Case report
https://doi.org/10.17816/2311-2905-17532

Artificial Deformity Creation in Treatment of Soft Tissue Wounds and Lower Leg Bones Defect: A Case Report

Vladimir V. Khominets, Sergey V. Mikhailov, Alexey V. Shchukin, Evgenii B. Nagornyi, Sayan E. Zhumagaziev, Danil R. Tsoy

Kirov Military Medical Academy, St. Petersburg, Russia

Abstract

Background. The problem of treating wounded patients with defects of soft tissues and bones of the extremities continues to be relevant. One of the ways to close soft tissue defects, especially in case of bone tissue loss, after open fractures of the extremities is acute shortening and creation of artificial angular deformity of the segment.

The aim of the study — to demonstrate the possibilities of acute shortening and angulation of the segment as a technique to replace soft tissue and bone defects in treatment of a patient with a gunshot wound to the lower leg.

Case description. A 30-year-old wounded man was admitted to the clinic with an extensive defect in soft tissues and bones of the lower leg in the middle third. To reduce the wound size, acute shortening and angulation of the lower leg was performed. The intentional angular deformation was 24°, shortening — up to 8 cm. The residual soft tissue wound defect was closed with local tissues and split skin autograft. The tibia was fixed by the Ilizarov hinge-distraction apparatus with following gradual correction of the angular deformity. After that, one performed osteotomy of the tibia in order to eliminate shortening with the Ilizarov method (the distraction rate of 1 mm per day). After restoring the length of the lower leg, in order to replace the defect along the anterior surface of the tibia, a marginal "flake" was formed from a displaced fragment. At a follow-up examination, in 18 months after the injury the patient walks with full weight bearing on the injured limb without any additional means of support, continues to perform military service duties in accordance with his position.

Conclusions. The presented clinical case demonstrates that acute shortening of a limb segment with creation of artificial angular deformity is an effective method for temporary closure of a gunshot defect of soft tissues. The technique allowed closing critical soft tissue defect of the lower leg and restoring the anatomy (length) of the segment. Consequently, one was able to achieve satisfactory treatment results and restore the functions of an injured limb. Besides, acute temporary shortening technique eliminated the need to perform technically sophisticated and lengthy microsurgical reconstructions, which are associated with a flap replacement for closure of soft tissue defects in a shotgun fracture area.

Keywords: gunshot fractures, soft tissues defects, bone defects, acute shortening, angulation, external fixation, limb salvage surgery.

Cite as: Khominets V.V., Mikhailov S.V., Shchukin A.V., Nagornyi E.B., Zhumagaziev S.E., Tsoy D.R. Artificial Deformity Creation in Treatment of Soft Tissue Wounds and Lower Leg Bones Defect: A Case Report. *Traumatology and Orthopedics of Russia*. 2024;30(3):85-94. (In Russian). https://doi.org/10.17816/2311-2905-17532.

✉ *Sayan E. Zhumagaziev*; e-mail: shumagasiev@mail.ru

Submitted: 26.04.2024. Accepted: 20.05.2024. Published Online: 29.08.2024.

Клинический случай
УДК 616.718.5/.6-001.45-089.84
https://doi.org/10.17816/2311-2905-17532

Применение искусственной деформации при лечении раненого с дефектом мягких тканей и костей голени: клинический случай

В.В. Хоминец, С.В. Михайлов, А.В. Щукин, Е.Б. Нагорный, С.Е. Жумагазиев, Д.Р. Цой

ФГБВОУ ВО «Военно-медицинская академия им. С.М. Кирова» Министерства обороны России, г. Санкт-Петербург, Россия

Реферат

Актуальность. Проблема лечения раненых с дефектом мягких тканей и костей конечностей продолжает сохранять свою актуальность. Одним из способов закрытия мягкотканных дефектов, особенно при потере костной ткани, у пациентов с открытыми переломами костей конечностей является острое укорочение и создание искусственной угловой деформации сегмента.

Цель — на клиническом примере показать возможности применения техники острого укорочения и ангуляции сегмента для замещения дефектов мягких тканей и кости при лечении пациента с огнестрельным ранением голени.

Описание клинического случая. Раненый 30 лет поступил в клинику с обширным дефектом мягких тканей и костей голени в средней трети. С целью уменьшения размеров раны выполнены острое укорочение и ангуляция голени. Преднамеренная угловая деформация голени составила 24°, укорочение — до 8 см. После закрытия остаточного раневого дефекта мягких тканей местными тканями и расщепленным кожным аутотрансплантатом выполнена фиксация большеберцовой кости шарнирно-дистракционным аппаратом Илизарова с последующей постепенной коррекцией угловой деформации, на следующем этапе — остеотомия большеберцовой кости с целью устранения укорочения методом Илизарова (темп дистракции 1 мм в сутки). После восстановления длины голени с целью замещения дефекта по передней поверхности большеберцовой кости выполнено формирование краевого «отщепа» от перемещенного фрагмента. При контрольном осмотре через 18 мес. после ранения пациент ходит с полной нагрузкой на травмированную конечность без дополнительных средств опоры, продолжает исполнять обязанности военной службы в соответствии с занимаемой должностью.

