ORIGINAL ARTICLE

Reamputation stumps below knee

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ABSTRACT

Aim To investigate rehabilitation outcomes of patients with malformed tibial stumps.

Methods Observations included 421 patients with residual limb diseases and malformations (extensive inactive scars adhered to the bone, excessively long or short stumps, bone filing, osteomyelitis of the stump, muscle attachment to the skin scar, excessive mobility and deviations of the fibula, improper filing). Four hundred and thirty-six (436) reconstructive surgeries were performed. A follow-up period was from 6 months to 15 years. Radiological, ultrasonic, tensometrical, and histological methods were used.

Results Due to the frequent combination of several malformations and diseases in the same patient, non-free skin grafting with displaced dermal-subcutaneous flaps, which cover rather large defects, was widely used. The surgeries were performed simultaneously and allowed for reconstruction without shortening the bone lever stump. Complications in the form of marginal necrosis were obtained in three (0.71%) patients. The improved technique of muscle grafting with the fixation of muscles to the bone provided an elastic stump covering the bone filing. The authors have developed original methods of surgery to create a bone block of the tibia, which make it possible to obtain painless, highly functional stumps using partial support and ensure long-term use of modern prosthesis designs in 100% of cases.

Conclusion Non-free dermal plasty with cutaneous-subcutaneous flap is the method of choice for closing skin defects on the residual limb. Muscle-bone fixation permits to eliminate some residual limb defects and to form an elastic muscular residual limb with closed bone filaments. Synostosis formation in different ways considerably improves functional quality of the residual limb.

Key words: bone synostosis, reconstructive surgery, stump

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INTRODUCTION

Currently, there is some decline in the interest in amputations and reconstructive interventions on limb stumps. However, increasing traumatism, thrombo-vascular diseases, military conflicts in some cases result in amputations. After them, due to a number of objective and subjective reasons, as well as irrational prosthetics, stump diseases and malformations occur, the elimination of which is sometimes more difficult than the primary amputation. In recent years, a number of studies (1-13) have highlighted particular issues in amputations, describing residual limb diseases and malformations, post-amputation pain syndrome, and nerve treatment techniques. The works (14,15) devoted to the creation of a bone bridge using the Ertl technique present the results of these operations. The essence of the method is the formation of a synostosis between the ends of the tibia and fibula in the form of a coiled periosteum with part of the cortical bone layer; above the bridge the muscles are sutured (15). The method is good, but in practice it is both difficult and prone to complications, ranging from displacement of the muscle and the flap to an irregularly shaped or missing bridge (14). In our practice, we perform bone-plastic formation of the synostosis with possible extension of the tibial section plane to optimize the use of partial support, because only with axial load there are hydrodynamic effects that ensure normal trophism.

Using the ideas of the Polish scientist Weiss M. (16), we have successfully used the technique of muscle-bone fixation for many years and have improved it somewhat for reconstructive interventions on the residual limb. The functionality of a truncated limb depends not only on the muscle and bone, but also on the condition of the skin. Therefore, when performing reconstructive interventions, their rational combination should be used. The development of prosthetics makes it possible to significantly improve the rehabilitation of persons with amputations and to return them to active work, everyday life, culture and sport.

The aim of the study was to improve the rehabilitation results of persons with tibia residual limb malformations.

PATIENTS AND METHODS

Patients and study design

A total of 421 patients with lower leg residual limb malformations and diseases were under observation in the clinic of Research Institute of Rehabilitation of National Pirogov Memorial Medical University (Vinnytsia, Ukraine) from 2010 to 2021. The patients' age ranged from 18 to 70 years. The period since the initial amputation ranged from 6 months to 15 years. The causes of primary amputation were: trauma in 391, chilblains in 12, burns in one, tumours in six and vascular diseases in 11 patients (Table 1).

Table 1. General material characteristics

Type of pathology	Number (%) of patients	No of reamputations		Other operations*
		Myoplastic	Bone grafting	
Painful neuromas, ligature fistulas	8 (1.90)	1	-	7
Extensive, low-mobile scars fused to the bone	96 (22.81)	54	36	6
Excessively long and short stumps	38 (9.02)	1	30	7
Bone filing stand-off	59 (14.02)	39	20	-
Osteomyelitis of the end of the stump	18 (4.27)	6	-	12
Bursitis	15 (3.56)	8	7	-
Excessively tapered stumps	18 (4.28)	7	9	2
Attachment of muscles to the skin scar	66 (15.68)	30	36	-
Fibula deviation	39 (9.26)	21	18	-
Excessive mobility of the fibula	16 (3.80)	2	6	8
Incorrect filing of the tibia	48 (11.40)	20	18	10
Total	421 (100.00)	189	180	52

*resection of neuroma; excision of fistula, bursa, ulcer, scar, excess of soft tissues; resection of osteophytes

An informed consent was obtained from all patients.

