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ORIGINAL ARTICLE

Ertl surgery on the short fibula stump after war injury

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ABSTRACT

Aim To propose a new technique of Ertl-type surgery for significantly shortened and valgus deviated fibula stump.

Methods We present the case of a 26-year-old patient who underwent reamputation surgery to replace a significantly shortened fibula stump using a distraction regenerate formed after tibial stump osteotomy and dosed distraction of the autograft using the Ilizarov apparatus. Its advantage is the elimination of valgus deviation of the fibula remnant, its lengthening, formation of bone synostosis, and increase of the bearing surface, which provides the possibility of total contact prosthetics. Radiography, ultrasound and MRI were used to monitor the regeneration. The observation period was 28 months.

Results Within 98 days after the operation, a regenerate was formed, replenishing the length of the fibula stump, the end of the fibula stump was consolidated with the regenerate, increasing the area of the bearing surface of the tibia stump by 2.5 times, which allowed for temporary and then permanent prosthetics.

Conclusion The proposed technique can be useful in reconstructive operations on the stump of the tibia.

Keywords: amputation, autografts, osteotomy, synostosis, surgical, tibia

INTRODUCTION

In the conditions of modern warfare, severe mine-explosive injuries of the lower limbs with tissue detachment and crushing, often leading to amputation, prevail. The desire to preserve the length of the residual limb as much as possible during primary amputation leads to extensive scars, bone sawdust standing out, other defects of the supporting tissues, requiring reconstructive and restorative surgeries, which, eliminating the defect, preserve the length of the residual limb as much as possible (1–3) and provide high-quality prosthetics. During military operations the most widespread (80%) level of amputation is the tibia (4). The greatest number of reoperations, including reamputation, is performed on the stumps of the tibia (5).

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Today, these interventions are performed using the Buerges and Ertl techniques (3,6,7). The Ertl technique in its classical version provides for the formation of bone synostosis by means of a periosteal sleeve formed from the periosteum of the tibia, filled with autospongiosa sutured to the fibula. Nowadays, a modified technique of the operation is more frequently used, which provides for the creation of a synostosis by means of free grafts from the fibula or tibia (1,8). The advantages of the operation are greater vertical reaction force during fast walking, a stable platform with a larger distal support area, less stress on the distal end, the possibility of total-contact prosthesis and return to military service (9–11).

A simpler and more commonly used technique is the modified Buerges technique, which involves myoplastic formation of the residual limb. It should be noted that this technique has some disadvantages, such as sliding or sagging of the muscles posteriorly and the inability to prevent valgus deviation of the fibula stump (12). With a short stump, valgus deviation causes a symptom complex including osteoporotic changes of the fibula stump end, peroneal neuritis, peroneal bursitis, and limitation or inability to use the prosthesis (1,13). Defibulation has been suggested in this regard (12,14). However, in fa-

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vouring defibulation, authors do not take into account the role of the fibula in walking. The fibula plays a key role in the transfer of weight and kinetic energy in knee joint motion (15) and supports the lateral plateau of the tibia, and the fibula creates an indispensable fulcrum for the mechanical arch between the tibiae. In addition, defibulation leads to rotational instability in the prosthesis (12).

Synostosis or creation of a bone bridge between the tibiae using the Ertl technique and its modifications requires a large shortening of the residual limb lever (12). If the fibula stump is significantly shortened, the Ertl operation becomes impossible but desirable, given the important role of its length in stable knee flexion and extension and lower energy expenditure during walking (15). In this regard, we have developed a reconstructive operation that allows not only to preserve the residual fibula and eliminate its valgus position, but also to compensate for the length of the fibula and increase the area of the supporting surface of the tibial stump. Objective: to propose a new modification of Ertl's operation for a significantly shortened and valgus deviated fibula stump.

PATIENT AND METHODS

Patient and study design

A 26-year-old man sustained a combat injury to his left lower limb with shattered foot and shin was presented to the Clinic of the Scientific and Research Institute of Rehabilitation of National Pirogov Memorial Medical University (Vinnytsia, Ukraine) in 2020. He underwent amputation at the level of the upper and middle thirds. Due to the fracture of the fibula, it was amputated in the upper third (Figure 1).