Заключение. Острое укорочение сегмента конечности с формированием искусственной угловой деформации является эффективной методикой для временного закрытия огнестрельного дефекта мягких тканей, позволяющей закрыть критический мягкотканный дефект голени, восстановить анатомию (длину) сегмента и, как следствие, добиться удовлетворительных результатов лечения и восстановления функций поврежденной конечности. Кроме того, техника острого временного укорочения исключает потребность в технически сложных и длительных микрохирургических реконструкциях, связанных с перемещением лоскута для закрытия дефектов мягких тканей в области огнестрельного перелома.

Ключевые слова: огнестрельные переломы, дефекты мягких тканей, дефекты кости, острое укорочение, ангуляция, внешний остеосинтез, органосохраняющие операции.

Для цитирования: Хоминец В.В., Михайлов С.В., Щукин А.В., Нагорный Е.Б., Жумагазиев С.Е., Цой Д.Р. Применение искусственной деформации при лечении раненого с дефектом мягких тканей и костей голени: клинический случай. *Травматология и ортопедия России*. 2024;30(3):85-94. https://doi.org/10.17816/2311-2905-17532.

Жумагазиев Саян Елемесьевич; e-mail: shumagasiev@mail.ru

Рукопись получена: 26.04.2024. Рукопись одобрена: 20.05.2024. Статья опубликована онлайн: 29.08.2024.

INTRODUCTION

In the structure of combat injuries, gunshot wounds to the limbs account for over 70%, with 40% of these being fragmentary fractures of long bones [1]. Primary and secondary defects of soft tissues and bones are identified in gunshot fractures. Primary defects occur due to the direct damaging effect of the projectile, while secondary defects arise from initial debridement or subsequent surgical interventions [1, 2]. The main techniques for replacing soft tissue defects involve various types of grafts, both free and pedicled [3, 4].

Nowadays, the nature of injuries has changed compared to previous military conflicts. Current combat surgical trauma to the musculoskeletal system is characterized by a high frequency of extensive primary defects in soft tissues and bones, vascular and nerve damage, and the avulsion and destruction of limb segments. Additionally, there is an increase in the number of multiple injuries and polytrauma [5, 6].

According to the literature, one method for closing soft tissue defects, especially when combined with bone loss, in open fractures of limbs is acute shortening and creating an angular artificial deformation of the segment [7, 8]. After correcting this deformation, subsequent restoration of the segment's length and shape is usually achieved through distraction osteogenesis using the Ilizarov technique [9, 10]. There are a few reports in the literature on the results of applying the technique of acute shortening and angulation in patients with gunshot defects of soft tissues and limb bones [10, 11].

The aim of this study is to demonstrate the effectiveness of using the technique of the acute shortening and angulation of the segment for replacing soft tissue and bone defects when treating a patient with a gunshot wound to the lower leg.

Case description

In May 2022, a 30-year-old military servant sustained a gunshot injury to the right lower leg, resulting in a gunshot defect of the middle third of the tibia, damage to the anterior tibial artery, the peroneal nerve, the peroneal muscles, and the tendons of the extensor of the toes. At the site of the injury, the patient underwent the debridement of the wound of the lower leg, ligation of the anterior tibial artery, and fixation of the tibia with an external fixator from the military-Field rod kit (MFRK). During evacuation by air medical transport, the patient received infusion, anticoagulant, and antibiotic therapy. The patient was transported to the clinic 36 hours after the injury.

Upon admission, the overall condition of the patient was assessed as moderate according to the VPH-SP scale (19 points). The severity of the injury was rated as severe on the VPH-P scale (OR) (6.6 points) [12]. On the AIS (Abbreviated Injury Scale), the severity of the injury was 3 points (significant but not life-threatening) [13]. According to the Gustilo-Anderson classification of open fractures, the fracture was classified as type IIIB [14]. The defect size in the tibia was 8 cm, classified as type 3 according to the SoFCOT classification (French Society of Orthopaedics and Traumatology) [15].

Local status upon admission: the right lower leg was fixed with the MFRK external fixator, which was stable, and there were no signs of skin inflammation around the half-pins. Plantar flexion in the right ankle was limited, and dorsal extension was absent. On the anterior surface of the right lower leg in the middle third, a lacerated and contused wound measuring 17×14 cm was visible with slight serosanguineous discharge. The wound bed was formed with damaged peroneal muscles, extensor muscles of the toes, and the tibia. There was a 2 cm-wide area of preserved skin in the middle of the wound. Pulsation of the dorsalis pedis artery was absent, but the pulsation of the posterior tibial artery was distinctly detectable. No signs of foot ischemia were present (Figure 1).

