Genij Ortopedii. 2022. Vol. 28, no. 1. P. 150-157.

Review article

https://doi.org/10.18019/1028-4427-2022-28-1-150-157

Soft tissues reconstruction in the patients with extensive wound defects of the foot using flaps with axial type of circulation (literature review)

B.Sh. Minasov, E.M. Biktasheva, M.M. Valeev✉, R.R. Yakupov, T.B. Minasov, T.R. Mavlyutov

Bashkir State Medical University, Ufa, Russian Federation

Corresponding author: Marat M. Valeev, valeevmm@rambler.ru

Abstract

Introduction The foot bears the load of the entire body while walking and particularly the plantar part of it resists a tremendous weight-bearing. A peculiarity of the skin cover of the supporting zones is that the elastic fibers of the soft tissues of the plantar foot fix the skin to the deep fascia and the bone skeleton, resulting in minimizing of the supportive tissue mobility and increasing pressure stability without circulation disorder in areas of increased weight-bearing. Therefore, the requirements to the plastic properties of the selected material for the reconstruction of the soft tissues of the foot increase. **Purpose** is to review the various methods and techniques of surgical treatment for extensive soft tissue defects of the foot using flaps with an axial type of circulation. **Material and methods** The search of materials was performed from 2015 through 2020 in the following sources of information: eLibrary.ru; bibliographic bases (Scopus,; Web of Science); electronic library of dissertations of the Russian State Library (http://diss.rsl.ru) and sites of Dissertation Boards. The review of 72 publications of national and foreign authors related to this topic is presented. The depth of source selection was 16 years, starting from 2004. In the last 5 years, 45 studies data have been published. The literature related to surgical treatment of extensive defects in the foot soft tissues using complex flaps with an axial type of circulation supply was analyzed. **Results** Basing on the analysis of publications from various sources, the disadvantages and advantages of various methods and techniques of reconstructive plastic surgery are presented and various approaches and criteria for choosing the techniques of surgical soft tissues reconstruction are described. **Conclusion** In the treatment of patients with extensive soft tissue defects of the foot at the current stage of the reconstructive plastic surgery development, the doctrines based on microsurgical technologies of autografts of tissue complexes with an axial type of circulation became the most acceptable ways and techniques for lost skin restoration.

Keywords: plastic surgery, reconstructive surgery, microsurgery, skin grafting, foot, soft tissue defect

For citation: Minasov B.Sh., Biktasheva E.M., Valeev M.M., Yakupov R.R., Minasov T.B., Mavlyutov T.R. Soft tissues reconstruction in the patients with extensive wound defects of the foot using flaps with axial type of circulation. *Genij Ortopedii*, 2022, vol. 28, no 1, pp. 150-157. https://doi.org/10.18019/1028-4427-2022-28-1-150-157

INTRODUCTION

The rapid development of current medicine in providing qualified medical aid after injuries of the locomotor system requires the development of certain doctrines, mainly aimed at the accelerated recovery after injuries. The need to develop concepts and doctrines is caused by the large-scale type of these injuries and progressive development of reconstructive surgery. The introduction of these doctrines is provided by up-to-date surgical technologies. Inflated expectations dictate the need to systematize both the surgical reconstructive plastic technologies and social, day-to-day and professional rehabilitation, stimulating the development of new concepts and doctrines. Current clinical practice aggravates the problem of providing practical care to patients with extensive soft tissue wound defects, in particular, in functionally active areas (joint areas, support areas, etc.) [1–28].

Currently, the optimal doctrines for the reconstruction of soft tissues in these areas are not fully developed. Peculiarity of the skin cover in the supportive area is that the elastic fibers of the soft tissues of the plantar foot and the palmar hand fix the skin to the deep fascia and the bone skeleton, resulting in minimizing of the supportive tissue mobility and increasing pressure stability without circulation disorder in areas of increased weight-bearing and minimizing of the skin mobility results in the increased stability of the support without disturbing blood circulation. In this context, the soft tissue components are inadequate but functional, and their transformation does not occur. Tissue destruction resulting from the injuries of the locomotor system have the tendency to increase due to the aggravation of the accident and life injuries and the severity of man-made accidents and catastrophes. This problem can be referred to the state problem and health care in general, in particular, due to the fact that the qualitative and quantitative injury increase directly affects the criteria for the health of population, especially of working age. We also observe the dynamics of combined and multiple injury growth causing rough and sometimes irreversible defects of the main skeleton segments changing the problem for the worse [1, 5, 10–18, 29, 30].

Purpose To review the various methods and techniques of surgical treatment for extensive soft tissue defects of the foot using flaps with an axial type of vascularization.

MATERIALS AND METHODS

The search of materials was performed from 2015 through 2020 in the following sources of information: eLibrary.ru; bibliographic bases (Scopus,; Web of Science); electronic library of dissertations of the Russian State Library (http://diss.rsl.ru) and sites of Dissertation Boards. The following terms were used in search: plastic surgery, reconstructive surgery, microsurgery, skin plasty, foot and soft tissues defect. The review of 72 publications of national and foreign authors related to this topic is presented. The depth of source selection was 16 years, starting from 2004. For the last 5 years 45 studies data have been published. The publications related to surgical treatment of extensive defects in the foot soft tissues using different ways and techniques of skin plasty with flaps of axial type of circulation were included in the analysis criteria. Exclusion criteria included articles related to the subject but without description of surgical aspects of the treatment.

RESULTS

Extensive traumatic wound surfaces of the skin cover in the distal limb, especially foot, refer to hard-to-solve manifestations of soft tissues destruction in the limb segments. The difficulty of solving this problem is caused by a number of factors, i.e. the increase of the injury severity and incidence of locomotor system limbs segments; peculiarity of circulation of the various parts of the foot; peculiarity of the soft tissues structure of the supportive foot surface; specific architectonics of the foot skin being unable to move and soft tissues deficit; and the mutual arrangement of numerous anatomical structures having close functional relationship in a small space. All the above factors make it difficult to cover extensive soft tissue defects, especially in cases of combined injuries with exposure of bones, joints, blood vessels and nerves with the possible development of infection bone complications. Since the weight-bearing of the entire body falls on the foot, there is a huge load like friction on its plantar part increasing in walking, therefore, the properties of the plastic material used need to have high potentials for mechanical strength. Considering the above peculiarities of the plastic material selection, currently the conventional methods and techniques of soft tissue reconstruction became unpopularity due to low functional efficiency. Therefore, to date, the techniques of covering extensive defects of investing tissues using tissue complexes with axial type of circulation have gained some popularity. [6, 10, 14, 15, 19–26, 30, 31, 32].

