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Shorting Resection and Correction of the Leg Length in the Treatment of Posttramatic Tibial Defects Complicated by Osteomyelitis

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BACKGROUND Severe fractures of the shin bones are often accompanied by the formation of defects in the tibia, suppuration and soft tissue necrosis. In the case of surgical treatment of fractures, infectious complications reach 3.6-9.1%. One of the methods of treatment of infected defects is resection of the ends of the tibia with shortening. This operation has proven to be effective in the treatment of fresh fractures. The relevance of the work is due to the prospects of using this technique in the treatment of the consequences of fractures with the formation of infected defects of the tibia.

AIM OF STUDY Improving the results of treatment of patients with post-traumatic defects of the tibia complicated by osteomyelitis by performing a shortening resection with simultaneous or sequential correction of the segment length.

MATERIAL AND METHODS The results of treatment of 65 patients with diaphyseal post-traumatic tibial defects complicated by osteomyelitis were analysed. They were divided into 2 groups. Group 1 was formed by 31 (47.7%) patients, they underwent shortening resection of the ends of bone fragments in the defect zone with simultaneous lengthening at another level. Group 2 included 34 (52.3%) patients who underwent a shortening resection of the tibia without lengthening. In all cases, the Ilizarov apparatus was used as a fixator.

RESULTS The technique for assessing the size of the true defect of the tibia was optimized taking into account the initial shortening of the segment and the distance between the proximal and distal fragments after resection of their ends. A treatment regimen was developed depending on the level of localization of the tibial defect, and the results of treatment of patients in the compared groups were assessed.

CONCLUSION Shortening resection is an effective treatment for patients with post-traumatic tibial defects complicated by osteomyelitis. Depending on the level of localization of the defect, it is advisable to carry out treatment according to one of two possible options. When the defect is localized in the upper and middle third of the tibia, shortening resection in an isolated form is shown. If the defect is localized in the lower third of the tibia, it is possible to supplement the shortening resection with an osteotomy in the upper third with Ilizarov lengthening.

Keywords: Glasgow Coma Scale (GCS), acute impairment of consciousness, validation, neuroresuscitation

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INTRODUCTION

The lower leg is the most vulnerable segment of the musculoskeletal system in terms of the formation of post-traumatic defects, which occur in more than 60% of cases of severe injuries and are localized mainly in the area of the diaphysis [1]. The concentration of attention on the lower leg, or rather, on the tibia, is due to the peculiarities of the anatomy of this segment, in particular, the deficiency of soft tissues on the anterior surface. On the one hand, this feature contributes to increased vulnerability of the tibia and the predominance of severe fractures with tissue detachment and the formation of necrosis. On the other hand, the superficial location of the bone and the relatively easy surgical access with the possibility of ideal reposition provoke traumatologists to perform osteosynthesis using massive constructions without taking into account the state of soft tissues. This fact obviously increases the risk of developing purulent complications, which reach a frequency of 3.6–9.1%, depending on the degree of damage [2].

Treatment of post-traumatic defects and false joints of the long bones of the lower limb in combination with suppuration is an extremely difficult task. Even isolated, bone defects or osteomyelitis are difficult to treat. Their combination contributes to mutual burdening and requires exceptional efforts to achieve a good result [3–5].

The difficulty in choosing the optimal treatment method is due to the fact that in the management of such patients, it is necessary to solve many problems. The main ones are as follows: bone consolidation, preservation and restoration of limb length, stopping the infectious process, preserving the function of adjacent joints. The priority is the first of the listed tasks - the integration of the tibia and, thus, the restoration of the limb's support ability. This contributes to the correction of the main biological processes at the local level (blood supply, bone mineralization, improvement of trophism, etc.) and, most importantly, the social and labor rehabilitation of patients. The rest of the named tasks can be solved by conservative measures or their solution is put on the back burner. The shortening of the limb could be successfully compensated for with orthopedic shoes, the fistulous form of osteomyelitis requires dressings. Restoration of the bone allows you to begin intensive development of movements in adjacent joints. In the absence of consolidation, the concentration of efforts on the solution of each separately taken of the listed tasks seems to be irrational.