Three days after admission, the patient underwent surgery: a repeated debridement of the lower leg wound, during which devitalized tibial fragments were removed. One of the bone fragments, which had not lost connection with the soft tissues, was fixed with a screw to the distal fragment of the tibia. To reduce the wound size, acute shortening and angulation of the lower leg were performed. The intentional angular deformity of the lower leg was 24°, and the shortening was up to 8 cm. During the shortening, blood flow in the distal parts of the limb was monitored using Doppler sonography and pulse oximetry. The remaining wound defects were covered with a vacuum drainage system (Figure 2).

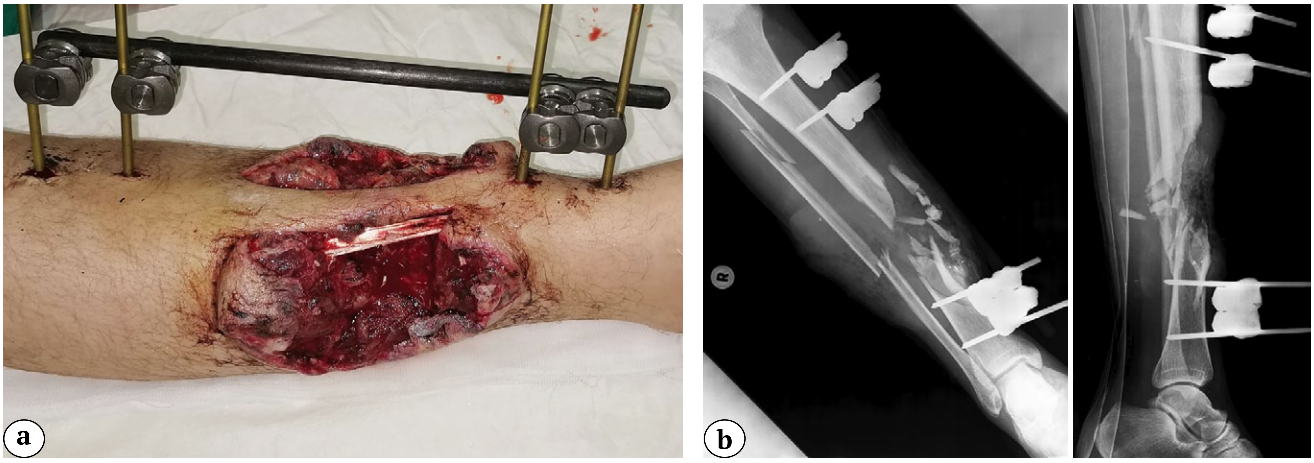

Figure 1. View (a) and X-rays of the patient's right lower leg in frontal and lateral projections (b) upon admission to the clinic: gunshot fractures of the tibia and fibula, fixation with the MFRK device (2 rods in each fragment)