The Ethics Committee of Pirogov Memorial Medical University, Vinnytsia, Ukraine approved this investigation.

Methods

In addition to the general condition, the clinical examination included assessment of the level of amputation, shape of the residual limb, degree of soft tissue coverage, skin, muscle, muscle strength, bone, postoperative scar, blood circulation, joint mobility, and the presence and nature of pain. The duration of the prosthesis use during the day was assessed.

Digital radiography was performed as standard in two projections.

Ultrasound polypositioning of the junction area with the graft was performed using Sonoline-SL450 (Siemens, Germany). The scanning was performed in longitudinal and transverse sections at the level of contact of the graft with the tibia bones. A convex sensor (3.5-4.5 MHz) was used to overcome soft tissue thickness.

Stump support was determined using magnetostrictive transducers that were fixed between the skin and the prosthesis receiving cavity.

Morphological examination was performed on material taken from 22 patients at the time of reamputation and from two patients who died 5 and 9 years after osteoplastic reamputation from concomitant diseases.

Methods of reconstructive operations. During myoplastic stabilization of an excessively mobile fibula residual limb, the long fibula muscle was fixed transosseously, first to the residual fibula and then to the outer surface of the tibia.

In the case of a protruding tibial ridge, the bursa was excised. The ridge was exposed and sawed off at a 45° angle during internal rotation of the residual limb. A 0.6-1 cm long transverse groove was made in the upper part of this saw cut with a drill, without penetrating the medullary canal. A resorbable thread was passed through the canal. One free end was stitched laterally to the anterior edge of the tibia muscle and medially to the edge of the medial head of the calf muscle. The ligature was tied, obtaining the closure of the ridge. After that, one loose end of the suture was passed through the lateral and the other through the medial (Figure 1) heads of the calf muscle in a U-shape returning to the anterior edge of the tibialis muscle. The sutures were tied. An elastic muscle stump was obtained on the operating table. In the case of excess muscle, a high resection of the camelback muscle was performed.

Bone reconstruction involved formation of the tibial synostosis by free plasty using autografts from the removed part.

Ligature fistulas were eliminated by excision after a dye injection.

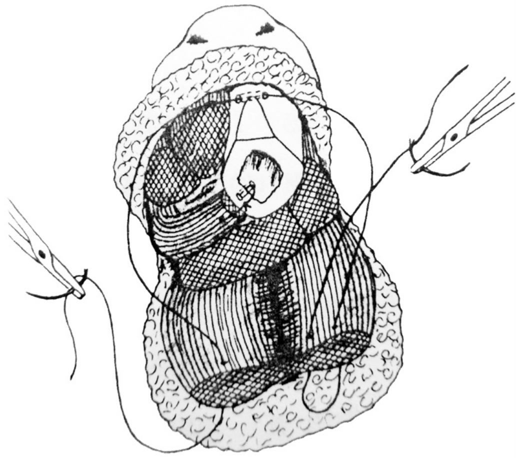

Figure 1. Schematic representation of myoplastic reamputation (Shevchuk V, 2020)

The tibial nerve, superficial and deep peroneal nerve and the posterior cutaneous nerve were necessarily shortened.

In the case of a short residual limb with scars fused to the bone, the latter were excised and reamputated by shortening the bone if necessary, with muscle grafting and fixation of the muscles to the bone. To lengthen the residual limb, a tibial osteotomy was performed, followed by distraction and regeneration. After achieving the required length and adequate strength of the regenerate, prosthetics were performed.

With osteomyelitis of the end of the stump, 1% brilliant green solution with 3% hydrogen peroxide solution was injected into the fistulous opening. An incision was made, followed by excision of the scar and necrectomy.