There are the following types of surgical approaches for the reconstruction of soft tissues of various limb segments, including foot. One of the simple techniques is the transfer of geometric flaps in various directions and combinations, aimed for approximation of the wound defect margins. Currently many authors began to widely use the method of dermotension with expanders in order to create a bulky skin, which is also aimed at making the wound margins closer together. This technique is not always effective in the foot due to the peculiarities of the latter contours. Split and full-layer skin flaps are particularly essential for covering extensive wounds with thermal injuries of the limbs and trunk and are aimed for immediate coverage of the lost skin. It is well known that skin flaps without autonomous blood supply do not have sufficient elasticity due to the inevitable retraction in the late postoperative period and, therefore, cannot contribute to complete reconstruction of the foot soft tissues, especially on the plantar surface. Adipo-cutaneous flaps known for centuries and tailored using Italian and Indian techniques can be referred to the earliest methods for coverage of extensive soft tissues defects in the limbs. Frequent errors in planning the boundaries of such autografts are caused by the fact that the formation of the ratio of the width to the length of the flap is carried out without anatomical analysis of the projection of the axial vessels being nutrient for this area. The origin of the axial type of the skin autograft circulation can be seen in Filatov tubed flap, that can be referred to the ancestor of current tissue complexes with an axial type of circulation. This flap allows to form the required amount of plastic material. The next advantage of the flap is a sufficient degree of blood supply due to two vascularized pedicles, providing adequate blood filling of the autograft. Pedicle flaps (“Italian” plastic, “Filatov tubed flap”), in addition to long process of treatment, frequent necrosis and trophic disorders, cause inconvenience to the patients associated with long forced position of the body [24, 26–29, 33-36].

Over the last years, many authors have widely used flaps with regional type of circulation without crossing the vascular pedicle. The popularity of these flaps is caused by their undeniable advantage, including the possibility to apply large tissue complexes with one vascular pedicle. The next advantage refers to the simplicity of these flaps tailoring without the obligatory usage of microsurgical instrumentations. The history of these flaps begins with the proposal of S. Esser (1817) to tailor vascularized tissue complexes, taking into account the anatomical vascular structure of the architectonics of the skin and underlying tissues. This initiative was continued by S. Manchot, who in 1889 published the atlas of the anatomical structure of 36 areas in human

body with an axial and regional type of vascularization. The first reference of island flap application based on thoracodorsal vessels for the reconstruction of soft tissues in large chest defect after radical mastectomy belongs to Tanzini (1896). According to J.V. McCrow and D.G. Dibbell (1977), the basic principle of vascularized myocutaneous flaps application lies in considering this complex as a single organ in common vascularized bundle. The studies performed by many authors, in particular, J. Hoopers (1976), B. Myers and W. Donovan (1977) have proven that the survival of non-free vascularized pedicle flaps is directly proportional to the caliber and blood flow velocity of the nutrient vessels, i.e. depends on the amount of blood flow. In this case, it is possible to ignore incorrect geometric ratio of the width and length of tailored flaps. The wide use of muscle and myocutaneous flaps with dominant vascular revascularization in non-free version in the reconstruction of soft tissues of various limb segments began after the publications of V.Y. Bakamjian (1969), B.S. Logosov and E.G. Kurbanova (1970) [1, 6, 8, 29, 30, 37–45].

Radical change in the basic principles and doctrines of surgical techniques in the reconstruction of extensive soft tissue defects, especially those combined with severe injuries of the bone skeleton, occurred after the wide-scale application of tissue complexes based on the concept of the dominant role of the septal cutaneous arteries in vascularization. This concept made it possible to develop new technologies for soft tissue defects repair, even the large ones, allowing to outweigh the shortcomings of existing conventional methods and techniques of soft tissue reconstruction based on reconstructive plastic surgery. It was proved that any segment injury of the limb damages the regional circulation, in particular the foot. Vacsularized flaps, together with the coverage function in these conditions, improve the vascularization of the ischemic foot due to the autonomic circulation. Practically complete exclusion of dense scar formation between the autograft and the underlying anatomical formations makes essential the application of vascularized flaps as a plastic material in the reconstruction of the plantar soft tissues of the foot being under enormous mechanical stress and sustaining significant displacement when walking. There is also reinnervation possibility of the free vascularized flaps when autograft perineural suture with the sensory nerve of the affected segment area is applied [6, 10, 28, 29, 33, 41, 42, 44, 46–52].

In current reconstructive plastic microsurgery there are two ways to use autografts with an axial type of vascularity. The first way involves the flap transfer from the donor area in a free form, i.e. crossing vascularized pedicle followed by revascularization with microsurgical vascular anastomoses. The second variant of these flaps usage includes the reversion of the autograft on the nutrient vessels. The first method of flap revascularization requires microsurgical instrumentation, magnifying optics and trained surgical team [34, 37, 38, 40].

As a rule, traumatic foot injuries with extensive destruction of soft tissues are accompanied by fracture of the segment bone skeleton. In these combined injuries, we face the problem of the sequence of the bone base restoration and the foot soft tissue structures reconstruction. The sequence and timing of restorative and reconstructive operations using various techniques of skin grafting and bone fragments osteosynthesis is actively discussed in literature today. There is also a problem of soft tissue defect repair in application of conventional and skin plasty techniques after the "maturation" of wound defect or vascularized skin grafting, both free and non-free ones.