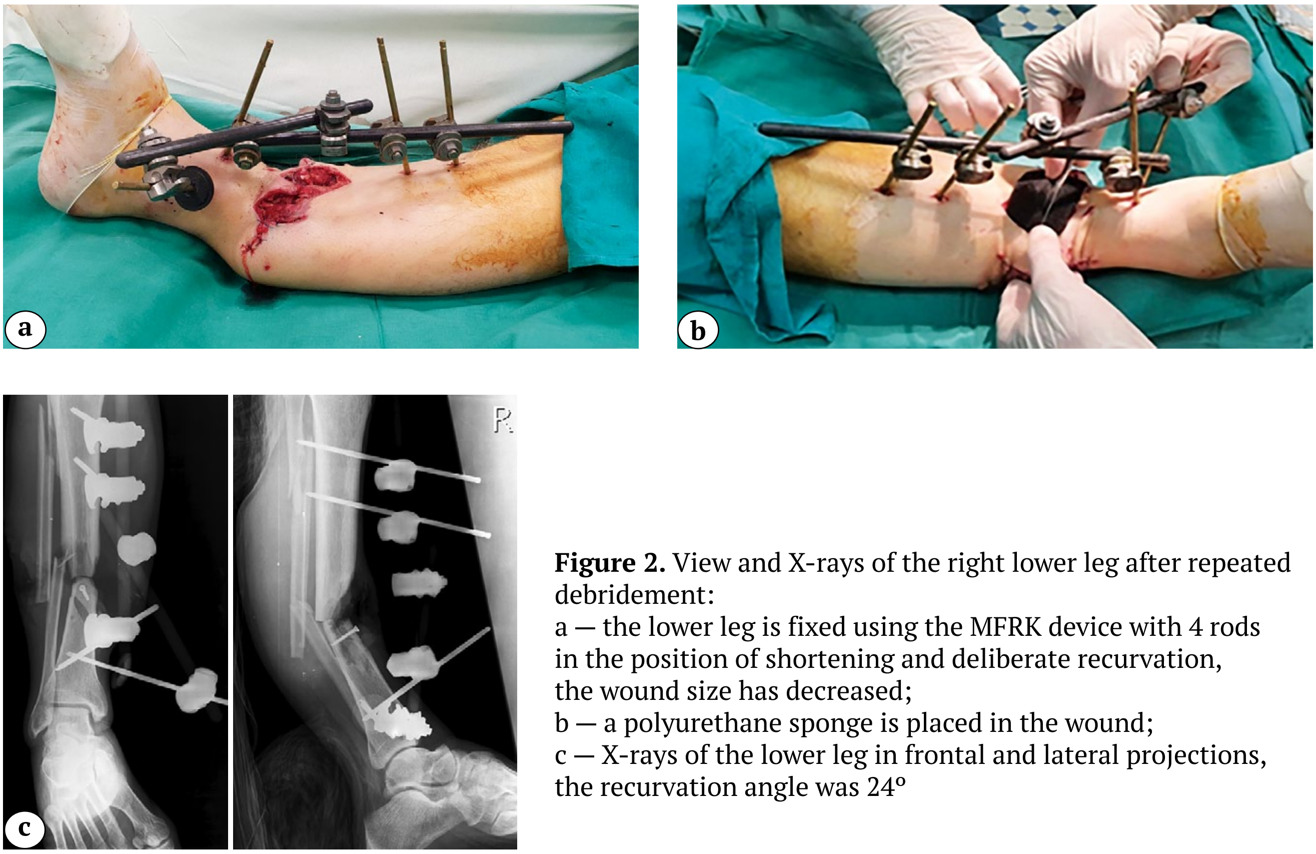

Figure 2. View and X-rays of the right lower leg after repeated debridement:
a — the lower leg is fixed using the MFRK device with 4 rods in the position of shortening and deliberate recurvation, the wound size has decreased;
b — a polyurethane sponge is placed in the wound;
c — X-rays of the lower leg in frontal and lateral projections, the recurvation angle was 24°

Eight days after admission, as a result of treatment procedures, the wound was cleaned, and granulation tissue appeared. The external fixator was reinstalled, and the soft tissue wound defect was closed with local tissues and a split skin autograft (Figure 3).

On the 15th day after engraftment, the operation was performed: partial removal of the external fixator, leaving one half-pin in each fragment to maintain the position of the lower leg, and fixation of the tibia with the Ilizarov hinged-distraction apparatus (Figures. 4, 5).

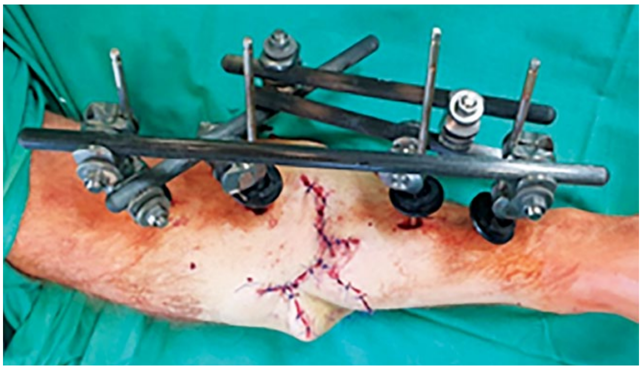

Figure 3. View of the lower extremity after closure of the skin defect

Figure 4. View of the lower extremity on the 1st day after surgery: the right lower leg is fixed with the Ilizarov hinged-distraction apparatus

In the following 8 days, the angular deformity of the lower leg was corrected with the subsequent corticotomy of the tibia in the upper third (Figure 6). Thirty days later, distraction was initiated in the ring fixator at the osteotomy site to correct the shortening using the Ilizarov method (distraction rate of 1 mm per day).

Three months later, the length of the lower leg was restored (Figure 7). Since a defect persisted on the anterior surface of the tibia, a marginal "split" was formed from the displaced fragment to fill the defect (so-called marginal graft) (Figure 8).

After 4.5 months, the contact between the "split" and the distal fragment was achieved (Figure 9 a), and after 7.5 months, a good remodeling of the regenerate was observed (Figure 9 b).

The patient was continuously monitored by clinic specialists to assess treatment outcomes, determine further management strategies, and direct the patient to medical rehabilitation and health resort treatment.

Fourteen months after the injury, the external fixator was removed (Figure 10). The anatomical-functional result was evaluated as good 18 months after the injury, with a score of 83 on the Neer-Grantham-Shelton scale [16]. The patient walks without additional support and continues to perform military duties according to his position. There is no dorsal flexion of the right foot (Figure 10).

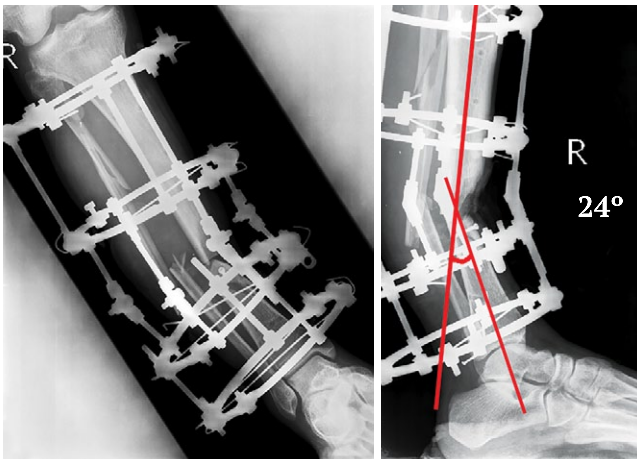

Figure 5. X-rays of the lower leg in frontal and lateral projections after fixation with the Ilizarov hinged-distraction apparatus, the recurvation angle was 24°