In the presence of a long residual limb, in some cases with a lower-third residual limb with malformed scarring in the distal region, given the excessive length of the residual limb, reamputation was performed on the border of the middle and lower thirds of the tibia. More often it was necessary to perform an economical reamputation with simultaneous skin grafting. The skin incision was made atypically, according to the location of the scarred tissue. After dissecting them and excising the scars, skin plasty was started. The latter was performed with a massive dermal-subcutaneous flap on a feeding base, cut off and displaced from the adjacent areas of the residual limb, the knee area and the thigh. Beforehand, intensive preparation was always carried out to create greater mobility and extensibility of the donor skin area.

On the middle third of the tibia stump, if the skin defect was located on the anterior-thoracic or posterior-thoracic surface, the skin with subcutaneous tissue was separated on the anterior or, respectively, on the external surface, and it was adjusted to the size of the defect to be excised. The opposite edge of the wound was mobilized along the entire incision. Sutures were applied without tension. If there were extensive defects on the anterior-thoracic surface of the residual limb in the upper third, a flap was moved from the anterior-external surface of the femur to close them. Thus, it was possible to close defects up to 70-80 cm^2 in size with full-fledged skin. Simultaneously with skin grafting, other reconstructive interventions were performed: removal of osteophytes, resection of nerve trunks above the loading zone of the residual limb in the prosthesis, sawing down the ridge, smoothing bone fillets, reamputation with muscle and skin grafting.

Depending on the conditions, several techniques for synostosis of the tibia bones with different grafts were used. A tubular graft was prepared from the amputated segment of the fibula and its length was equal or slightly shorter than the width of the intertibial space. The graft was placed perpendicular to the bone between the lateral surfaces of the bone stumps. On the fibula side, a spoke with a support pad was inserted through the end of the fibula, the medullary canal of the graft and the tibia. A second spoke was crossed over to the first one through the tibia. The spokes were fixed in the ring of the Ilizarov apparatus, creating compression. A base ring was placed in the upper third of the tibia, where the spokes were also crossed. The rings were connected with screws. This technique eliminates the possibility of graft displacement. Bone synostosis occurs 6-7 weeks after the amputation (Figure 2).

Figure 2. Synostosis formation using a fibula graft (Shevchuk V, 2019)

The fibula graft can be fixed with an autograft taken from the tibia or fibula. For this purpose, a channel was made from the outer surface of the fibula, which is inserted into the autograft. The pin was inserted into the channel, achieving a stable fixation. In some cases, an indentation was made on the outer surface of the tibia for better retention of the graft. The medial and lateral portions of the calf muscle were fixed to the tubules formed in the graft.

If the residual limb was long enough, the bone was sawn off obliquely from the inside back. A trapezoid-shaped graft was taken from the part of the tibia to be removed. The sides of this trapezium corresponded to the cross-sectional planes of the tibia and fibula and the length of the larger base was equal to the distance between their lowest points. The graft was placed between the fillets of the bones, tightly closing the openings of the medullary canals. A wire with a support pad was passed through the ends of both bones and the graft on the fibula side using an electric drill. Fixation was performed with the Ilizarov apparatus (Kurgan, Russia).

Another variant of this operation was also used, which allowed for a slight, up to 1 cm, shortening of the residual limb and obtaining synostosis. The tibia was sawed obliquely from top to bottom and from outside to inside, forming a trapezoidal graft with the smaller base corresponding to the width of the intertibial space and the larger base corresponding to the distance between the inner edges of the tibia and fibula. The resulting graft was rotated 180°, aligning the lateral sides of the trapezium with the fillet of the tibia and the lateral surface of the fibula. Fixation was performed with an Ilizarov apparatus as in the previous technique. The healing time was 6-7 weeks (Figure 3).

The following method of synostosis formation using a tibial bone graft did not require additional means of fixation.

A fragment whose length was equal to the distance between the outer and inner points of the tibia bones was taken from the part of the tibia to be removed. An aperture was cut into it, the width of which corresponded to half of the anteroposteri-

Figure 3. Synostosis formation using a trapezoid graft (Shevchuk V, 2019)

or dimension of the tibia. A groove with a width equal to the thickness of the cortical layer of the graft and a length of 1 cm was formed in the frontal plane at the end of the tibia. The transplant was inserted into the groove. The posterior surface of the tibia was inserted into the groove; the stump of the fibula was also placed in the groove. This method allows the graft to be held firmly in place.

Additional fixation is not required for the tibial bone synostosis with a tubular graft placed on the fibula.