Figure 1. Radiographs of the tibial stump in two projections before surgery (Shevchuk V.I., Scientific and Research Institute of Rehabilitation of National Pirogov Memorial Medical University, 2020)

This study was approved by the Ethics Committee of the Scientific and Research Institute (Approval no: 04/2024, 05.02.2024). A written informed consent was obtained from the patient for the case details and images to be published.

Methods

Ultrasound examinations were performed on a VOLUSON-730 PRO (GE Medical Systems Kretztechnik GmbH & Co OHG, Tiefenbach, Austria) using linear and convex transducers at 7.5 MHz. The state of the regenerate, the nature of diastasis, the homogeneity of the echogenic substrate, the presence of endosteal and periosteal bone formation and hypoechogenic areas were visually assessed. The echodensity index (PEC unit) was determined in seroscale mode. The intact area of the proximal tibia of a healthy limb was taken as a control. The presence of vessels in the distraction zone and in the surrounding soft tissues was assessed in the colour Doppler mapping and energy Doppler modes. The study of the distraction regenerate was performed after 10 and 30 days of distraction, 60 days of fixation and 24 months.

Radiography was performed once every 10 days in the distraction period and once a month in the fixation period. The magnitude of diastasis and the nature of the course of osteogenesis were determined.

Surgical technique. The operation was performed under general anaesthesia. The surgical field was treated twice with betadine solution. Two pairs of crossed needles were inserted through the proximal metaepiphysis of the tibia and fibula perpendicular to the axis of the limb (taking into account the passage of the peroneal nerve, without piercing the muscles). Using the lower pair of spokes with stop pads, the remaining fibula was brought from the valgus position to the physiological position. The tensioned spokes are fixed in two rings of the Ilizarov apparatus, which are interconnected by threaded rods. The main base of the apparatus was formed. At the end of the stump, a skin incision was made with subcutaneous tissue and fascia. Scarred tissue was removed. The stumps of the tibia and fibula were isolated. The ridge of the tibia was cut down. The vessels were ligated. The tibial, superficial and deep peroneal and posterior cutaneous nerves were shortened. At the level of the end of the shortened fibula, an L-shaped periosteum incision was made along the anterior-external surface of the tibia. Along the upper edge of the incision, the periosteum was moved proximally by 0.2 cm. A ½-diameter transverse cut was made with an oscillating saw on the outer-posterior surface of the tibia. The end surface of the tibia was used to make a chip of the future graft with a sharp bit. The periosteum and the contents of the bone marrow cavity were preserved as much as possible.

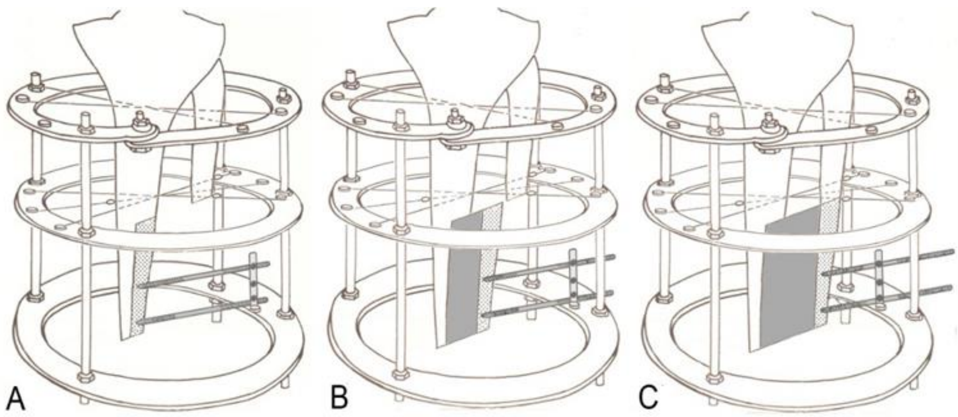

Figure 2. Operation scheme. A) Compression at the osteotomy site; B) Graft distraction;C) Graft fixation (Shevchuk V.I., Scientific and Research Institute of Rehabilitation of National Pirogov Memorial Medical University, 2020)