Some authors actively support the soft tissues reconstruction using free vascularized flaps with microvascular anastomoses, motivating their position by the fact that free transfer of vascularized flaps reduces the risk of infection complications of bone tissue and minimizes the possibility of malformations in bone fragment healing in comparison with non-free vascularized skin grafting.

Another group of authors does not find much difference between the types of revascularization of tissue complexes in terms of the frequency and prevalence of infection complications and the timing of bone fragments healing. [1, 3, 14, 35, 53–60].

The other group of authors takes the view that extensive destruction of soft tissues in high-energy injuries in the acute period is the contraindication for the tissue complexes application with an axial type of vascularization as a plastic material in any type of revascularization. At the same time, some authors follow more active tactic, giving priority to vascularized tissues to cover extensive soft tissue defects, including the same of the foot.

According to various publication data, in the practice of even the most experienced microsurgeons using up-to-date microsurgical equipment, the obstruction of microvascular anastomoses like thrombosis, considering the location and damage severity, is observed in 5–18 % of cases. Therefore, many surgeons are looking for the safest ways to use vascularized tissue complexes, especially for covering extensive skin defects of the distal limb, in particular the feet, with preference to use island vascularized flaps. These autografts are more simple for surgical procedure, and their application is practically free of the risk of vascular thrombosis compared to free

flaps on microvascular anastomoses [1, 3, 6, 8, 15, 19, 22, 25, 37, 43, 45].

In the available current literature, there are various publications, sometimes contradictory, on the timing of soft tissue reconstruction with extensive defects, in particular, the distal limbs. Some authors suggest early active surgical approach, when the others, on the contrary, offer more cautious, sometimes delayed approach. The latter refers to M.B. Kim, who basing on an analysis of the treatment of the patients with the leg soft tissue defects came to the conclusion that closing the wounds with skin sutures or various techniques of vacuum treatment, the proportion of reconstructive plastic surgeries using microsurgical techniques sharply decreases. The incidence of treatment complications including osteomyelitis, non-union of bone fragments and deep ischemia of the distal limb, according to the author, did not decrease. Recommendations for reducing the portion of the vascularized flaps application for covering the extensive soft tissue defects with combined injuries of the distal limb are given by V.B. Bondarev et al. in favor of primary shortening of the affected limb and autoplasty with a split skin autograft after the preparation of the wound defect using vacuum treatment. This statement excludes the lack of options for the repair of extensive soft tissue defects using microsurgical techniques [7, 10, 16, 21, 24, 36, 50].

Basing on the analysis of Russian literature today it can be concluded that in recent years there was a significant increase in the proportion of early reconstruction of the distal lower limb soft tissues, including feet, with skin grafting using microsurgical techniques. Therefore, L.A. Rodomanova and A.Yu. Kocis, analyzing the results of treatment of two groups comprising 594 patients, came to the conclusion that it is useful to perform early reconstruction of soft tissues by microsurgical technique before the development of the rough scar tissue. This tactic allows to minimize disability, length of treatment and the proportion of multi-stage surgical applications. A.A. Bogov et al. follow the tactics of primary radical surgical treatment of the area of traumatic destruction of the soft tissues, claiming that a wound defect of soft tissues, regardless the size, location and combined character, should be replaced immediately after injury. Comprehensive studies performed in the RNIIT named after R.R. Vreden, led to the conclusion that the period of up to six weeks from the moment of injury is optimal for plastic coverage of soft tissue defects. In this case, it is preferable to use only vascularized tissue complexes both in free and non-free version [2, 6, 10, 23, 36, 45, 60–65].

To this date of reconstructive plastic surgery development, the method of choosing one or another type of skin plasty in repair of extensive wound defects in the limb soft tissues especially in functionally active zones, according to most authors, can include the surgical doctrines using tissue complexes with an axial type of circulation. The application of vascularized tissue complexes in early active surgical tactics in extensive destruction of the soft tissues of the limbs prevents infection complications, significantly optimizes reparative processes and protects the underlying anatomical formations from further involvement in the infection process. Acute restoration of all damaged anatomical structures in the area of injury, including deeper tissues (bone tissue, peripheral nerves and main arteries, tendons), allowing significantly reduce the recovery time of the injured limb functions, using early functional rehabilitation treatment can be referred to the next positive statement [1, 5, 6, 8, 15, 17, 41, 44, 53, 58].

There are also different opinions regarding the application of tissue complexes with an axial type of vascularized pedicle in an island version or in a free form on microvascular anastomoses.

Lipatov K.V. et al. are the supporters of broadening the indications for free flaps application with microvascular anastomoses at the early stages after injury and explain their beliefs by the fact that the use of island tissue complexes as a plastic material for covering extensive wound defects increases the incidence of infection complications and nonunion of bone fragments [2, 6, 10, 31, 32, 36, 52, 66–69].

DISCUSSION

The analysis of the above problem resulted in the conclusion that it is preferable to cover extensive defects in the soft tissues of the foot using complex flaps with autonomic circulation. The decision to use these flaps in a free or non-free version is made depending on the interval after injury, the severity, area and combination of injuries, and the competence of the operating team in application of microsurgical technologies [1, 3, 6, 8, 10, 12, 15, 17, 21, 29, 34, 44, 53, 58, 68].

During retrospective analysis of the studies, the efficiency of using various flaps with an axial type of circulation was evaluated. Fasciocutaneous flaps are more preferable for extensive defects without evident infection of the wound surface and involvement of deeper anatomical structures in the process. Myocutaneous flaps are recommended in exposure of bone tissue, joints, tendons, and neurovascular bundles. We believe that infection process in the area of large soft tissue defect is not a contraindication for application of vascularized myocutaneous flaps, but, on the contrary, an indication for surgery since the usage of this flap allows to arrest the infection process by connecting additional blood

supply to the pathological area [1, 4, 9, 15, 16, 24, 27, 29, 31, 36].

In definition of timing of reconstructive operations after traumatic destruction of the foot soft tissues most of the researchers are inclined to an earlier surgical intervention that prevents the development of scar deformities and joint contractures. This treatment strategy is rest on the results of our own observations. It is needless to say that the beginning of early rehabilitation treatment also depends on the timing of soft tissue reconstruction. Moreover, in cases of the infection complications of the soft tissues and bone skeleton, this treatment tactics is the most appropriate and eliminates the transition of the process into the chronic form. [2, 5, 8, 13, 16, 28, 29, 31, 36, 61].