Currently, in the treatment of the consequences of injuries and complications accompanied by the formation of long bone defects, the technique is traditionally popular, known in the Russian-language literature as "bilocal ostosynthesis", but in English-language literature — as *«bone transport»* [6–9]. The main disadvantage of the technique is the delayed contact of bone fragments in the defect zone for the period of distraction, which requires additional surgical interventions to create conditions for bone consolidation in this zone.

An alternative to bilocal osteosynthesis is shortening resection, better known as *«acute shortening»* [10–12]. Shortening resections have proven themselves in the treatment of severe, including gunshot fractures with the formation of a bone defect [13]. This is a simple and effective operation aimed at the fastest possible solution to the main problem - fracture healing. Its essence lies in the fact that the ends of the fragments of the damaged bone are resected within the limits of healthy tissues and are brought together with the help of external devices until full contact. With this approach, the formation of a bone defect is excluded, the fusion process begins in favorable conditions. Yes, limb shortening is formed. But this, in terms of the difficulty of solving, is an incomparably easier problem than replacing a long bone defect. Unfortunately, despite the obvious simplicity of the operation and the ability to restore the support ability of the limb in the shortest possible time, shortening resection is not in demand by orthopedic traumatologists who are faced with the problem of providing assistance to this very difficult contingent of victims. In the domestic literature there are no publications on this topic, and in the foreign literature there is a single experience of using this operation in the treatment of the consequences of injuries [14].

We have already discussed the use of shortening surgery in the treatment of the consequences of trauma [15]. Since the publication of the previous article, we have accumulated additional experience and optimized some elements of the method. The constantly increasing number of patients with this extremely severe pathology and the insurmountable difficulties that doctors have to face, forced us to revisit this topic. This determined the need for this publication with an emphasis on indications for individual treatment options and highlighting the technical aspects of surgical intervention.

The aim of this work is to improve the results of treatment of patients with post-traumatic tibial defects complicated by osteomyelitis by performing a shortening resection with simultaneous or sequential correction of the segment length.

MATERIAL AND METHODS

The study is based on the analysis of the results of treatment of 65 patients with post-traumatic infected defects and pseudoarthrosis of the tibia (46 men and 19 women) in the period from 2003 to 2020. The patients were divided into two groups according to the treatment option. Group 1 was formed by 31 patients (47.7%), they underwent shortening resection of the ends of bone fragments in the area of the post-traumatic defect with simultaneous lengthening at another level. Group 2 included 34 patients (52.3%) who underwent shortening resection of the tibia without lengthening. General characteristics of patients are presented in Table. 1.

Table 1

General characteristics of patients

Characteristics	1st group, *n*=31 (47.7%)	2nd group, *n*=34 (52.3%)	Statistical significance of differences, *p*
Age, years	31,2±10,3	29,9±7,6	0,11 ($p>0,05$)
Term from the moment of injury, years	2,7±1,4	2,4±0,9	0,06 ($p>0,05$)
Number of previously performed operations, *n*	3,7±1,5	2,9±1,3	0,018 ($p<0,05$)
Amount of true shortening, cm	6,9±2,9	7,9±3,1	0,021 ($p<0,05$)
Closed fracture, *n* (%)	10 (32,3)	5 (14,7)	0,003 ($p<0,05$)
Open fracture, *n* (%)	17 (54,9)	22 (64,7)	0,004 ($p<0,05$)
Open fracture with primary tissue defect, *n* (%)	4 (12,9)	7 (20,6)	0,005 ($p<0,05$)
Fracture in the upper third, *n* (%)	2 (6,5)	7 (20,6)	0,0001 ($p<0,05$)
Fracture in the middle third, *n* (%)	2 (6,5)	20 (58,8)	0,0001 ($p<0,05$)
Fracture in the lower third, *n* (%)	27 (87,1)	7 (20,6)	0,000 ($p<0,05$)

Attention is drawn to the prevalence of more than 4 times in group 1 of patients with defects of the tibia in the lower third. Accordingly, in group 2, the number of patients with localization of post-traumatic defect in the middle and upper third is almost 6 times greater than in group 1. The level of localization of the defect was the basis for the developed scheme for determining the indications for performing a shortening resection in an isolated form (group 2) or with simultaneous lengthening at another level (group 1). The diagram is shown in Fig. 1.