Two self-tapping rods d 3.5 mm were passed through the cortical layer of the graft perpendicular to the bone and parallel to each other. The shears are fixed in the ring of the Illizarov apparatus using the fixator-attachment. The proximal base of the device is connected to the distal ring with threaded rods. Compression at the osteotomy site (Figure 2A). The calf and tibialis anterior muscles are fixed to the tibial crest. Layer formation of the residual limb. Drainage. Control over the condition of the wound and tissues at the entry and exit points of the spokes and rods was carried out daily for the first 10 days, and in the following days as necessary. The sutures were removed on the 10^{th} day. To ensure early functional loading, a semi-finished foot was attached to the Ilizarov apparatus on external rods. Dosed load was started on the 5^{th} day after the operation (Figure 3).

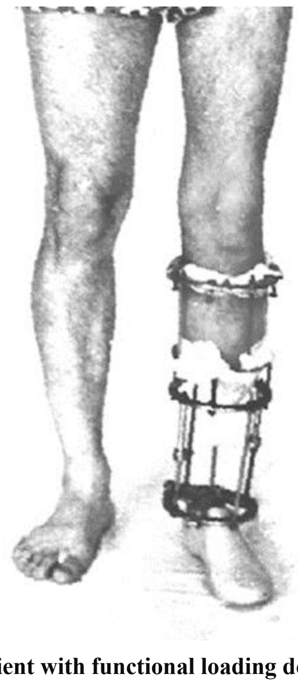

Figure 3. Patient with functional loading device after amputation (Shevchuk V.I., Scientific and Research Institute of Rehabilitation of National Pirogov Memorial Medical University, 2020)

Distraction of the graft was started on the 8^{th} day by 0.25 mm 4 times a day and continued for 30 days. Fixation lasted for 60 days (Figure 2B, 2C).]

RESULTS

Before reamputation surgery

The postoperative wound healed with secondary healing. Due to pain in the upper third of the stump, prosthetics are limited. In objective status amputated tibia stump on the border of the upper and middle third. Movement in the knee joint is full. There was a linear scar on the outer surface of the stump from the end to the level of the protruding end of the fibula. The muscles of the posterior and lateral group are preserved, sagging in a single conglomerate. Hypersensitivity on the outer surface of the stump. The tibial crest protrudes under the skin. The length of the tibial stump is 11 cm, fibula – 2.5 cm.

After reamputation surgery

At X-ray examination after ten days of distraction (18 days after surgery), bone trabeculae directed after the transferred fragment were detected in the diastasis between the parent bone and the graft. After 20 days of distraction (28 days after the operation) cloud-like shadows of the regenerate of medium intensity were detected over the whole area of the diastasis. After 30 days (38 days after surgery) the diastasis was filled with normoplastic type regenerate. The contact between the lower end of the fibula, the regenerate and the graft was achieved (Figure 4A). The apparatus was transferred to fixation. After one month of fixation (68 days postoperatively), homogeneous high-intensity shadows were determined in the diastasis. After 2 months of fixation (98 days after surgery) the regenerate had a homogeneous structure. The fusion of the residual fibula with the graft and the regenerate, which is a "continuation" of the fibula, was noted (Figure 4B). It approximated the adjacent areas of the parent bone in terms of density.