According to the data from the most of the authors, the following tactics is acceptable for revascularization of the tissue complex. The flaps with an axial type of circulation without crossing the vascular pedicle are simple in reproduction and the nutrient vessels of the autograft are practically not subject to the thrombosis. Therefore, these tissue complexes are widely used by many authors. [1, 3, 5, 10, 19, 22, 34, 38, 68].

On the other hand, the limited size of these autografts does not allow their application for covering large defects in the foot soft tissues. In these cases, many authors recommend the application of microsurgical technologies, namely, free composite tissue complexes and their advantage is the ability to obtain the required large area and various configuration flaps. Revascularization of an autograft using microsurgical anastomoses requires appropriate magnifying equipment, specific instrumentation and what counts most is a qualified operating team, that will take years to prepare. Free microsurgical transfer of flaps from distant parts of the body is indicated for soft tissue defects of significant area, when it is impossible to use area-limited "island" flaps [2, 4, 6, 12, 15, 17, 23, 31, 32, 40, 41, 53, 54].

At the same time, indications for operations using tissue complexes with axial vascularity should be clearly defined, since the excessive reconstructive surgical interventions of this kind may be an unjustified risk for the patient.

CONCLUSION

Therefore, the relevance of the problem of the foot soft tissue repair is caused by significant number of scientific reports with comprehensive analysis of various surgical approaches using up-to-date technologies of reconstructive plastic surgery. Conventional methods of free skin plasty with split or full-thickness autografts require granulating wound surface with good vascularization, which preparation takes considerable time. This situation aggravates the development of contracture of the affected segment joints, especially when a large soft tissue defect is located in functionally active areas, and deeper anatomical structures (bone fragments, peripheral nerves, tendons, joint capsules, etc.) are exposed. In this method of skin grafting, the newly formed skin has low mechanical strength, that almost completely excludes the technique application if the injury is located in the supportive area of the foot [2, 5, 10, 16, 24, 32, 36, 51, 64].

Basing on the above-mentioned, it can be stated that in the treatment of patients with extensive soft tissue defects of the foot at the current stage of reconstructive plastic surgery development, the most acceptable methods and techniques for restoring lost skin are doctrines based on microsurgical technologies of autotransplantation of tissue complexes with an axial type of circulation. The questions about the timing and methods of plasty with the above flaps, remain unsolved considering the location of the wound defect, the combination of injuries and the resources themselves of the affected foot. Solution to the problem of social, day-to-day and professional rehabilitation of patients with extensive traumatic defects of the soft tissues of the foot is possible by involving further research with the development of an optimal surgical doctrine, including the definition of indications and contraindications for various methods and techniques of reconstructive plastic surgery, the timing and scope of surgical interventions and evidence-based rehabilitation measures.

REFERENCES

1. Biktasheva E.M., Minasov B.Sh., Valeev M.M. Sovremennye khirurgicheskie tekhnologii pri obshirnykh defektakh i rubtsovykh deformatsiiakh miagkikh tkanei proksimalnogo otdela stopy s ispolzovaniem funktsionalnykh loskutov [Modern surgical technologies for extensive defects and cicatricial deformities of the soft tissues of the proximal foot using functional flaps]. *Meditsinskii Vestnik Bashkortostana*, 2015, vol. 10, no. 1, pp. 39-44. (in Russian)
2. Hallock G.G. Soft Tissue Coverage after Revisional Foot and Ankle Surgery. *Clin. Podiatr. Med. Surg*., 2017, vol. 34, no. 3, pp. 389-398. DOI: 10/1016/j.cpm.2017.02.009.
3. Bogov A.A., Ibragimova L.Ia., Mullin R.I. Primenenie vaskuliarizirovannoi kozhnoi plastiki medialnym loskutom stopy dlia zameshcheniia defekta miagkikh tkanei stopy [The use of vascularized skin plasty with foot medial flap for replacement of soft tissue defects of the foot]. *Prakticheskaia Meditsina*, 2012, no. 8, pp. 86-88. (in Russian)
4. Valeev M.M. Ispolzovanie autovitalnykh loskutov u bolnykh s defektom miagkikh tkanei konechnostei [The use of autovital flaps