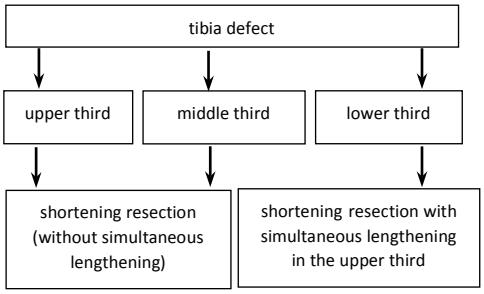

Fig. 1. Scheme for determining treatment options depending on the level of shortening resection

It should be noted that one-stage treatment (shortening resection with simultaneous lengthening) is a risky option due to the problems associated with the formation of a distraction regenerate, as well as the risk of formation of a false joint in the contact zone of fragments after resection (the so-called *docking site*). Most often, problems arise precisely in the area of *docking site*, because in conditions of purulent infection and trophic changes after numerous operations, the conditions for regeneration are extremely unfavorable here. Osteotomy proximal or distal to this zone worsens the conditions for consolidation. Therefore, doubts about the possibility of achieving fusion in the *docking site* zone should be interpreted in favor of refusing one-stage surgical treatment.

The main indication for shortening resection with simultaneous lengthening of the leg is the localization of the defect in the lower third of the tibia, because after resection in the lower third by 2-7 cm, the proximal fragment is long enough to perform corrective and lengthening operations and form a full-fledged distraction regenerate [16].

When shortened in the upper third, the distal tibial fragment is also of sufficient length for the potential formation of a distraction regenerate. At the initial stages of work, in 2 cases (6.5%) we performed simultaneous lengthening in the distal tibia after shortening resection in the upper third of the tibia, but we found a delayed formation of distraction regenerate and an imbalance in the tendons regulating the function of the foot. This made us refuse to restore the length of the lower leg in the distal part. When performing shortening resection in the middle third, it is inappropriate to use simultaneous lengthening. This is due to the fact that the proximal and distal fragments are short, bone fusion slows down due to the presence of infection and impaired osteogenic potential caused by previous operations. In such cases, it is advisable to shorten the segment without lengthening.

Group 2 included patients in whom we cannot perform additional osteotomy of the proximal or distal fragment due to unfavorable conditions for the formation of a full-fledged regenerate in the elongation zone.

Surgical restoration of the length in the second stage after shortening in the upper or middle third of the tibia is not necessary. After consolidation in the defect zone, it is necessary to compensate for the shortening by conservative measures. Modern orthopedic products are aesthetically pleasing and provide good function. This allows us to consider conservative correction as an important and integral element of treatment. This option for compensation of shortening satisfies many patients, and they eventually refuse to surgically lengthen the shortened limb.

An important planning element is to determine the level of resection and the potential magnitude of true tibia shortening. We optimized the method for assessing the potential segment shortening and the interfragmental diastasis value was determined taking into account the resected tibial fragments, which are shown in Fig. 2 and are presented as a shaded area.

Existing classifications of defects and methods for assessing true shortening are focused on determining the quality ΔL_1 of the distance between the ends of the fragments [17]. In our opinion, this is not entirely true. In cases where the ends have an elongated cone-shaped shape (such as icicles), the amount of resection can be so significant that it ultimately changes the treatment plan or even forces you to abandon it.

All patients underwent resection of the ends of the proximal and distal bone fragments, followed by approximation with the Ilizarov apparatus until full contact. The fibula was resected with the formation of a defect 1–1.5 cm larger in size than the expected convergence of the tibial fragments. The results of treatment were tracked in terms of 6 months to 5 years.

In cases where the ends of the bone fragments had a conical shape (such as icicles), in order to maximize the preservation of the length of the bone, an economical resection was performed, as shown in Fig. 3.