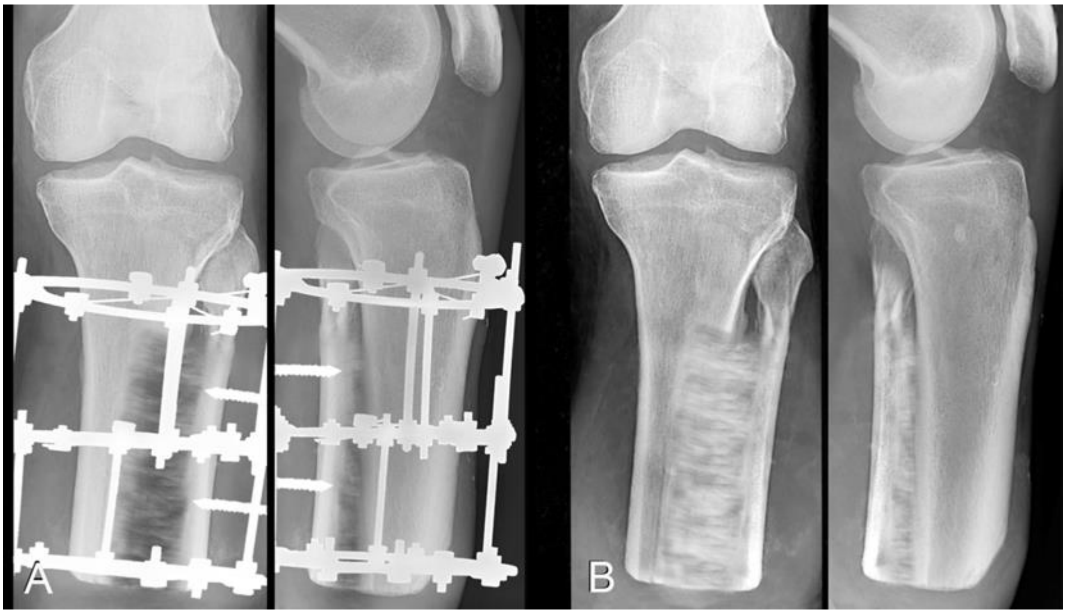

Figure 4. Radiographs of the stump in two projections A) 1 month and B) 2 months after the surgery (Shevchuk V.I., Scientific and Research Institute of Rehabilitation of National Pirogov Memorial Medical University, 2020)

A continuous contour of the cortical plate was formed. After 28 months, the remodelling of the regenerate was completed (Figure 5).

Figure 5. Radiographs of the stump in two projections 28 months after surgery (Shevchuk V.I., Scientific and Research Institute of Rehabilitation of National Pirogov Memorial Medical University, 2022)

Scanning after 30 days of distraction revealed the presence of linear hyperechogenic structures in the area of diastasis, pronounced endosteal reaction, accelerated narrowing of the echopositive zone of the regenerate, formation of large hyperechogenic fragments along the edge of the parent bone, and decreased ultrasound penetration depth. Areas of osteogenesis with different osteogenesis activity (echo density index from 136 to 151 units) were determined. At the beginning of distraction, scanning of the regenerate in duplex and triplex modes revealed small vessels in the soft tissues of the proximal and distal sections of the regenerate. After 30 days of distraction, vessels with a diameter of 0.09-0.14 cm were detected. After 60 days of fixation, polyposition scanning in the 3-D reconstruction mode allowed us to detect in all scanned planes an almost continuous contour of the cortical layer and areas of vessels in the intermedial zone of the regenerate with a diameter of 0.19 – 0.26 cm with peripheral indices P1 = 3.39 and P1 = 1.1, which is evidence of the maturity of the distraction regenerate.

The preoperative cross-sectional area of the tibial stump end was 5.0 cm^2. After regenerate formation and removal of the device, the cross-sectional area was 14.3 cm^2. The patient was fabricated a primary prosthesis and 9 months later a permanent prosthesis. At the follow-up examination after 28 months, the residual limb was in a satisfactory condition. The patient uses a total-contact prosthesis with loading on the residual limb end. He works as a mechanic at a fruit and vegetable processing plant. He does not use any additional means of support. He walks 12-14 kilometres per day.

DISCUSSION

The proposed method is developed on the basis of the regularity of tissues to respond to the tensile stress created in them by growth and regeneration revealed by Ilizarov (16). By analogy with hardware treatment of defects of long tubular bones (17–19) the formation of synostosis of the bones of the amputation stump of the tibia is conditionally divided into three periods. In the first period, the valgus deviation of the shortened fibula was eliminated, reamputation with the formation of a longitudinal tibial detachment, compression of the graft with the parent bone is performed with the Ilizarov apparatus. Dosed distraction is performed in the second period, and fixation was performed in the third period. Dosed functional load was carried out during all periods.