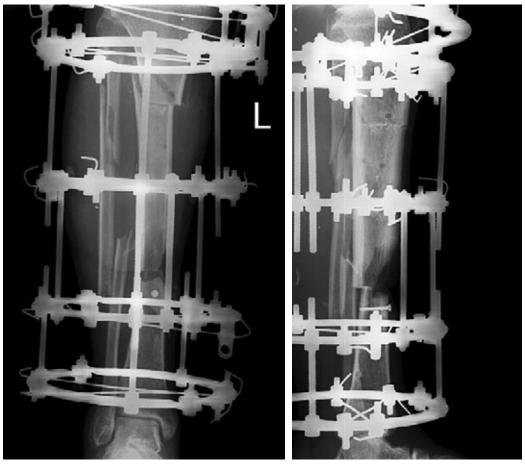

Figure 6. X-rays of the lower leg in frontal and lateral projections after osteotomy of the upper third of the tibia

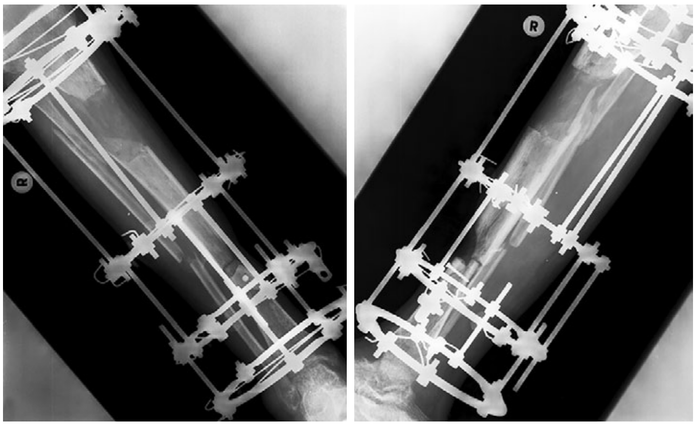

Figure 7. X-rays of the lower leg in frontal and lateral projections after restoration of limb length: maturing tibial regenerate

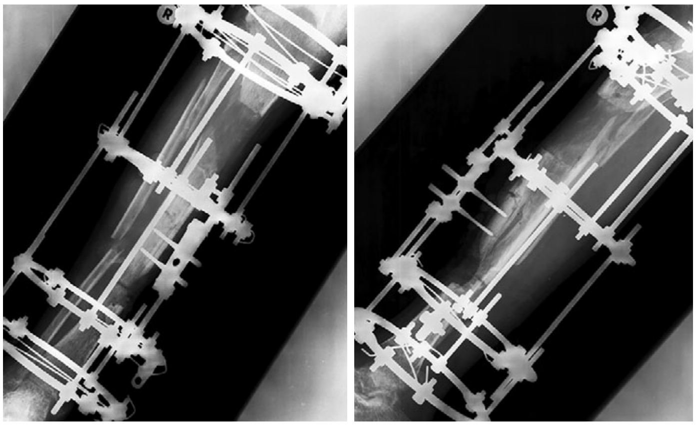

Figure 8. X-rays of the lower leg in frontal and lateral projections after the formation of the marginal “split” of the tibia

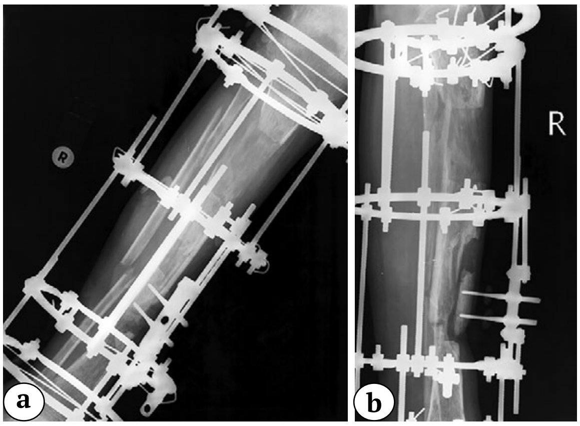

Figure 9. X-rays of the patient’s lower leg in frontal and lateral projections in the Ilizarov apparatus with 4 rings:
a — the contact between the “split” and distal fragment of the tibia is determined;
b — the reconstructed bone regenerate of the tibia in the upper third is determined

Figure 10 (a). X-rays and the appearance of the wounded 18 months after the injury:
a — X-rays of the lower leg in frontal and lateral projections — a rebuilt bone regenerate in the upper third and a healed fracture in the lower third of the tibia, a healed fracture of the fibula are noted

Figure 10 (b). X-rays and the appearance of the wounded 18 months after the injury:
b — functional result of treatment

DISCUSSION

The literature contains sufficient evidence that the method of acute limb shortening is one of the techniques for replacing soft tissue defects. This approach allows for the primary closure of extensive wounds with subsequent reconstruction of the limb using external fixators, significantly reducing the need for microsurgical operations [8]. Today, various terms are used to describe this technique — acute shortening, primary shortening, acute deformity, angular shortening, intentional temporary deformity, intentional deformity, intentional temporary shortening and deformity, shortening with angulation and rotation, etc. [17, 18]. We agree with K. Plotnikov et al., who propose a unified term — "artificial deformity creation" (ADCr), which can include various options for the shortening, angulation, and rotation of the limb segment, either separately or in combination [9].