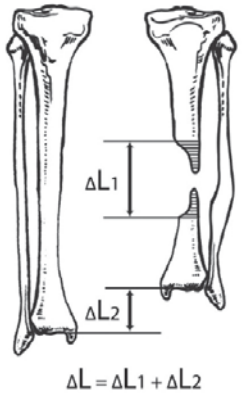

Fig. 2. Scheme for determining the magnitude of the true shortening. Δ L is the value of the true shortening; Δ L $_1$ — the value of interfragmental diastasis, taking into account the resection of the proximal and distal fragments; Δ L $_2$ — the difference in the length of the legs, formed as a result of muscle contraction

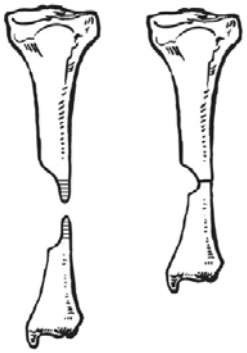

Fig. 3. Scheme of economical resection of the ends of the bone fragments of the tibia with localization of the defect along the antero-inner surface

After long (sometimes many years) treatment and numerous operations, the zone of the pathological focus is presented usually by coarse scar tissue with cavities of a complex configuration. When performing resection of bone tissue in such patients, it is difficult to count on radical sanitation of the infectious focus. With osteomyelitis, long-term antibiotic therapy is indicated, but its effectiveness is reduced due to microflora resistance. Therefore, we used antibiotics locally in the form of cement-based spacers and we used vacuum wound drainage in the postoperative period.

A prerequisite for the consolidation of the proximal and distal fragments of the tibia is their close contact. After extensive resections with widespread lesions of soft tissues, the simultaneous convergence of fragments is dangerous, as it can lead to squeezing of blood vessels and, as a result, necrosis of the distally located parts of the limb. Intraoperatively, to determine the effectiveness of blood flow, we were guided by such clinical signs as pulsation of peripheral arteries, color of the limb, capillary test. In those cases when the value of interfragmental diastasis (ΔL_1 in Fig. 2) was 3-4 cm, the bone fragments were brought together at the same

time. With a larger diastasis, the bone fragments were brought together at the same time during the operation by 3-4 cm, and in the postoperative period, we continued to converge the fragments at a rate of 1-3 mm per day, adjusting the rate depending on the pain syndrome and the state of blood supply to the distal limb.

In group 1, simultaneously with shortening, an osteotomy of a longer fragment of the tibia was performed, and in the postoperative period, the tibia was lengthened (Fig. 4). In group 2, only shortening resection was performed. Correction of shortening after surgery was carried out using orthopedic shoes.

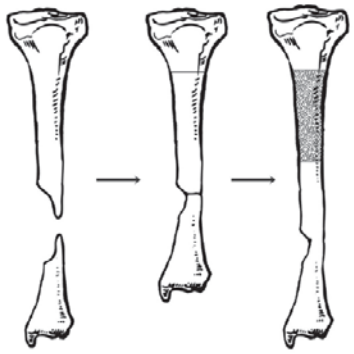

Fig. 4. Scheme of shortening the tibia in the lower third with simultaneous osteotomy in the proximal third and lengthening in the postoperative period

Statistical analysis of the significance of differences between groups was performed using *Statistica* 12.0 software. For a number of values with normal distribution, Student's *t*-test was applied; with no normal distribution - Mann-Whitney test.

RESULTS

The results of the treatment are presented in Table. 2, the evaluation criteria were the presence or absence of consolidation, as well as the magnitude of the limb shortening formed as a result of resection.

Table 2

Main indicators characterizing the process and outcome of treatment

Characteristic	1st group, *n*=31 (47,7%)	2nd group, *n*=34 (52,3%)
Consolidation with full length restoration	8 (25,8%)	—
Consolidation with shortening up to 2 cm	11 (35,5%)	3 (8,8%)
Consolidation with shortening of 2–5 cm	8 (25,8%)	18 (52,9%)
Consolidation with 5-10 cm shortening	—	12 (35,3%)
Consolidation with a shortening of 10-15 cm	—	3 (8,8%)
False joint in the resection area	3 (9,7%)	1 (2,9%)
Amputation	1 (3,2%)	

Table 2 shows that the study is devoted to the treatment of post-traumatic defects of the tibia and fusion with restoration of the limb's support ability. Simultaneous surgical restoration of the length of the limb is technically possible if it is indicated and risks are minimizing. These are the cases that formed Group 1. However, the expansion of the volume of intervention has a downside in the form of an increased risk of the formation of false joints. Therefore, the treatment options used in the compared groups were considered not according to the principle of "better or worse", but according to the principle of choosing the optimal

treatment option for each specific case. In Group 2, the simultaneous restoration of the tibia length with shortening was risky, therefore, we limited ourselves to fusion with shortening of the tibia.