In the first – pre-distraction – period, it was important to create conditions for reparative regeneration: stability of fixation and full primary compensation of impaired blood circulation created by two self-tapping rods in the distal base of the apparatus connected with the proximal one.

In the time that has elapsed since the amputation, the tibial end undergoes structural remodelling (1). Along with the intraosseous blood supply, additional multiple sources of its blood supply from the periosteum and soft tissues are established around the bone stump. As a result, the blood supply to the end of the bone stump becomes similar to that of the epimetaphyseal region (17). This explains the early onset of reparative reaction and good regenerate formation.

As it turned out, the period of 8 days was optimal for the formation of fusion over the entire area of contact due to proliferating skeletogenic tissue. During this period, intimate connective tissue periosteal-paraossal-endosteal fusion of the graft with the parent bone, referred to as the growth zone of the distraction regenerate, occurs (17).

In the second period on the 9th day the graft distraction was started 4 times a day by 0.25 mm. At the same time in the process of distraction the connective tissue bridges formed between the mother bone and the graft are stretched, their fibres acquire transverse orientation, the conditions of microcirculation restoration are changed. Coarse fibrous bone beams are formed in the regenerate at the border of bone sections of the regenerate with the connective tissue layer.

During the fixation period of 60 days, the bone tissue remodelling of the mother bone, graft and regenerate that started during distraction continued. The formation of the capillary channel was completed (17). The maturity of fibrous structures increased and there was a replacement of the connective tissue layer by the newly formed bone. In our opinion, in connection with the possible increase of osteoporotic changes, functional dynamic load on the bone played an important role, which agrees with the data of the authors (18), who were engaged in the treatment of bone fractures. The acceleration of ossification was favoured by tension and stability of fixation (17). Taking into account that the gentle functional load, starting from the 5th day, continued until 98 days, the reorganization of processes ensured regenerate restoration and ossification of the growth zone of the distraction regenerate. We took into account the fact that osteoporosis and delayed formation of the cortical layer may cause writhing or secondary resorption of the regenerate. Therefore, the fixation period lasted up to 60 days, even though the horizontally positioned synostosis is responsible for up to 50% of the load in prosthetics (12). According to the data (17), if the necessary shape of the regenerate is achieved and the processes of cortical layer restoration (temporary structural incompleteness) are in progress, functional reconstruction proceeds most favourably. In our case, sufficient size, ongoing processes of cortical layer restoration, regenerate density, and increased peripheral vascular indices of the regenerate allowed us to discontinue fixation, perform primary and then permanent prosthetics.

Contrary to the known Ertl's method and its modifications, the proposed technique allows to eliminate valgus deviation and lengthen the short residual fibula without shortening the tibia, to obtain tibial synostosis with an enlarged area of the supporting surface, which makes it possible to utilize a full-contact prosthesis with maximum load on the residual limb end.

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TRANSPARENCY DECLARATION

Conflict of interests: None to declare.

REFERENCES

1. Shevchuk VI, Bezsmertnyi YO, Jiang Y, Bezsmertna HV, Dovgalyuk TV. Reamputation stumps below knee. Med Glas (Zenica) 2021;18;(2):479–86. doi: 10.17392/1374-21.
2. Felder JM, Skladman R. Translating Technique into Outcomes in Amputation Surgeries. Mo Med 2021; 118;(2):141–6.
3. Taylor BC, Poka A. Osteomyoplastic Transtibial Amputation: The Ertl Technique. J Am Acad Orthop Surg 2016;24;(4):259–65. doi :10.5435/JAAOS-D-15-00026.
4. Nizamli FM. Quality of life among Syrian patients with war-related lower limb amputation at the Military Hospital in Lattakia. Int J Nurs Sci 2020;7;(3):297–302. doi: 10.1016/j.ijnss.2020.05.001.
5. Kingsbury T, Thesing N, Collins JD, Carney J, Wyatt M. Do patients with bone bridge amputations have improved gait compared with patients with traditional amputations? Clin Orthop 2014;472;(10): 3036–43. doi: 10.1007/s11999-014-3617-7.