Acute shortening using the Ilizarov apparatus can be applied in the treatment of open fractures of the tibia associated with soft tissue defects. C. Sen et al. reported good and excellent functional outcomes in 23 out of 24 patients, with all 24 patients showing signs of bone union according to D. Paley's classification [19].

Several studies have been published on the treatment of patients with bone and soft tissue defects using acute shortening techniques combined with intentional angular deformity formation of the limb segment [20, 21, 22]. K.G. Bundgaard and K.S. Christensen described a case of surgical treatment of a patient with a defect of the tibia and fibula measuring 9 cm and 3 cm, respectively, associated with a soft tissue defect measuring 10×15 cm located in the projection of the anterior and lateral fascial compartments, against the background of a wound infection caused by *Staphylococcus aureus*. The patient's limb was fixed with a ring external fixator, and the bone defect was managed by acute shortening of 3 cm, followed by the gradual formation of a deformity with an anteriorly open angle until the proximal and distal wound edges made contact. The second stage involved osteotomy of the tibia in the upper third, bone transport, and gradual correction of the deformity. The fixator was removed after a year. The authors reported that the described technique allowed for the elimination of the bone defect through distraction osteogenesis and the soft tissue defect, including muscle, through distraction histogenesis [20].

A. Lerner et al. reported the use of acute shortening with the ring external fixator for the treatment of severe bone injuries and soft tissue defects. All 12 patients had open fractures classified as type IIIB according to the Gustilo-Anderson classification, with an average bone mass loss of 7.9 cm and an average score of 6.7 on the Mangled Extremity Severity Score (MESS) scale [23]. All patients underwent acute segment shortening, and 3 patients also had deformity with an angle of 50 to 60° at the fracture site, open anteriorly, to minimize the existing bone and soft tissue defect. One of these 3 patients required a local flap for coverage, while 2 required split skin grafts. After wound healing, the authors corrected the deformity over the course of another 3 weeks [21].

Thus, one of the best devices currently used for correcting artificial deformities is the ring external fixator. Acute shortening alone leads to the formation of a simple uniplanar deformity, while additional angulation creates a biplanar two-component deformity — specifically shortening and angular deformity in two planes. If a rotational component is added to axial shortening and angulation, a complex, multicomponent, multiplanar deformity appears. The Ilizarov method allows for the correction of each component of the deformity. Each stage of correction requires radiographic control to confirm its effectiveness [9, 24]. One of the ways to address the problem of complex deformity correction, which arises after soft tissue defect closure using the artificial deformity creation method, is the use of circular hexapod fixators [11, 18, 25].

S.J. Nho et al. described a surgical technique for limb segment shortening by creating an acute angular deformity in the treatment of nonunion against the background of a chronic infection and persistent deep wound infection. Acute shortening eliminated the need for further soft tissue reconstruction. In the case presented in this work, acute shortening alone was insufficient to close the wound. When an additional deformity component was created, the wound edges were approximated without tension. Once the wound healed, the Ilizarov/Taylor apparatus was adjusted to restore the length and correct the angular deformity. The ability of the Taylor frame to correct complex deformities is particularly useful in the treatment of patients with this pathology [25].

K. Plotnikov et al. analyzed literature data on the use of acute shortening in open tibial fractures with soft tissue defects and divided the studies into two groups. In one group, the authors applied acute shortening techniques, combinations of acute shortening and subsequent gradual shortening, acute shortening and angulation, as well as combinations of acute shortening, angulation, and rotation in cases of acute trauma. The other group of authors used the acute shortening method in the treatment of patients with infectious complications as a consequence of trauma. The ring external fixator was most frequently used for deformity correction, and less often, the Taylor Spatial Frame (TSF) hexapod system. Corrections using various types of monolateral external fixators were performed much less frequently. In the group of patients with infectious complications, the ring external fixator was most frequently used, and less often, the Taylor hexapod. Only two authors used monolateral external fixation devices for deformity correction. The review also noted that the limit of acute shortening should be determined by the condition of the soft tissues and the vascular status of the injured limb. To ensure the safety of acute shortening, it is recommended to use intraoperative Doppler ultrasound and monitor blood flow in the distal vessels of the limb (a. dorsalis pedis and a. tibialis posterior) or pulse oximetry on the big toe. According to several authors, the maximum acute shortening performed in a single stage was 3 cm. Analysis of the studies revealed that the size of the bone defect in the group of patients with acute trauma ranged from 1 to 22 cm, and from 1 to 14 cm in the group of patients with traumatic sequelae. The total external fixation time (including primary fixation, deformity correction, and consolidation) for acute trauma ranged from 2-3 to 53 months. In the treatment of patients with infectious complications of trauma, this period varied from 3 to 16 months. In both groups, the authors noted a reduction in the need for microsurgical intervention, specifically the use of free flaps, when applying the acute shortening method to close extensive soft tissue defects [9].