Despite the fact that in Group 1 the shin was lengthened simultaneously with a shortening resection, it was possible to achieve full length correction only in 8 patients (25.8%). This is due to the fact that, against the background of trophic and cicatricial changes, inflammation often develops in the places where the wires and rods exit, and patients stop distraction and insist on earlier dismantling of the Ilizarov apparatus followed by fixation with orthoses until consolidation is complete. Due to the significant amount of diastasis between the fragments in 19 patients (61.3%), a shortening of up to 5 cm remained. Such patients were recommended to compensate for the shortening with the help of orthopedic devices.

Fusion in the contact area of bone fragments did not occur in 3 patients (9.7%) in group 1 and in 1 patient (2.9%) in group 2. Apparently, this is due to the fact that osteotomy of one of the bone fragments worsens trophism and reduces osteogenic potential, which negatively affects the consolidation process. In all 4 cases, to achieve bone fusion, repeated operations were required, which consisted in additional resection of the ends of the fragments by 1–1.5 cm - for exacerbation of a widespread purulent process. Initially, this case was characterized by a difficult local status. The patient was injured as a result of a bus hitting the leg 28 years before the visit. During this period, as a result of numerous operations, severe trophic changes developed, shortening of the lower leg by more than 20 cm in the absence of fusion and the presence of a widespread purulent bone lesion. In this case, reconstructive intervention was considered as an attempt to achieve consolidation and preserve the limb, however, due to exacerbation of osteomyelitis, it was necessary to resort to amputation at the level of the upper third of the leg.

The relief of the infectious process was achieved in 21 patients (67.7%) in group 1 and in 20 patients (58.8%) in group 2. In the remaining patients - 10 (32.3%) and 14 (41.2%), respectively - there is a fistulous form of osteomyelitis with periodic exacerbations.

Case report

A 37-year-old patient presented with a diagnosis: pseudarthrosis of the right tibia in the lower third, osteomyelitis, abscess of the lower third of the right leg. Six months before the visit, he received an open fracture of the bones of the right shin. In another medical institution, an operation was performed - osteosynthesis with a pin. In the postoperative period, wound suppuration occurred with the formation of a fistula. The pin was removed, a new pin with a cement mantle with antibiotic was installed. The purulent process could not be stopped, the fracture did not grow together, the pin was removed. Thus, at the previous stages of treatment, within six months, the patient underwent 3 operations, which were unsuccessful. In this case, taking into account the localization of the pathological process in the lower third of the leg, the patient was included in group 1. The patient was operated on, the main elements of the surgery were as follows: opening of the abscess (about 100 ml of pus was evacuated); resection of the fibula in the lower third for 5 cm; resection of the ends of fragments of the tibia with a shortening of about 4 cm; osteosynthesis with the Ilizarov apparatus; osteotomy of the tibia in the upper third, implantation of a cement spacer with 1 g of vancomycin into soft tissues in the lower third. Given the local use of the antibiotic, antibacterial therapy was not fulfilled in the postoperative period. The wound in the area of tibial resection was not sutured. Leg lengthening according to Ilizarov began on the 5th day after the operation at a rate of 1 mm / day, 3 weeks after the operation, the granulating wound was closed with a split skin graft. The lower leg was lengthened by 3.5 cm. The Ilizarov apparatus was removed 7 months after the operation, when the formation of the distraction regenerate was completed and the consolidation of the fragments in the resection zone began. Thus, the result of the treatment was the restoration of the limb's ability to support and its length, the relief of the purulent process, as well as the preservation of the function of the adjacent joints. The main stages of the surgery are demonstrated in Fig. 5.