A 3-4 cm long continuous tubular graft was cut from the part of the tibia to be removed, freed from soft tissues and firmly placed on the residual limb of the fibula. The graft was placed so that one of its three sides was tightly adjacent to the external-lateral surface of the tibia. The anterior tibial and calf muscles were fixed to the graft. The time to fusion was 6-8 weeks (Figure 4).

The next technique involves synostosis of the tibia bones with a tibial trough graft. A navicular graft was formed from the part of the tibia to be removed using a saw and chisel, which was fitted under the crest of the tibia and overlapped with the fibula. A firm block is formed after the operation.

In the case of a short tibial residual limb with a remnant of the fibula, which is always deflected backwards and outwards by the permanent traction of the biceps muscle, creating a club-like shape and making prosthetics impossible, one of the following bone grafting operations was performed.

One of them involves forming a synostosis with a thin autograft from the crest of the tibia. The remainder of the fibula was brought into the physiological position. If this was unsuccessful,

Figure 4. Synostosis formation by grafting the tibia on the residual limb of the fibula (Shevchuk V, 2019)

a Z-shaped lengthening of the bicep's tendon was performed. An electric drill with a drill corresponding to the thickness of the graft was used to form a transverse blind canal on the outer surface of the tibia and inner surface of the fibula. The graft was inserted into the canals. Muscle plasty was performed and the wound was sutured.

Synostosis of the tibia bones with short stumps can be performed by compression of the fibula to the tibia with the Ilizarov apparatus or by placing the fibula stump in a groove on the external-lateral surface of the tibia.

RESULTS

The excision of ligature fistulas with wound closure and drainage and removal of the bursa in the area of the tibial crest was ended with wound healing in all patients. The elimination of excessive mobility of the fibula was achieved in all patients too.

Percutaneous reconstruction of the middle and upper third residual limbs was complex. The stumps and functionally very important adjacent areas were covered with scar changed tissues, which were tightly fused with the underlying formations and easily injured at the slightest load. The patients had long-term non-healing wounds, painful or ulcerative scars and trophic ulcers, areas of altered skin with signs of atrophy and degeneration, and tightening scars causing a deformed residual limb. Partial necrosis of the flap margins occurred in three (0.71%) patients, which was corrected by resection and suturing of the defect.

The formation of the residual limb by fixing the muscles to the file resulted in 100% resilient muscular residual limbs with well-closed bones. In some cases (15%), it was difficult to tighten the contracted calf muscle against the crest of the tibia. It was lengthened by serrated incisions of two-thirds thickness to avoid tension.

Indications for osteoplastic reconstructive surgery include excess soft tissue, muscle attachment to the skin scar, incorrect bone filing, outward deviation and excessive mobility of the residual fibula, overly long residual limb, scar tissue, tightening scars and areas of skin alteration. More often than not, the same patient had more than one malformation.

In almost all cases of osteoplastic surgery, muscle grafts were used to cover the bones and good functioning of the residual limb. No serious complications were noted with their use. Postoperative hematomas, which occurred in some cases, indicated the need for more active drainage.

Recovery was achieved in all cases of reconstructive stump interventions. Individual weighted approach, reasonable combination of skin, muscular, bone plasty, careful attitude to muscles, their fixation to fillets prevents the formation of high standing truncated muscles, protrusion of bone fillet under the skin, excess of soft tissues under bone fillet. Careful smoothing and cleaning of the irregularities of the bone filing and the formation of a bone block of the tibia bones help to prevent possible diseases and malformations of the residual limbs.

All patients are fitted with lightweight prosthesis constructions of the half-length prosthesis type. These prostheses are aesthetically pleasing, lightweight and easy to use. They allow for a maximum contact between residual limb and prosthetic socket as well as the end-face pressure. The blood circulation in the residual limb is good. There were no trophic disorders. They exclude the presence of chronic distal residual limb oedema. Atrophy of the thigh muscles is insignificant. Rotation in the knee joint is free. Almost all patients use a prosthesis.

When assessing the results of amputations in terms of prosthetics, the varying degree of supportability at different levels must be emphasized. Stumps above the ankles, due to the connection of the tibia bones and the increase in the bearing surface, are slightly better than conventional stumps because the diameter of the plane is larger. These stumps are considered not to be very good, but since we created an enlarged pain-free distal region, prosthesis in the prosthesis socket with full contact was satisfactory.

