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Features of Surgical Treatment of Posttraumatic Lower Limbs of Different Lengths in Adult Patients

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RELEVANCE Different lengths of the lower extremities have a negative impact on the position of the pelvis and spine and lead to secondary deformities. To prevent these consequences, early surgical correction of the shortening is necessary.

AIM OF STUDY Study of the features of post-traumatic shortening of the lower extremities, mechanisms of adaptation to this condition and, on the basis of this, optimization of surgical technique when performing reconstructive and restorative operations.

MATERIAL AND METHODS A total of 276 patients with posttraumatic shortening of the lower extremities were examined, 102 of whom were operated on. Comparative radiography of both legs was used to diagnose different lengths. The Ilizarov method was used as the main method of surgical correction.

RESULTS We studied the mechanisms of adaptation of patients to post-traumatic shortening of the hip and lower leg and optimized surgical technique. A method was developed for determining the optimal elongation value.

CONCLUSION The most effective and least traumatic method is external osteosynthesis according to Ilizarov. Distraction in the apparatus allows the formation of a regenerate of the required shape and length and the elongation of exactly the amount that is optimal for a given patient.

KEYWORDS: different lengths of the lower limbs, post-traumatic deformity, post-traumatic shortening, lengthening of the lower limbs

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CT - computed tomography
PPF - post-traumatic pathological focus
DLLE - different lengths of the lower extremities

The main cause of post-traumatic deformities of the lower extremities in adult patients are fractures of the femur and tibia fused with displacement. Shortening is a particular case of deformation and is often combined with axis deviation in other planes (varus – valgus, recurvation – antecurvation, external – internal rotation). Particular interest in this particular type of deformity is due to the most intense negative impact of different lengths of the lower extremities (DLLE) on the biomechanics of other parts of the skeleton (pelvis, spine) with the formation of compensatory mechanisms in the form of functional, and with long-term existence - and irreversible structural changes. Incorrectly fused fractures account for 40–60% of the total number of fractures of the long bones of the lower extremities [1–5]. At the same time, different lengths of the lower limbs occur in at least every third case.

The organization of care for such patients is associated with serious problems in the form of long periods of treatment and the likelihood of complications, which are comparable in severity to the shortening itself [6]. Specific features of post-traumatic deformities in the form of foci of

chronic infection, cicatricial and trophic changes, the presence of foreign bodies increase the risks of complications and form a whole list of relative contraindications to lengthening reconstructive surgeries. It is also impossible not to take into account the changes associated with the adaptation of the body to this pathological condition. Secondary deformities of the pelvis, spine and other parts of the skeleton in such cases are an adaptive response of the body, although in fact they can be considered as complications or consequences of DLLE. [7–10]. In such cases, elongation by the full amount of true shortening will lead to a violation of the compensatory reactions. This is fraught with serious problems and disruption of adaptation. Therefore, it is necessary to differentiate such concepts as the value of the true shortening and the value of the optimal compensation. The question of determining the value of the optimal compensation of DLLE in post-traumatic shortening remains open to this day. When considering the potential for surgical treatment of this category of patients, it is necessary to take into account the features of post-traumatic deformities and, at the stage of preoperative planning, to clearly understand in which cases it is necessary and advisable to lengthen the shortened limb, and by what amount.

Purpose of the work — study of the features of post-traumatic shortening of the lower extremities, mechanisms of adaptation to this condition and, on the basis of this, optimization of surgical technique when performing reconstructive and restorative operations.

MATERIAL AND METHODS

The study was based on the results of examination of 276 patients with DLLE due to fractures of the femur and tibia in the period from 1996 to 2019.

Contingently, the patients were divided into two groups according to the severity of the condition and the magnitude of the true shortening.

Group 1 - incorrectly fused fractures. The main reason for such shortening is the fusion with the overlap of bone fragments.

Group 2 - fusion with shortening after resection for severe trauma or post-traumatic (postoperative) osteomyelitis.

The distribution of patients by groups and the magnitude of the true shortening is presented in Table 1.