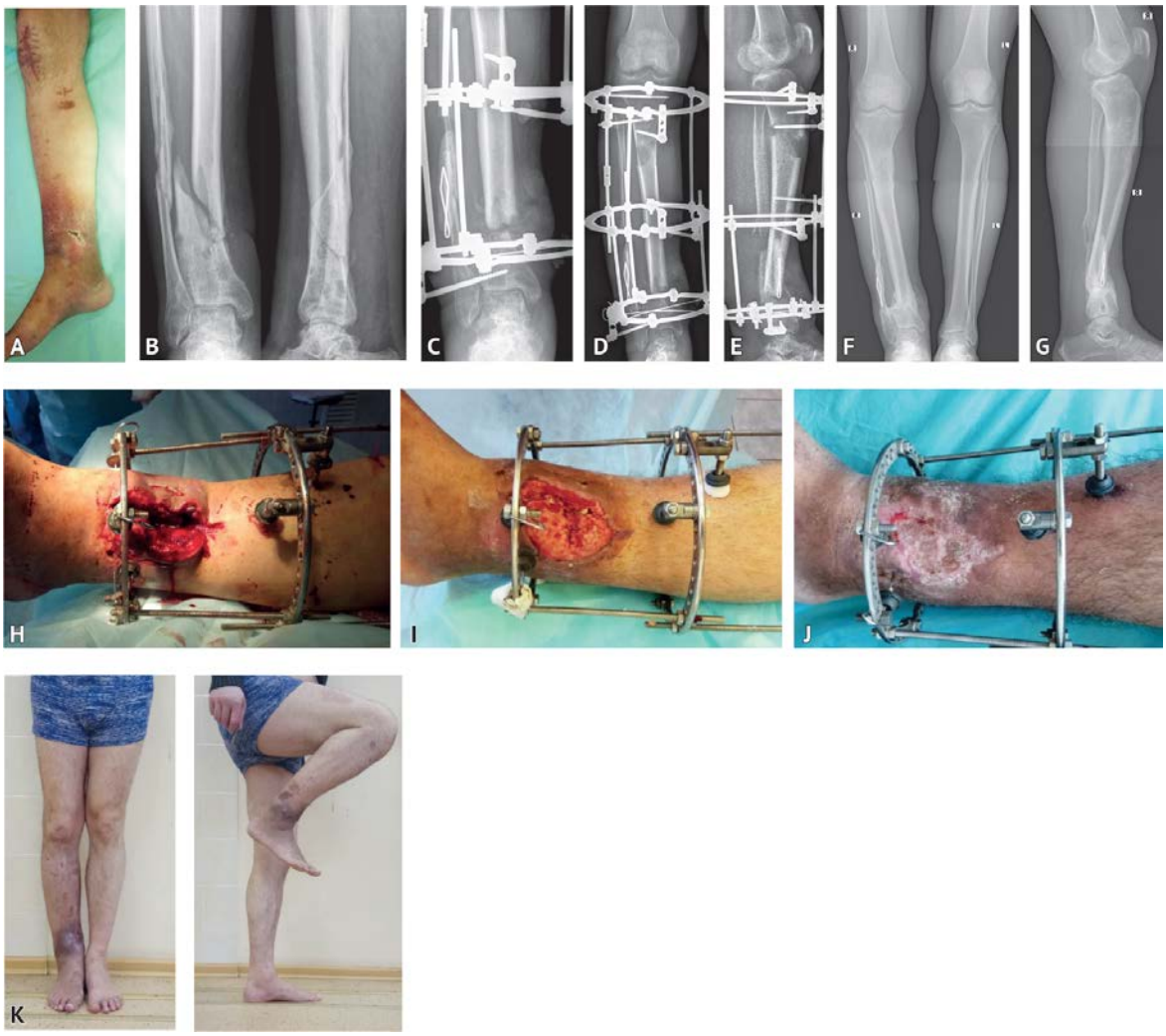

Fig. 5. A 37-year-old patient with pseudarthrosis of the right tibia in the lower third, osteomyelitis, abscess of the lower third of the right leg: A — appearance of the leg on admission; B — X-ray scans of the right lower leg upon admission; C — X-ray scans in frontal projection after surgery; D, E — X-ray scans of the lower leg in frontal and lateral projections 3 months after surgery; F, G — X-ray scans in frontal and lateral projections 1 year after surgery; H — the appearance of the wound after surgery; I — the appearance of the wound after 3 weeks; J — the appearance of the wound 2 months after surgery; K — the appearance and function 1 year after surgery

DISCUSSION

The material presented in the article, possibly, will allow many orthopedists to overcome the psychological barrier, who are stopped by the still unusual approach to surgical treatment associated with a significant change in the anatomy of the affected segment in favor of restoration of function.