The tibial stumps in the middle third are well covered by the muscles. The increased cross-sectional surface area allows for a permissible load of up to 60% of the body weight. The residual limbs are smooth, elastic and painless.

The residual limb in the upper third of the tibia, thanks to synostosis and enlargement of the residual limb area, enables good contact with the prosthesis.

In no case had the radiographical graft displacement or non-unionization been observed.

After 4 weeks, the ultrasound picture was characterized by a decrease in diastasis and crevice depth. An increase in echo positive inclusions with their transformation into linear echo positive structures oriented longitudinally along the stump axis was observed in the fissure structure. In some observations, along with the change of the junction structure, "bone bridges" emanating from the bone fragment in the form of a thin hyperechogenic line were determined.

After 8 weeks the ultrasound picture was continuous throughout, in some cases there was an uneven hyperechogenic fusion line with the presence of acoustic shadow, i.e. there was a complete fusion of the graft with the bone.

Tensometric tests carried out show significantly greater support and uniformity of the end-piece pressure on the socket of the residual limb following bone grafting of the synostosis. All patients used the prosthesis for 12-14 hours per day.

DISCUSSION

The restoration of a functionally sound skin on the residual limb is of great importance. Skin grafting also plays an important role in muscular and bone graft reconstruction. Its use in reamputations allows bone length to be maintained, which has a positive effect on the functionality of the residual limb in prosthetic reconstructions. The skin transferred to the defect area is homogenous with the surrounding skin, it retains natural blood circulation and innervation. The most important role is played by the subcutaneous fat included in the contour flap, because tissues can be easily moved and deep defects can be compensated. The skin with subcutaneous fat must be incised at the same level within the healthy tissue and separated from the fascia with one flap. If there is tension, skin incisions should be made without damaging the tissue. The closure of tibial residual limb defects by moving a skin-subcutaneous flap from the anterior surface of the knee joint and thigh is particularly effective if preparation is done to train skin mobility and extensibility.

There is currently no doubt about the usefulness of muscle grafting in tibia reamputation (16). Fixation of the muscles to the bone allows for the covering of the fillets, the crest of the bone and the tight closure of the medullary canal by tight stitching of the fixed muscles. The rational combination of stabilising the residual fibula with the long fibula muscle and restoring the anterior and posterior intermuscular septa and creating a layer covering the crest of the tibia with fixation of the calf muscle to it enables a resilient muscle residual limb to be created. Fixation of the muscles to the bone during bone grafting of the residual limb fulfils the same role (4). During subsequent residual limb formation, the end-stem muscles are converted into a dense, organ-shaped fibrous tissue that serves as a firm gasket between the bone and the residual limb. The muscles on the lateral surfaces of the residual limb undergo atrophy, the extent of which depends on the use of the prosthesis.

When evaluating bone grafting techniques, it should be noted that the technique is not complicated.

The wide variety of options allows the surgeon to choose the most appropriate one for the particular case. The reparative process generally proceeds smoothly. Closure of the medullary cavity creates the conditions for a normal course of the reparative process. No additional bone formation along the lateral bone surfaces in the form of periosteal deposits was detected. With good fixation, graft-bone fusion occurs as a primary bone fusion within 6-12 weeks.

Earlier studies (5) found that in bone grafting with bone synostosis, the durability and degree of loading of the residual limb was more than four times higher than without it. The latter is particularly important because functional loading creates elastic deformations in the bones, causing a hydrodynamic effect that contributes to normal intraosseous microcirculation and hence bone trophism.

The performed morphological studies testify that the processes of physiological reorganization with a full balance of osteogenesis and osteoresorption proceeded in the bone tissue of the residual limb ends. The tibial bone block even 6-9 years after amputation is represented by a compact structure of mature bone tissue, which confirms full functional compliance of the residual limb.

The use of methods of non-free bone grafting, myoplasty and free bone grafting allows to obtain elastic muscle stumps with the possibility of long-term complete functioning.

In conclusion, non-free skin grafting with a dermal-subcutaneous flap is the method of choice for closing skin defects on the residual limb. Fixation of muscles to bone allows to eliminate some residual limb defects and to form an elastic muscular residual limb with closed bone filaments. Synostosis formation in different ways significantly improves the functional quality of the residual limb.

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TRANSPARENCY DECLARATION

Conflicts of interest: None to declare.

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