Table 1

Distribution of patients by groups

Etiology of different lengths of the lower extremities	Amount, n (%)	
	appeals	operations
1. Incorrectly healed fractures	187 (67,8)	65 (63,7)
2. Fusion with shortening after resection	89 (32,2)	37 (36,3)
Total	276 (100)	102 (100)

In all cases of surgical treatment, the method of G.A. Ilizarov was used, sequentially performing several stages: 1 — osteosynthesis with the Ilizarov apparatus in an arrangement that allows to eliminate all available types of displacement; 2 — performing an osteotomy at the level of the segment to be lengthened; 3 — postoperative gradual correction and distraction of the shortened segment; 4 — fixation before the onset of consolidation and dismantling of the device.

Since 2015, when examining patients to obtain long X-ray images, special attachments to standard X-ray units have been used, which allow obtaining an image up to 120 cm in length in the patient's standing position (so-called teleradiograms). On the basis of the obtained long-length images, the value of the true shortening (lengthening) of one limb relative to the other one was assessed.

In order to study the mechanisms of adaptation of patients to different lengths of the lower extremities, anamnestic data were collected, a clinical examination was carried out, including video filming. A universal method for determining the value of the optimal compensation was developed. We compared the value of the true shortening, determined on the basis of radiography, and the value of the optimal compensation of DLLE, determined by the developed method.

RESULTS

The causes of post-traumatic shortenings are either severe injuries, or complications of trauma and treatment, or mistakes made in the previous stages. All this leaves traces in the form of a rather large list of additional factors aggravating the condition of patients with DLLE. Table 2 presents a list of such factors based on the results of the examination of the patients who applied.

Table 2

Distribution of concomitant factors aggravating the condition of patients with different lengths of the lower limbs

Characteristic	1st group (n=187)	2nd group (n=89)
	n (%)	n (%)
Non-removed foreign bodies	41 (21,9)	29 (32,6)
Knee joint contracture	38 (20,3)	41 (46,1)
Ankle joint contracture	59 (31,6)	44 (49,4)
Scoliosis	19 (10,2)	9 (10,1)
Multiplanar deformations	131 (70,1)	27 (30,3)

Gonarthrosis	36 (19,3)	22 (24,7)
Chronic osteomyelitis	21 (11,2)	17 (19,1)
Trophic disorders and gross scars	15 (8,0)	47 (52,8)

Table 2 shows that in group 2 patients with post-resection shortenings were dominated by cases with the presence of contractures of the knee (46.1%) and ankle (49.4%) joints, as well as with trophic disorders and rough scars (52,8%). This is a consequence of numerous operations in the area of injuries, including for purulent complications. In the 1st group, in patients with improperly healed fractures, attention is drawn to a significant number of observations with multiplanar deformities (30.1%) due to inadequate reduction, accompanied by displacement of fragments.

The most representative radiographs of patients with post-traumatic shortenings are shown in Fig. 1. A characteristic feature is the presence of foreign bodies in the form of previously installed implants and fragments of injuring shells. The presented X-ray picture reflects the serious efforts of surgeons aimed at achieving fusion, because there is evidence of numerous operations. Naturally, all this is accompanied by the formation of rough scars and deformation of soft tissues.

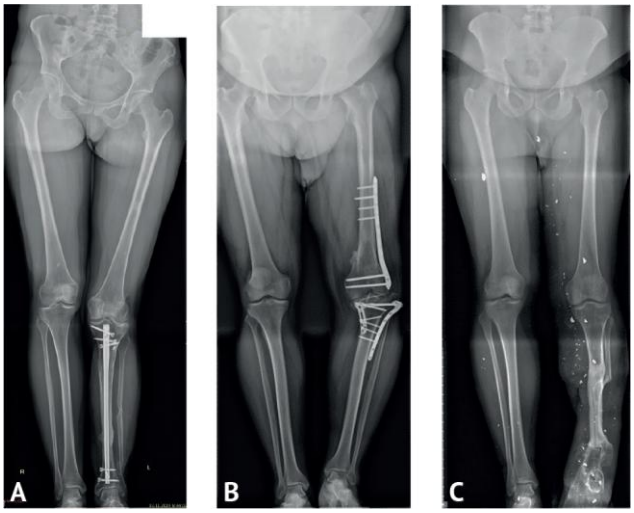

Fig. 1. Typical examples (radiographs) of patients with post-traumatic shortenings of the lower extremities, characterized by the presence of unremoved implants and multicomponent deformities at the level of previously performed operations (A, B) and fragments of wounding shells (C)