in patients with soft tissue defects of the limbs]. *Zdravookhranenie Bashkortostana*, 2004, no. 6, pp. 67-80. (in Russian)
5. Bogdanov S.B., Babichev R.G. Novye podkhody k khirurgicheskomu lecheniiu ozhogov tylnoi poverkhnosti kistei i stop [New approaches to the surgical treatment of burns of the dorsum of the hands and feet]. *Voprosy Rekonstruktivnoi i Plasticheskoi Khirurgii*, 2016, vol. 19, no. 2 (57), pp. 5-10. (in Russian)
6. Tikhilov R.M., Kochish A.Iu., Rodomanova L.A., Kutianov D.I., Afanasev A.O. Vozmozhnosti sovremennykh metodov rekonstruktivno-plasticheskoi khirurgii v lechenii bolnykh s obshirnymi posttravmaticheskimi defektami tkanei konechnostei [Scopes of modern methods of reconstructive plastic surgery in the treatment of patients with extensive post-traumatic defects of limb tissues]. *Travmatologiia i Ortopediia Rossii*, 2011, no. 2, pp. 164-170. (in Russian)
7. As'adi K., Salehi S.H., Shoar S. Early Reconstruction of Distal Leg and Foot in Acute High-Voltage Electrical Burn: Does Location of Pedicle in the Zone of Injury Affect the Outcome of Distally Based Sural Flap? *Ann. Plast. Surg*., 2017, vol. 78, no. 1, pp. 41-45. DOI: 10.1097/SAP.0000000000000719.
8. Kutianov D.I., Rodomanova L.A. Sovremennye printsipy i tendentsii ispolzovaniia osevykh krovosnabzhaemykh loskutov v rekonstruktivnoi khirurgii konechnostei [Modern principles and trends in the use of axial blood-supplied flaps in reconstructive limb surgery]. *Travmatologiia i Ortopediia Rossii*, 2015, no. 1 (75), pp. 106-115. (in Russian)
9. Beidas O.E., Tan B.K., Petersen J.D. The rotational advancement of medial plantar flap for coverage of foot defect: a case report. *Microsurgery*, 2012, vol. 32, no. 4, pp. 322-325. DOI: 10.1002/micr.21956.
10. Bogov A.A., Ibragimova L.Ia., Mullin R.I., Khannanova I.G., Masgutov R.F. Vaskuliarizirovannaia kozhnaia plastika osevymi loskutami v khirurgicheskom lechenii bolnykh s sochetannymi povrezhdeniiami goleni i stopy. Obzor literatury [Vascularized skin grafting with axial flaps in the surgical treatment of patients with concomitant leg and foot injuries. Review of the literature]. *Sovremennye Problemy Nauki i Obrazovaniia*, 2013, no. 1, pp. 28. (in Russian)
11. Zheng H., Liu J., Dai X., Schilling A.F. The Distally Based Sural Flap for the Reconstruction of Ankle and Foot Defects in Pediatric Patients. *Ann. Plast. Surg*., 2016, vol. 77, no. 1, pp. 97-101. DOI: 10.1097/SAP.0000000000000341.
12. Davenport C., Dubin A. Tadalafil therapy and severe chronic foot wound resolution. *Int. Wound J*., 2015, vol. 12, no. 6, pp. 733-736. DOI: 10.1111/iwj.12378.
13. Jian L., Cheng L., Heping Z., Hua L., Tianhao Z., Zhijiang W., Huajun W. [Clinical application of venous nutrition flap pedicled by medial plantar artery of the hallux on the medical aspect of the foot]. *Zhonghua Zheng Xing Wai Ke Za Zhi [Zhonghua Zhengxing Waike Zazhi = Chinese Journal of Plastic Surgery]*, 2015, vol. 31, no. 3, pp. 179-182. (in Chinese)
14. Romakina N.A., Fedonnikov A.S., Kireev S.I., Bakhteev N.Kh., Norkin I.A. Ispolzovanie metodov biomekhaniki v otsenke sostoianiia i korrektsii patologii oporno-dvigatelnoi sistemy (obzor) [The use of biomechanics methods in the assessment of the state and correction of the pathology of the locomotor system (review)]. *Saratovskii Nauchno-Meditsinskii Zhurnal*, 2015, vol. 11, no. 3, pp. 310-316. (in Russian)
15. Biktasheva E.M., Minasov B.Sh., Valeev M.M. Mikrokhirurgicheskie tekhnologii pri lechenii bolnykh s obshirnymi defektami miagkikh tkanei proksimalnykh otdelov stopy [Microsurgical technologies for the treatment of patients with extensive soft-tissue defects of the proximal foot]. *Prakticheskaia Meditsina*, 2015, no. 6 (91), pp. 90-93. (in Russian)
16. Bondarev V.B., Kalenskii V.O., Ivanov P.A. Osobennosti povrezhdenii zadnego otdela stopy u patsientov s sochetannoi travmoi [Peculiarities of hindfoot injuries in patients with concomitant injury]. *Neotlozhnaia Meditsinskaia Pomoshch*, 2016, no. 2, pp. 20-24. (in Russian)
17. Rybchenok V.V., Aleksandrov A.V., Volkov V.V., Smoliankin A.A. Vozmozhnosti mikrokhirurgicheskoi autotransplantatsii pri lechenii obshirnykh ran i defektov tkanei u detei [Possibilities of microsurgical autotransplantation in the treatment of extensive wounds and tissue defects in children]. *Annaly Plasticheskoi, Rekonstruktivnoi i Esteticheskoi Khirurgii*, 2015, no. 1, pp. 77. (in Russian)
18. Mahmoud W.H. Foot and Ankle Reconstruction Using the Distally Based Sural Artery Flap versus the Medial Plantar Flap: A Comparative Study. *J. Foot Ankle Surg*., 2017, vol. 56, no. 3, pp. 514-518. DOI: 10.1053/j.jfas.2017.01.019.
19. Verega G.M., Fegiu L.G. Nekotorye osobennosti ispolzovaniia ostrovkovogo medialnogo podoshvennogo loskuta [Some features of using the islet medial plantar flap]. *Voprosy Rekonstruktivnoi i Plasticheskoi Khirurgii*, 2010, vol. 11, no. 2, pp. 10-17. (in Russian)
20. Haddock N.T., Wapner K., Levin L.S. Vascular bone transfer options in the foot and ankle: a retrospective review and update on strategies. *Plast. Reconstr. Surg*., 2013, vol. 132, no. 3, pp. 685-693. DOI: 10.1097/PRS.0b013e31829acedd.
21. Kim M.B., Lee Y.H., Kim J.H., Lee J.E., Shin W.C., Baek G.H. Distally based adipofascial flaps covering soft-tissue defects of the dorsal foot and ankle in children. *Ann. Plast. Surg*., 2014, vol. 73, no. 5, pp. 568-577. DOI: 10.1097/SAP.0b013e318276d127.
22. Minasov B.Sh., Biktasheva E.M., Valeev M.M. Novyi sposob nesvobodnoi peresadki osevogo medialnogo loskuta stopy [A new method of non-free grafting of the axial medial foot flap]. *Travmatologiia i Ortopedii Rossii*, 2015, no. 1, pp. 90-94. (in Russian)
23. Kutianov D.I., Rodomanova L.A. Ispolzovanie tekhnologii rekonstruktivno-plasticheskoi mikrokhirurgii pri lechenii patsientov s patologiei oblasti golenostopnogo sustava [The use of technologies of reconstructive plastic microsurgery in the treatment of patients with the ankle pathology]. *Travmatologiia i Ortopediia Rossii*, 2013, no. 2, pp. 39-46. (in Russian)
24. Korostelev M.Iu., Shikhaleva N.G. Sovremennoe sostoianie problemy lecheniia patsientov s obshirnymi otsloikami pokrovnykh miagkikh tkanei [Current state of treating patients with extensive degloving injuries of integumentary soft tissues (literature review)]. *Genij Ortopedii*, 2017, vol. 23, no. 1, pp.88-94. (in Russian)
25. Oganesian A.R. Kompleksnye autotransplantaty pri rekonstruktsii defektov miagkikh tkanei i nizhnikh konechnostei [Complex autografts in the reconstruction of soft tissue and lower limb defects]. *Annaly Plasticheskoi, Rekonstruktivnoi i Esteticheskoi Khirurgii*, 2015, no. 1, pp. 67. (in Russian)
26. Cho E.H., Garcia R.M., Pien I., Kuchibhatla M., Levinson H., Erdmann D., Levin L.S., Hollenbeck S.T. Vascular considerations in foot and ankle free tissue transfer: Analysis of 231 free flaps. *Microsurgery*, 2016, vol. 36, no. 4, pp. 276-283. DOI: 10.1002/micr.22406.
27. Lin T.S., Quing R. Long-Term Results of a One-Stage Secondary Debulking Procedure after Flap Reconstruction of the Foot. *Plast. Reconstr. Surg*., 2016, vol. 138, no. 4, pp. 923-930. DOI: 10.1097/PRS.0000000000002510.
28. Ostrovskii N.V., Belianina I.B. Sovremennye podkhody k profilaktike i lecheniiu rubtsov v rekonstruktivno-plasticheskoi khirurgii [Modern approaches to the prevention and treatment of scars in reconstructive plastic surgery]. *Annaly Plasticheskoi, Rekonstruktivnoi i Esteticheskoi Khirurgii*, 2016, no. 1, pp. 95-96. (in Russian)
29. Minasov B.Sh., Valeev M.M., Gazizov R.F., Valeeva E.M. Rekonstruktsiia miagkikh tkanei stopy slozhnosostavnymi loskutami [Reconstruction of the foot soft tissues with composite flaps]. *Travmatologiia i Ortopediia Rossii*, 2007, no. 3, pp. 18-21. (in