CONCLUSIONS

The clinical case we presented demonstrates that acute shortening of a limb segment with the formation of an artificial angular deformity is an effective method for the temporary closure of gunshot soft tissue defects. This method allowed us to close a critical soft tissue defect in the lower leg, to restore the segment's anatomy (length), and, as a result, to achieve satisfactory treatment outcomes and the recovery of function in the injured limb. Moreover, the technique of acute temporary shortening eliminated the need for technically complex and extended microsurgical reconstructions, which involve flap transfer for the closure of soft tissue defects in the area of the gunshot fracture.

DISCLAIMERS

Author contribution

Khominets V.V. — study concept and design.

Mikhailov S.V. — data acquisition, data analysis and interpretation, editing the manuscript.

Schukin A.V. — data analysis and interpretation, editing the manuscript.

Nagornyi E.B. — data analysis and interpretation, literature search and review, drafting the manuscript.

Zhumagaziev S.E. — data acquisition, data analysis and interpretation, drafting the manuscript.

Tsoy D.R. — data acquisition, data analysis and interpretation, literature search and review.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

Funding source. This study was not supported by any external sources of funding.

Disclosure competing interests. The authors declare that they have no competing interests.

Ethics approval. Not applicable.

Consent for publication. Written consent was obtained from the patient for publication of relevant medical information and all of accompanying images within the manuscript.

REFERENCES

1. Khominets V.V., Shapovalov V.M., Mikhailov S.V., Brizhan L.K. Improving medical and evacuation measures in modern local wars. In: Treatment of wounded limbs in wars and armed conflicts. St. Petersburg: Istoricheskaya illyustraciya; 2021. p. 40-64. (In Russian).
2. Grubor P., Falzarano G., Medici A., GruborM., Franzese R., Errico G. et al. The Damage Control Orthopedics and External Fixation in traffic accident after 20 Years in the Bosnian War: Our Experience and a Review of the Literature. *SYLWAN*. 2014;158(6):90-109.
3. Volgas D.A., Kharder I. Methods of surgical suture and wound coverage. In: *Soft tissues in traumatology. Treatment principles and clinical cases.* Berlin: Vassa-media; 2016. p.126-201. (In Russian).
4. Liu H., Liu J., Wu Y., Ma Y., Zhou M., Xue Y. et al. Analysis of the Risk Factors for Free Flap Necrosis in Soft Tissue Reconstruction of the Lower Limbs. *Orthop Surg*. 2023;15(6):1534-1540. doi: 10.1111/os.13727.
5. Kryukov E.V., Davydov D.V., Khominets V.V., Kudyashev A.L., Brizhan L.K., Kulnev S.V. Staged treatment of the wounded with injuries of the musculoskeletal systems in modern armed conflict. *Military Medical Journal*. 2023;344(3):4-17. (In Russian). doi: 10.52424/00269050_2023_344_3_4.
6. Samokhvalov I.M., Kryukov E.V., Markevich V.Yu., Badalov V.I., Chuprina A.P., Petrov A.N. et al. Ten surgical lessons of the initial stage of a military operation. *Military Medical Journal*. 2023;334(4):4-10. (In Russian). doi: 10.52424/00269050_2023_344_4_4.
7. Jones C.M., Roberts J.M., Sirlin E.A., Cavanaugh G.A., Anagnostakos J.P., Hauck R.M. et al. Acute limb shortening or creation of an intentional deformity to aid in soft tissue closure for IIIB/IIIC open tibia fractures. *J Plast Reconstr Aesthet Surg*. 2021;74(11):2933-2940. doi: 10.1016/j.bjps.2021.03.105.
8. Robert Rozbruch S., Weitzman A.M., Tracey Watson J., Freudigman P., Katz H.V., Ilizarov S. Simultaneous treatment of tibial bone and soft-tissue defects with the Ilizarov method. *J Orthop Trauma*. 2006;20(3):197-205. doi: 10.1097/00005131-200603000-00006.
9. Plotnikovs K., Movcans J., Solomin L. Acute Shortening for Open Tibial Fractures with Bone and Soft Tissue Defects: Systematic Review of Literature. *Strategies Trauma Limb Reconstr*. 2022;17(1):44-54. doi: 10.5005/jp-journals-10080-1551.
10. Lerner A., Reis N.D. Definitive Skeletal Reconstruction: Conversion to the Ilizarov Method. In: Lerner A., Soudry M. (eds.) Armed Conflict Injuries to the Extremities. A Treatment Manual. Springer Berlin: Heidelberg; 2011. p. 233-278.
11. Pierrie S.N., Beltran M.J. Acute shortening and angulation for complex open fractures: an updated perspective. *OTA Int*. 2023;6(4 Suppl):e245. doi: 10.1097/OI9.0000000000000245.
12. Gumanenko E.K., Boyarintsev V.V., Suprun T.Yu., Lyashedko P.P. Objective estimation of injury severity. St. Petersburg; 1999. p. 3-5. (In Russian).
13. Rating the severity of tissue damage. I. The abbreviated scale. *JAMA*. 1971;215(2):277-280. doi: 10.1001/jama.1971.03180150059012.
14. Gustilo R.B., Anderson J.T. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am*. 1976;58(4):453-458.
15. Mathieu L., Mourtialon R., Durand M., de Rousiers A., de l'Escalopier N., Collombet J.M. Masquelet technique in military practice: specificities and future directions for combat-related bone defect reconstruction. *Mil Med Res*. 2022;9(1):48. doi: 10.1186/s40779-022-00411-1.
16. Neer C.S. 2nd, Grantham S.A., Shelton M.L. Supracondylar fracture of the adult femur. A study of one hundred and ten cases. *J Bone Joint Surg Am*. 1967; 49(4):591-613.