Local tissue changes in the area of the fracture that occurred are called post-traumatic pathological focus (PPF) [2]. The presence of PPF dramatically affects the choice of the volume of surgery and the determination of the level of correction. In the presence of implants to be removed, it is necessary to plan the sequence of surgical interventions in such a way as to minimize their number and, if possible, use the existing constructions for subsequent stabilization after lengthening. In particular, if shortening has developed after intramedullary osteosynthesis, the nail can be used as a guide during distraction and as a fixator after its completion. In two patients of the 1st group, just such a variant of limb length correction was used, using the femur for the traction effect (clinical example 1).

Clinical example 1 (1st group)

Patient S., 42 years old, diagnosis: "Incorrectly fused fracture of the right femur, shortening by 2 cm and external rotation, condition after intramedullary osteosynthesis". A year before the visit, he received a fracture of the right femur. Intramedullary osteosynthesis was performed, delayed consolidation was noted. As a result, fusion occurred with a shortening of 2 cm and external rotation of the right thigh by 24° (on the left 11°). Surgical treatment of the deformity consisted of two stages. The first stage – removal of distal locking screws, osteotomy of the femur above the level of periosteal callus in the fracture zone, osteosynthesis with the Ilizarov apparatus. In the postoperative period, the femur was lengthened by 2 cm and external rotation was eliminated. The total period of fixation with the device was 2.5 months. The second stage is distal blocking of the pin and dismantling of the Ilizarov apparatus, rehabilitation treatment aimed at developing movements in the knee joint. Figures 2–4 show computed tomograms (CT) before and after lengthening and photographs of the patient's appearance.

Fig. 2. Computed tomogram of patient S., 42 years old with a diagnosis: "Incorrectly fused fracture of the right femur, shortening by 2 cm and external rotation, condition after intramedullary osteosynthesis"

Fig. 3. Computed tomography of the same patient after osteotomy and lengthening of the right femur by 2 cm


Fig. 4. The appearance of the same patient during treatment with the Ilizarov apparatus


Fig. 5. Appearance of patient M., 28 years old (left) and his radiographs (right) before correction. On radiographs, attention is drawn to the deviation of the mechanical axis of the lower limb up to 3 cm on the left, as well as multiplanar deformity in the region of the distal metaepiphysis of the tibia

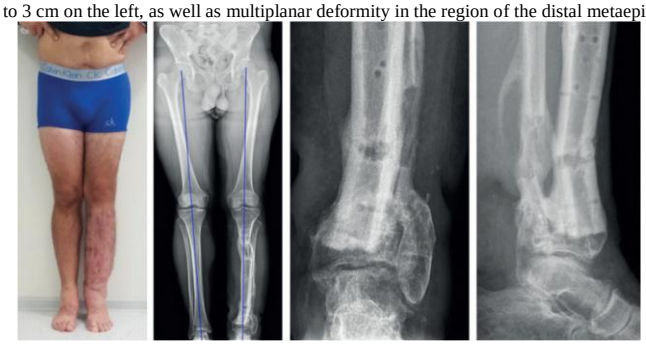
Fig. 6. Appearance of patient M., 28 years old (left) and his radiographs (right) after correction. The position of the mechanical axis is identical on both sides, the axial and angular relationships in the area of the left ankle joint are restored

The presented case from group 1 demonstrates a relatively small shortening of the femur with the presence of rotational deformity in the absence of gross deformity of soft tissues, purulent complications and restriction of movement in adjacent joints.