6 Burgess EM, Romano RL, Zettl JH, Schrock RD. Amputations of the leg for peripheral vascular insufficiency. J Bone Joint Surg Am 1971;53;(5): 874–90.
7 Ertl J. Uber amputationsstumpfe. Chir Z Für Alle Geb Oper Medizen 1949;20;(218):24.
8 Chang BL, Kleiber GM. Evolution of amputee care. Orthoplastic Surg 2023;12:1–14. doi: 10.1016/j.orthop.2023.05.001.
9 Keeling JJ, Shawen SB, Forsberg JA, Kirk KL, Hsu JR, Gwinn DE, et al. Comparison of functional outcomes following bridge synostosis with non-bone-bridging transtibial combat-related amputations. J Bone Joint Surg Am 2013;95;(10):888–93. doi: 10.2106/JBJS.L.00423.
10 Hobusch GM, Döring K, Brånemark R, Windhager R. Advanced techniques in amputation surgery and prosthetic technology in the lower extremity. EFORT Open Rev 2020;5;(10):724–41. doi: 10.1302/2058-5241.5.190070.
11 Heszlein-Lossius H, Al-Borno Y, Shaqqoura S, Skaik N, Giil LM, Gilbert MF. Traumatic amputations caused by drone attacks in the local population in Gaza: a retrospective cross-sectional study. Lancet Planet Health 2019;3;(1):e40–7. doi: 10.1016/S2542-5196(18)30265-1.
12 Baumgartner R, Botta P. Amputation und prothesenversorgung der unteren extremität: Indikationsstellung, operative technik, nachbehandlung, prothesenversorgung, gangschulung, rehabilitation. Enke; 1995:486.
13 Pinzur MS, Beck J, Himes R, Callaci J. Distal tibiofibular bone-bridging in transtibial amputation. J Bone Joint Surg Am 2008;90;(12):2682–7. doi: 10.2106/JBJS.G.01593.
14 Godwin Y, Almaqadma A, Abukhoussa H, Obaid M. Stump-plasty: An Operation Born of Necessity in Gaza. Strateg Trauma Limb Reconstr 2021; 16;(2):102–9. doi: 10.5005/jp-journals-10080-1526.
15 Jiang W-B, Sun S-Z, Li C, Adds P, Tang W, Chen W, et al. Anatomical basis of the support of fibula to tibial plateau and its clinical significance. J Orthop Surg 2021;16;(1):346. doi: 10.1186/s13018-021-02500-8.
16 Ilizarov GA, Popova LA, Shevtsov VI. A method of transosseous osteosynthesis--a new stage in the development of Russian traumatology and orthopedics (Metod chreskostnogo osteosinteza--novyĭ etap v razvitii otechestvennoĭ travmatologii i ortopedii) [In Russian]. Ortop Travmatol Protez 1986;(1):1–5.
17 Klimovitsky V, Chernysh V. Transosseous osteosynthesis in injuries and diseases of the musculoskeletal system (Cherezkistkovyy osteosyntez pry travmakh ta zakhvoryuvannyakh oporno-rukhovoho aparatu) [in Ukrainian] Trauma 2013; 14(1):105-13. doi: 10.22141/1608-1706.1.14.2013.88939.
18 Grubor P, Milicevic S, Grubor M, Meccariello L. Treatment of Bone Defects in War Wounds: Retrospective Study. Med Arch Sarajevo Bosnia Herzeg 2015;69;(4):260–4. doi: 10.5455/medarh.2015.69.260-264.
19 Rollo G, Falzarano G, Ronga M, Bisaccia M, Grubor P, Erasmo R, et al. Challenges in the management of floating knee injuries: Results of treatment and outcomes of 224 consecutive cases in 10 years. Injury 2019;50 Suppl 4:S30–8. doi: 10.1016/j.injury.2019.03.016.

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