Russian)
30. Shapovalov V.M., Gubochkin N.G., Gaidukov V.M., Lukicheva N.P., Miasnikov N.I. Rekonstruktivno-plasticheskie operatsii pri lechenii bolnykh s defektami pokrovnykh tkanei [Reconstructive-and-plastic surgeries in treatment of patients with defects of integumentary tissues]. *Genij Ortopedii*, 2014, no. 4, pp. 58-62. (in Russian)
31. Panov A.V., Shapovalov S.G., Pleshkov A.S., Loktionov P.V. Plasticheskoe zakrytie obshirnogo defekta miagkikh tkanei podoshvy stopy [Plastic closure of an extensive soft tissue defect of the sole of the foot]. *Annaly Plasticheskoi, Rekonstruktivnoi i Esteticheskoi Khirurgii*, 2015, no. 1, pp. 67-68. (in Russian)
32. Zygouris P., Michalinos A., Protogerou V., Kotsiomitis E., Mazarakis A., Dimovelis I., Troupis T. Use of lateral calcaneal flap for coverage of hindfoot defects: an anatomical appraisal. *Plast. Surg. Int*., 2015, vol. 2015, pp.. 212757. DOI: 10.1155/2015/212757.
33. Struckmann V., Hirche C., Struckmann F., Kolios L., Lehnhardt M., Kneser U., Daigeler A. Free and pedicled flaps for reconstruction of the weightbearing sole of the foot: a comparative analysis of functional results. *J. Foot Ankle Surg*., 2014, vol. 53, no. 6, pp. 727-734. DOI: 10.1053/j.jfas.2014.06.009.
34. Kurbanov U.A., Davlatov A.A., Dzhanobilova S.M., Nosiri M. Primenenie medialnogo podoshvennogo loskuta v khirurgicheskom lechenii defektov pokrovnykh tkanei piatochnoi oblasti [The use of the medial plantar flap in the surgical treatment of defects in the integumentary tissues of the calcaneal region]. *Vestnik Avitsenny*, 2010, no. 2, pp. 9-17. (in Russian)
35. Hong, J.P., Park S.W., Choi D.H. Reply: The thin gluteal artery perforator free flap to resurface the posterior aspect of the leg and foot. *Plast. Reconstr. Surg*., 2015, vol. 135, no. 4, pp. 794e. DOI: 10.1097/PRS.0000000000001072.
36. Lipatov K.V., Komarova E.A. Osobennosti kozhno-plasticheskikh rekonstruktsii u bolnykh so streptokokkovoi nekrotiziruiushchei infektsiei miagkikh tkanei [Peculiar features of skin-plastic reconstructions in patients with streptococcal necrotizing infection of soft tissues]. *Annaly Plasticheskoi, Rekonstruktivnoi i Esteticheskoi Khirurgii*, 2015, no. 4, pp. 51-57. (in Russian)
37. Minasov B.Sh., Valeev M.M., Chastichenko S.A., Gazizov R.F., Valeeva E.M. *Sposob rotatsii medialnogo kozhno-fastsialnogo loskuta stopy pri plastike defektov miagkikh tkanei stopy* [The way of rotation of the medial fasciocutaneous flap of the foot in the plasty of soft tissue defects of the foot]. Patent RF no. 2357696, A 61 B 17/56, 2008. (in Russian)
38. Shvedovchenko I.V., Fomin N.F., Aristov A.M. Potentsialnye vozmozhnosti podoshvennoi oblasti stopy kak donorskoi zony v rekonstruktivno-plasticheskoi khirurgii nizhnikh konechnostei (kliniko-anatomicheskoe issledovanie) [Potential possibilities of the foot plantar region as a donor area in reconstructive plastic surgery of the lower limbs (A clinical and anatomical study)]. *Travmatologiia i Ortopediia Rossii*, 2007, no. 3, pp. 12-17. (in Russian)
39. Rausky J., Binder J.P., Mazouz-Dorval S., Hamou C., Revol M. Perforator-based chimaeric thoracodorsal flap for foot reconstruction. *J. Plast. Reconstr. Aesthet. Surg*., 2013, vol. 66, no. 12, pp. 1798-1800. DOI: 10.1016/j.bjps.2013.04.064.
40. Leclère F.M., Casoli V. Reconstruction of a traumatic plantar foot defect with a novel free flap: The medial triceps brachii free flap. *J. Cosmet. Laser Ther*., 2015, vol. 17, no. 5, pp. 286-289. DOI: 10.3109/14764172.2015.1022188.
41. Song B., Chen J., Han Y., Hu Y., Su Y., Li Y., Zhang J., Guo S. The use of fabricated chimeric flap for reconstruction of extensive foot defects. *Microsurgery*, 2016, vol. 36, no. 4, pp. 303-309. DOI: 10.1002/micr.22399.
42. Willegger M., Seyidova N., Schuh R., Windhager R., Hirtler L. Anatomical Footprint of the Tibialis Anterior Tendon: Surgical Implications for Foot and Ankle Reconstructions. *Biomed. Res. Int*., 2017, vol. 2017, pp. 9542125. DOI: 10.1155/2017/9542125.
