the Capanna technique for treatment of congenital pseudarthrosis of the tibia. *Acta Orthop*. 2020;91(5):605-610. doi: 10.1080/17453674.2020.1773670.
24. Garkavenko YE, Zakharyan EA, Zubairov TF, et al. Microsurgical autotransplantation of fibula fragment in the treatment of bone defects in children – possibilities for further reconstructive surgery. *Modern problems of science and education*. 2021;(2). (In Russ.) doi: 10.17513/spno.30624.
25. Bae DS, Waters PM, Sampson CE. Use of free vascularized fibular graft for congenital ulnar pseudarthrosis: surgical decision making in the growing child. *J Pediatr Orthop*. 2005;25(6):755-762. doi: 10.1097/01.bpo.0000186241.29415.df.
26. Bauer AS, Singh AK, Amanatullah D, et al. Free vascularized fibular transfer with langenskiöld procedure for the treatment of congenital pseudarthrosis of the forearm. *Tech Hand Up Extrem Surg*. 2013;17(3):144-150. doi: 10.1097/BTH.0b013e318295238b.
27. Ding DY, LaMartina J, Tai C, Pandya NK. Congenital Pseudoarthrosis of the Distal Radius Treated With Physeal-Sparing Double-Barrel Vascularized Free Fibula Transfer: A Case Report. *Hand (N Y)*. 2017;12(5):NP140-NP144. doi: 10.1177/1558944717702472.
28. Van Den Heuvel SCM, Winters HAH, Ultee KH, et al. Combined massive allograft and intramedullary vascularized fibula transfer: the Capanna technique for treatment of congenital pseudarthrosis of the tibia. *Acta Orthop*. 2020;91(5):605-610. doi: 10.1080/17453674.2020.1773670.
29. Grishin IT, Golubev VT, Kroshkin MM, et al. Plasty of extensive defects of long bones with vascularized peroneal grafts. *N.N. Priorov Journal of Traumatology and Orthopedics*. 2001;8(2):61-65. (In Russ.) doi: 10.17816/vto98415.
30. Tu YK, Yen CY, Yeh WL, et al. Reconstruction of posttraumatic long bone defect with free vascularized bone graft: good outcome in 48 patients with 6 years' follow-up. *Acta Orthop Scand*. 2001;72(4):359-364. doi: 10.1080/000164701753542014.
31. Borzunov DY, Kolchin SN, Malkova TA. Role of the Ilizarov non-free bone plasty in the management of long bone defects and nonunion: Problems solved and unsolved. *World J Orthop*. 2020;11(6):304-318. doi: 10.5312/wjo.v11.i6.304.
32. Borzunov DYu, Mokhovikov DS, Kolchin SN. New technology for humerus reconstruction with a free fibular autologous graft in hypotrophic pseudarthrosis. *Genij Ortopedii*. 2020;26(3):408-412. doi: 10.18019/1028-4427-2020-26-3-408-412.
33. Mokhovikov DS, Kolchin SN, Borzunov DYu. *Method of humerus reconstruction in hypotrophic pseudoarthrosis*. Patent RF, no. 2695268, 2019. Available at: https://www.fips.ru/registers-doc-view/fips_servlet?DB=RUPAT&DocNumber=2695268&TypeFile=html. Accessed May 16, 2025. (In Russ.)
34. Mukhametov UF, Lyulin SV, Borzunov DY, et al. Alloplastic and Implant Materials for Bone Grafting: a Literature Review. *Creative surgery and oncology*. 2021;11(4):343-353. (In Russ.) doi: 10.24060/2076-3093-2021-11-4-343-353.
35. Schmidt AH. Autologous bone graft: Is it still the gold standard? *Injury*. 2021;52(Suppl 2):S18-S22. doi: 10.1016/j.injury.2021.01.043.
36. Healy WL, White GM, Mick CA, et al. Nonunion of the humeral shaft. *Clin Orthop Relat Res*. 1987;(219):206-213.
37. Marti RK, Verheyen CC, Besselaar PP. Humeral shaft nonunion: evaluation of uniform surgical repair in fifty-one patients. *J Orthop Trauma*. 2002;16(2):108-115. doi: 10.1097/00005131-200202000-00007.
38. Sitati FC, Kingori J. Outcome of management of humerus diaphysis non-union. *East Cent Afr J Surg*. 2009;14(2):13-17.

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