Clinical example 2 (2nd group)

Patient M., 28 years old, diagnosis "Post-traumatic deformity and shortening of the left leg, contracture of the left ankle joint". Three years before the visit he received a severe concomitant injury to the head and extremities, an open fracture of the shin bones with displacement of fragments as a result of a road traffic accident. As a result, the fusion of the fractures of the left leg bones occurred with deformation and

shortening. The patient underwent several reconstructive surgeries, including lengthening of the left lower leg in the upper third. The patient was admitted with a diagnosis of "Post-traumatic deformity and shortening of the left leg, contracture of the left ankle joint".

During the examination, attention was drawn to the presence of deformity at 2 levels: in the upper third of the leg in the area of previous lengthening, and in the lower third, in the area of the fracture. The possibilities of compensating for this condition with orthopedic shoe were limited due to severe deformity and cicatricial changes in the area of ankle joint. It was decided to make the correction at two levels: in the proximal part – for lengthening and partial correction, in the distal part - in order to correct the deformity and restore the normal position of the axes in the ankle joint. Commenting on this observation, it should be noted that at the stage of preoperative planning, the issue of the exact size of the difference in length and the optimal amount of correction was not discussed, since it was impossible to determine these values. The actual size of distraction in the proximal region was 37 mm.

This article discusses the possibility of surgical correction of DLLE. However, conservative corrections should not be excluded or considered as competing methods. It is advisable to evaluate them as an element of comprehensive treatment. Modern orthopedic products are quite comfortable and functional, so not all patients are ready to undergo surgery even with a significant DLLE value. It is important to compensate for the difference in leg length, while the correction method (conservative or operative) is not of fundamental importance.

Differences in the length of the lower limbs with an upright position of the body force a person to compensate for this difference in order to prevent the development and progression of the so-called "syndrome of different leg lengths". In practical terms, according to the mechanism, it is advisable to divide such compensation into passive and active one.

Passive compensation involves the use of additional methods for DLLE correction. These include various types of orthopedic products and surgical lengthening interventions. With this type of compensation, the body's own resources do not participate in the adaptation process, and secondary deformation of other parts of the skeleton does not develop.

Active compensation of DLLE occurs with the involvement of a person's own mechanisms (resources) of adaptation. As a rule, in the process of walking, the patient has a so-called "merciless lameness" [11]. With prolonged lameness, deformation of the spine and pelvis gradually develops, and contractures of the joints progress. Ankle extensor contracture due to walking on the forefoot is typical.

It can be difficult to understand why some patients are ready to use the possibilities of the proposed methods of passive compensation, while others categorically refuse to do so. Table 3 shows the distribution of patients in the study groups by the type of compensation.

Table 3

Distribution of patients by type of compensation

Group	The difference in the length of the lower limbs, cm	Compensation type		Total n (%)
		Passive n (%)	Active n (%)	
1st	2,7±1,2	66 (35,3%)	121 (64,7%)	187 (100%)
2nd	7,8±2,7	71 (79,8%)	18 (20,2%)	89 (100%)

Commenting presented in Table 3 data, it should be noted that most of the patients of the 1st group – 121 patients (64.7%) – refused to use orthopedic devices. In group 2, on the contrary, the majority of patients resorted to passive compensation – 71 patients (79,8%). This can be explained by the fact that with a relatively small value of DLLE in group 1, patients do not see the need to use additional correction with the help of orthopedic devices. In group 2, with a significant value of DLLE, it is difficult to do without additional compensation, this forces patients to use special shoes.

The developing mechanisms of compensation in the form of secondary deformities lead to the formation at the level of the central nervous system (CNS) of certain mechanisms of proprioception, which, according to the feedback mechanism, determine the degree of comfort in compensating for post-traumatic shortening [12, 13]. In other words, the value of the optimal compensation of DLLE, determined by the patient himself, often differs from the value of the true shortening.