43. Medina M.A. 3rd, Salinas H.M., Eberlin K.R., Driscoll D.N., Kwon J.Y., Austen W.G. Jr., Cetrulo C.L. Jr. Modified free radial forearm fascia flap reconstruction of lower extremity and foot wounds: optimal contour and minimal donor-site morbidity. *J. Reconstr. Microsurg*., 2014, vol. 30, no. 8, pp. 515-522. DOI: 10.1055/s-0034-1383499.
44. Sannikov A.B. Rekonstruktivno-vosstanovitelnaia khirurgiia konechnostei s ispolzovaniem kozhno-fastsialnykh ostrovkovykh loskutov s osevym krovosnabzheniem [Reconstructive and restorative surgery of the limbs using fasciocutaneous islet flaps with axial blood supply]. *Annaly Plasticheskoi, Rekonstruktivnoi i Esteticheskoi Khirurgii*, 2015, no. 1, pp. 77-78. (in Russian)
45. Fengjing Z., Jianmin Y., Xingqun Z., Liang M., Longchun Z., Yibo X., Peng W., Zhen Z. [Repair of soft tissue defect in hand or foot with lobulated medial sural artery perforator flap]. *Zhonghua Zheng Xing Wai Ke Za Zhi*, 2015, vol. 31, no. 6, pp. 418-421. (in Chinese)
46. Gomez M.M., Casal D. Reconstruction of large defect of foot with extensive bone loss exclusively using a latissimus dorsi muscle free flap: a potential new indication for this flap. *J. Foot Ankle Surg*., 2012, vol. 51, no. 2, pp. 215-217. DOI: 10.1053/j.jfas.2011.07.008.
47. Zhu L., Wei J., Daluvoy S., Hollenbeck S.T., Chuan D., Xu H., Dong J. Free partial latissimus dorsi myocutaneous flap for coverage of severe achilles contracture in children. *J. Plast. Reconstr. Aesthet. Surg*., 2013, vol. 66, no. 1, pp. 113-119. DOI: 10.1016/j.bjps.2012.08.010.
48. Parajuli N.P., Shrestha D., Panse N. Distally based sural faciocutaneous and fascial (adipofascial) flap for reconstruction of distal leg, ankle and foot defects. *Kathmandu Univers. Med. J*. (KUMJ), 2014, vol. 12, no. 46, pp. 126-131. DOI: 10.3126/kumj.v12i2.13659.
49. Santanelli di Pompeo F., Pugliese P., Sorotos M., Rubino C., Paolini G. Microvascular reconstruction of complex foot defects, a new anatomo-functional classification. *Injury*, 2015, vol. 46, no. 8, pp. 1656-1663. DOI: 10.1016/j.injury.2015.05.002.
50. Horta R., Valença-Filipe R., Nascimento R., Monteiro D., Silva A. The adipofascial dorsalis pedis perforator turn-over flap for reconstruction of a distal defect of the foot. *Microsurgery*, 2015, vol. 35, no. 4, pp. 333-334. DOI: 10.1002/micr.22343.
51. Kaplun V.A., Kopysova V.A., Martel I.I. Metody khirurgicheskogo lecheniia bolnykh s povrezhdeniiami golenostopnogo sustava [Methods of surgical treatment of patients with the ankle injuries]. *Vestnik Travmatologii i Ortopedii im. N.N. Priorova*, 2013, no. 1, pp. 27-33. (in Russian)
52. Cho E.H., Garcia R., Pien I., Thomas S., Levin L.S., Hollenbeck S.T. An algorithmic approach for managing orthopaedic surgical wounds of the foot and ankle. *Clin. Orthop. Relat. Res*., 2014, vol. 472, no. 6, pp. 1921-1929. DOI: 10.1007/s11999-014-3536-7.
53. Minasov B.Sh., Biktasheva E.M., Valeev M.M. *Plastika loskutami s osevym tipom krovosnabzheniia pri obshirnykh defektakh miagkikh tkanei zadnego otdela stopy* [Plasty using flaps with an axial type of blood supply for extensive soft tissue defects of the hindfoot]. Ufa, 2019, 132 p. (in Russian)
54. Rodomanova L.A., Kochish A.Iu. *Rekonstruktivnye mikrokhirurgicheskie operatsii pri travmakh konechnostei: rukovodstvo dlia vrachei* [Reconstructive microsurgical operations for injuries of the limbs: guide for physicians]. SPb., 2012, 116 p. (in Russian)
55. Barve D.J., Gupta A. The extended distally based sural neurocutaneous flap for foot and ankle reconstruction: a retrospective review of 10 years of experience. *Ann. Plast. Surg*., 2015, vol. 74, no. 6, pp. 743. DOI: 10.1097/SAP.0000000000000476.
56. Scaglioni, M.F., Kuo Y.R., Chen Y.C. Reconstruction of distal hand and foot defects with the free proximal peroneal artery perforator flap. *Microsurgery*, 2016, vol. 36, no. 3, pp. 183-190. DOI: 10.1002/micr.22364.
57. Eser C., Kesiktaş E., Gencel E., Aslaner E.E., Yavuz M. An alternative method to free flap for distal leg and foot defects due