Unfortunately, in the domestic literature there are no publications devoted to the application of this technique in patients with osteomyelitis, and the technique itself is actually ignored. In this regard, we would like to cite a quote from the last review on this issue: "At present, four areas can be distinguished in reconstructive surgery of tubular bone defects: free transplantation of bone tissue and bones, replacement of the defect with osteo-substituting and osteoinductive materials, non-free bone tissue grafting according to G.A. Ilizarov and combined methods" [18]. Therefore, it is necessary to say a few words in defense of this technique, describe the merits and advantages and, as a result, justify its wider application.

In the introduction, we have highlighted the main tasks that need to be solved in the treatment process. The first and main one is the fusion of the tibia and, thus, the restoration of the support ability of the limb.

Sharp shortening is a direct way to solve this problem. In fact, by bringing together the bone fragments, we eliminate the defect, it disappears. And along with it, the problem disappears and all the difficulties associated with replacing the defect. The problem of adhesion remains in conditions close to those of a conventional open fracture. Moreover, the fusion begins immediately from the moment the first operation is performed.

In conditions of bilocal osteosynthesis, when the bone fragment is brought down while maintaining the length, fusion in the primary focus zone begins only after the intermediate split-off fragment reaches the distal one (if we talk about the replacement of the defect in the lower third of the leg). It is not difficult to calculate that at a standard rate of descent of 1 mm per day, depending on the size of the defect, this will not happen very soon. For example, when a 5 cm defect is replaced, the fragments will "meet" in almost 2 months. Moreover, this meeting will take place in extremely unfavorable conditions, for the optimization of which it will almost certainly be necessary to re-process the ends of the fragments, free them from scar tissue and, possibly, additional resection. So even under the most favorable conditions, fusion will begin with a delay of 2 months, as in the example under consideration. With acute shortening, such problems do not arise.

Comparing the two groups of patients presented in this article, differing in the volume of intervention it is necessary to note the advantages and disadvantages of each of them. The restoration of length simultaneously with shortening (group 1) attracts with the opportunity to solve two problems at once - to heal the bone in the defect zone and partially or completely restore the bone length. However, it should be understood that this is a much more technically complex option. Fusion control is required at two levels - in the area of the distraction regenerate and in the area of the bone defect. It is possible to successfully implement this version of the technique only if you have a certain experience in lengthening operations. In addition, when performing an osteotomy of one of the bone fragments, the risks of disruption of the regeneration process naturally increase at the level of contact of bone fragments in the defect zone. In other words, the body's resources may not be enough to ensure consolidation at two levels. This is confirmed by the formation of false joints in 3 patients (9.7%) in group 1.

Isolated shortening resection (group 2) has several advantages. First of all after long-term treatment, the patient has the opportunity to literally enjoy freedom of movement, since as a result of bone consolidation, the support ability of the limb is restored without additional means of fixation. This is the reason that the quality of life of patients improves so much that they refuse surgical lengthening in the second stage and use conservative methods of shortening correction in the form of insoles, platform shoes, etc. Therefore, out of 34 patients (52.3%) who underwent a shortening resection without simultaneous restoration of length, only 14 (41.2%) had surgical length restoration, and 20 (58.8%) refused surgical treatment. in favor of a conservative correction. Surgical correction of different lengths of the lower extremities as the second stage after a period of recovery and rehabilitation at the end of treatment for a bone defect is carried out in more favorable conditions. These features are the rationale for choosing this option.

CONCLUSIONS

Shortening resection is an effective treatment for patients with post-traumatic tibial defects complicated by osteomyelitis. Depending on the level of localization of the defect, it is advisable to carry out treatment according to one of two possible options. When the defect is localized in the upper and middle third of the tibia, shortening resection in an isolated form is indicated. If the defect is localized in the lower third of the tibia, it is possible to supplement the shortening resection with an osteotomy in the upper third followed by lengthening using Ilizarov method.

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