17. Hernández-Irizarry R., Quinnan S.M., Reid J.S., Toney C.B., Rozbruch S.R., Lezak B. et al. Intentional Temporary Limb Deformation for Closure of Soft-Tissue Defects in Open Tibial Fractures. *J Orthop Trauma.* 2021;35(6):e189-e194. doi: 10.1097/BOT.0000000000001988.
18. Lahoti O., Findlay I., Shetty S., Abhishetty N. Intentional deformation and closure of soft tissue defect in open tibial fractures with a taylor spatial frame – a simple technique. *J Orthop Trauma.* 2013;27(8):451-456. doi: 10.1097/BOT.0b013e318284727a.
19. Sen C., Kocaoglu M., Eralp L., Gulsen M., Cinar M. Bifocal compression-distraction in the acute treatment of grade III open tibia fractures with bone and soft-tissue loss: a report of 24 cases. *J Orthop Trauma.* 2004;18(3):150-157. doi: 10.1097/00005131-200403000-00005.
20. Bundgaard K.G., Christensen K.S. Tibial bone loss and soft-tissue defect treated simultaneously with llizarov-technique – a case report. *Acta Orthop Scand.* 2000;71(5):534-536. doi: 10.1080/000164700317381306.
21. Lerner A., Fodor L., Soudry M., Peled I.J., Herer D., Ullmann Y. Acute shortening: modular treatment modality for severe combined bone and soft tissue loss of the extremities. *J Trauma.* 2004;57(3):603-608. doi: 10.1097/01.ta.0000087888.01738.35.
22. Lerner A., Fodor L., Stein H., Soudry M., Peled I.J., Ullmann Y. Extreme bone lengthening using distraction osteogenesis after trauma: a case report. *J Orthop Trauma.* 2005;19(6):420-424. doi: 10.1097/01.bot.0000177388.05060.a4.
23. Johansen K., Daines M., Howey T., Helfet D., Hansen S.T.Jr. Objective criteria accurately predict amputation following lower extremity trauma. *J Trauma.* 1990;30(5): 568-572. doi: 10.1097/00005373-199005000-00007.
24. Manner H.M., Huebl M., Radler C., Ganger R., Petje G., Grill F. Accuracy of complex lower-limb deformity correction with external fixation: a comparison of the Taylor Spatial Frame with the Ilizarov ring fixator. *J Child Orthop.* 2007;1(1):55-61. doi: 10.1007/s11832-006-0005-1.
25. Nho S.J., Helfet D.L., Rozbruch S.R. Temporary intentional leg shortening and deformation to facilitate wound closure using the Ilizarov/Taylor spatial frame. *J Orthop Trauma.* 2006;20(6):419-424. doi: 10.1097/00005131-200607000-00010.

Authors' information

✉ *Sayan E. Zhumagaziev* — Cand. Sci. (Med.)
Address: 6, St. Petersburg, Akademika Lebedeva st., 194044, Russia
https://orcid.org/0000-0002-5169-2022
e-mail: shumagasiev@mail.ru

Vladimir V. Khominets — Dr. Sci. (Med.), Professor
https://orcid.org/0000-0001-9391-3316
e-mail: khominets_62@mail.ru

Sergey V. Mikhailov — Cand. Sci. (Med.)
https://orcid.org/0000-0002-3738-0639
e-mail: msv06@mail.ru

Alexey V. Shchukin — Cand. Sci. (Med.)
https://orcid.org/0000-0001-7754-8478
e-mail: ossa.76@mail.ru

Evgenii B. Nagornyi — Cand. Sci. (Med.)
https://orcid.org/0000-0003-2132-4429
e-mail: 9099744@gmail.com

Danil R. Tsoy
https://orcid.org/0009-0007-3354-4644
e-mail: tsoydanil@mail.ru