to electrical burn injury: distally based cross-leg sural flap. *Ulus. Travma Acil. Cerrahi Derg*., 2016, vol. 22, no. 1, pp. 46-51. DOI: 10.5505/tjtes.2015.35306.
58. Yoon C.S., Noh H.J., Malzone G., Suh H.S., Choi D.H., Hong J.P. Posterior interosseous artery perforator-free flap: treating intermediate-size hand and foot defects. *J. Plast. Reconstr. Aesthet. Surg*., 2014, vol. 67, no. 6, pp. 808-814. DOI: 10.1016/j.bjps.2014.03.007.
59. Afonichev K.A., Nikitin M.S., Kuptsova O.A. Lechenie posleozhogovoi vtorichnoi deformatsii stopy [Treatment of post-burn secondary deformity of the foot]. *Ortopediia, Travmatologiia i Vosstanovitelnaia Khirurgiia Detskogo Vozrasta*, 2015, vol. 3, no. 2, pp. 52-55. (in Russian)
60. Rodomanova L.A., Medvedev G.V., Afanasev A.O., Tsybul E.S. Atipichnye sposoby revaskuliarizatsii krovosnabzhaemykh kompleksov tkanei v retsipientnoi zone [Atypical methods of revascularization of blood-supplied tissue complexes in the recipient zone]. *Annaly Plasticheskoi, Rekonstruktivnoi i Esteticheskoi Khirurgii*, 2018, no. 1, pp. 100-101. (in Russian)
61. Mikusev I.E., Mikusev G.I., Khabibullin R.F. Diagnostika tipa zakrytoi travmaticheskoi otsloiki kozhi [Diagnosis of the type of closed traumatic skin detachment]. *Prakticheskaia Meditsina*, 2015, vol. 1, no. 4, pp. 129-131. (in Russian)
62. Xie S., Deng X., Chen Y., Song D., Li K., Zhou X., Li Z. Reconstruction of foot and ankle defects with a superthin innervated anterolateral thigh perforator flap. *J. Plast. Surg. Hand Surg*., 2016, vol. 50, no. 6, pp. 367-374. DOI: 10.1080/2000656X.2016.1184158.
63. Bista N., Shrestha K.M., Bhattachan C.L. The reverse sural fasciocutaneous flap for the coverage of soft tissue defect of lower extremities (distal 1/3 leg and foot). *Nepal Med. Coll. J*., 2013, vol. 15, no. 1, pp. 56-61.
64. Scaglioni M.F., Rittirsch D., Giovanoli P. Reconstruction of the Heel, Middle Foot Sole, and Plantar Forefoot with the Medial Plantar Artery Perforator Flap: Clinical experience with 28 cases. *Plast. Reconstr. Surg*., 2018, vol. 141, no. 1, pp. 200-208. DOI: 10.1097/PRS.0000000000003975.
65. Wang Z.Q., Cao Y.L., Huang Y.F., Liu D.Q., Li X.F. Cross-leg repair of large soft-tissue defects in distal sites of the feet by distally based neuro-fasciocutaneous flaps with perforating vessels. *Genet. Mol. Res*., 2014, vol. 13, no. 3, pp. 5484-5491. DOI: 10.4238/2014.July.25.1.
66. Lee K.J., Lee S.H., Kim M.B., Lee Y.H. Adipofascial fold-down flaps based on the posterior tibial artery perforator to cover the medial foot and ankle defects. *J. Plast. Reconstr. Aesthet. Surg*., 2016, vol. 69, no. 12, pp. e229-e237. DOI: 10.1016/j.bjps.2016.08.019.
67. Chaput B., Eburdery H., Laguerre J., Spiecker A., Herlin C., Grolleau J.L. Chimeric flap and free-style puzzle flap for extended coverage of the foot and ankle. *Plast. Reconstr. Surg*., 2015, vol. 135, no. 4, pp. 797e-799e. DOI: 10.1097/PRS.0000000000001048.
68. Gizatulina L.Ia., Bogov A.A., Mullin R.I., Ibragimov Ia.Kh. Primenenie vaskuliarizirovannoi kozhnoi plastiki zadnim fastsialno-zhirovym loskutom goleni na retrogradnom krovotoke dlia zameshcheniia defekta miagkikh tkanei nizhnei treti goleni i stopy [The use of vascularized skin grafting with a posterior fascial fat flap of the lower leg on retrograde blood flow to replace a soft tissue defect in the lower third of the leg and foot]. *Prakticheskaia Meditsina*, 2017, no. 8, pp. 53-55. (in Russian)
69. Acartürk T.O., Tunc S., Acar F. Versatility of the Perforator-Based Adipose, Adipofascial, and Fasciocutaneous Flaps in Reconstruction of Distal Leg and Foot Defects. *J. Foot Ankle Surg*., 2016, vol. 55, no. 2, pp. 362-367. DOI: 10.1053/j.jfas.2014.12.020.

The article was submitted 11.04.2020; approved after reviewing 25.01.2021; accepted for publication 23.12.2021.

Information about authors:

1. Bulat Shamilevich Minasov – Doctor of Medical Sciences, Professor, B.minasov@ya.ru;
2. Elina Maratovna Biktasheva – Candidate of Medical Sciences, dr.elinabiktasheva@yandex.ru;
3. Marat Mazgarovich Valeev – Doctor of Medical Sciences, valeevmm@rambler.ru;
4. Rasul Radikovich Yakupov – Doctor of Medical Sciences, rasulr@mail.ru;
5. Timur Bulatovich Minasov – Doctor of Medical Sciences, m004@yandex.ru;
6. Tagir Ryfatovich Mavlyutov – Doctor of Medicine, mavlutovtagir@mail.ru.

Conflict of interests *Not declared.*

Source of funding *The study is performed without sponsorship support.*