With this in mind, we have developed a three-stage technique for determining the optimal amount of compensation in patients with post-traumatic DLLE. First stage – selection of the stand, optimal in height, in a standing position of patient. Second stage – assessment of the degree of comfort when walking in comfortable shoes with a sole increase in height by the value determined at the first stage. It is better to make such a sole from a laminated material so that you can adjust the height of the sole. Only after such a study, when the patient has precisely determined the optimal correction value for him, the issue of surgical lengthening by this value is to be discussed. In the process of treatment according to the Ilizarov method, the 3rd stage is implemented. After the completion of distraction, the patient is invited to undergo a rehabilitation course for 2–3 weeks, restore gait and range of motion in the joints, and then return to the discussion of the final value of the optimal correction. The fact is that with Ilizarov elongation, a regenerate is formed, which in the early stages of its formation, immediately after distraction, has plastic properties. This makes it possible to compress or stretch it additionally within 5–7 mm. After that, the device performs a fixing function until the onset of consolidation.

In both groups, the value of the optimal correction was less than the value of the true DLLE. Table 4 shows the data of comparison of these values.

Data of Table 4 show that the optimal correction value in the 1-st group was 87.0% of the true shortening, and in the 2-nd group – 78.9%. This is due to the fact that in these groups DLLE was formed already in adulthood, the patients quickly enough paid attention to it, and they could not adapt to it and had to resort to surgical correction.

Table 4

Comparison of the value of the optimal correction and different lengths of the lower limbs in different groups

Groups, number of operations	Average value of different lengths of the lower limbs, cm	Average value of correction, cm	Volume of corrections, %
Incorrectly healed fractures (n=65)	2,3±0,8	2,0±0,7	87,0

Resections after severe trauma, for osteomyelitis or tumor (n=37)	7,1±2,4	5,6±1,5	78,9

DISCUSSION

Post-traumatic shortening of the lower extremities is a special case of deformity and is often accompanied by a deviation of the axis in different planes. A history of severe injuries, numerous surgeries and (often) complications contributes to the formation of PPF, which is characterized by cicatricial changes, trophic disorders and remnants of unremoved foreign bodies. When determining the level of corrective osteotomy, it is necessary to avoid intervention in this area, choosing unchanged areas above or below.

It is necessary to take into account the severe psychological status of such patients, many of whom have undergone numerous operations and, as a result of many years of treatment, received an unsatisfactory result, which forces them to resort to new surgical interventions. In order to reduce the number of operations, it is advisable to perform the maximum number of manipulations within one intervention. In particular, in the presence of unremoved fixators, they should be removed and corrective osteotomy performed simultaneously, within the framework of one surgery. In the presence of an intramedullary fixator, it can be used as a guide during distraction and as a final fixator after completion of DLLE correction.

Long-term lack of compensation for different lengths of the lower extremities in patients with consequences of severe fractures of the hip and leg leads to the development of persistent irreversible deformities of the superior parts of the skeleton (pelvis and spine). Subsequently, these deformations, according to the feedback mechanism, will themselves determine the amount of necessary compensation. The longer the time elapsed from the moment of the development of DLLE to the moment of correction, the less amount it is necessary to lengthen (or shorten) the affected limb. Therefore, it is necessary to diagnose DLLE as early as possible and focus the attention of patients on the possible negative consequences of the syndrome of different leg lengths.

CONCLUSION

1. A feature of post-traumatic shortening of the lower extremities is their frequent combination with other types of deformities (angular and rotational), as well as the presence of foreign bodies, cicatricial and trophic changes that form the so-called post-traumatic pathological focus.

2. Depending on the type of post-traumatic shortening, either active or passive adaptation mechanisms are switched on, which lead to secondary compensatory deformations of other parts of the skeleton and, according to the feedback mechanism, determine the feeling of comfort when compensating for post-traumatic shortenings.

3. The value of the optimal correction of different lengths of the lower extremities is always less than the value of the true shortening, which must be taken into account when planning lengthening operations. The Ilizarov method allows in the course of treatment to determine the value of the optimal correction and to make lengthening exactly by the amount that is most comfortable for a given patient.

4. Optimization of the surgical technique by performing corrective operations outside the pathological focus zone can significantly reduce the risks of complications.

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