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Modern treatment of post-traumatic extra-articular deformity of the femur

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The issue of adequate treatment of post-traumatic deformities of long bones has become more urgent due to the large number of injured as a result of combat trauma and the presence of residual displacement of fragments after primary care providing. Objective. On the basis of literature analysis and own clinical experience, present methods of treatment of post-traumatic extra-articular deformity of the distal part of the femur (DF). Methods. The available professional literature, publications in electronic systems Google Scholar, PubMed, ScienceDirect were analyzed. The results of treatment of 38 patients with post-traumatic extra-articular deformities of the DF, in which the fracture line was extended to the area of the joint at the time of the primary injury, were studied. To plan the surgical treatment, the author's 3D-printing technology was used in 12 patients with the most complex cases. A clinical example is given. Results. Key moments of patient examination, principles of correction and approaches to its planning in case of DF multiplanar deformities are defined. The results of 3D-visualization and 3D-printing of the damaged segment during the examination and planning of deformity correction were evaluated. All patients to whom the 3D-modeling technique was applied were operated on, considering the individual characteristics of the deformity. After each stage of surgical treatment, a course of individual rehabilitation treatment was carried out. Positive dynamics of functional results were obtained within 12 months according to SF-36 and AOFAS scales. Conclusions. The use of 3D-modeling during the planning of corrective surgery allows the surgeon to increase the accuracy of the correction and significantly reduce the time of the operation. Well-known and improved methods with individually selected rehabilitation, used for the treatment of post-traumatic extra-articular deformities of the distal femur contribute to faster recovery, avoiding potential complications and achieving positive functional outcome in such patients.

Питання адекватного лікування післятравматичних деформацій довгих кісток набуло більшої актуальності через велику кількість поранених в результаті бойової травми і наявність залишкового зміщення відламків після надання первинної допомоги. Мета. На підставі аналізу літератури та власного клінічного досвіду показати сучасні методики лікування післятравматичної позасуглобової деформації дистального відділу стегнової кістки (СК). Методи. The available professional literature, publications in electronic systems Google Scholar, PubMed, ScienceDirect were analyzed. Проаналізовано доступну фахову літературу, публікації в електронних системах Google Scholar, PubMed, ScienceDirect. Вивчено результати лікування 38 пацієнтів із післятравматичними позасуглобовими деформаціями СК, в яких на час первинної травми лінія перелому була поширена на ділянку суглоба. Для планування хірургічного лікування авторську технологію 3D-принту використано у 12 пацієнтів із найскладнішими випадками. Наведено клінічний приклад. Результати. Визначено ключові моменти обстеження пацієнтів, принципи корекції та підходи до її планування в разі деформацій СК в різних площинах. Оцінено результати застосування під час обстеження та планування корекції деформації 3D-візуалізації та 3D-друку ушкодженого сегмента. Усіх пацієнтів, яким застосовано методику 3D-моделювання, прооперовано з урахуванням індивідуальних особливостей деформації. Після кожного етапу хірургічного лікування проведений курс індивідуального реабілітаційного лікування. Отримано позитивну динаміку функціональних результатів протягом 12 міс. згідно з результатами обстеження за шкалами SF-36 та AOFAS. Висновки. Використання 3D-моделювання під час планування коригувального хірургічного втручання надає можливість хірургу підвищити точність корекції та значно скоротити час виконання операції. Відомі й удосконалені нами методики з індивідуально підібраною реабілітацією, застосовувані для лікування післятравматичної позасуглобової деформації стегнової кістки сприяють швидшому відновленню, уникненню потенційних ускладнень і досягненню гарних функціонального результатів таких хворих. Ключові слова: післятравматична позасуглобова деформація, стегнова кістка, хірургічне лікування, 3D-моделювання, 3D-друк. Ключові слова. Післятравматична позасуглобова деформація, стегнова кістка.

Key words. Post-traumatic extra-articular deformity, femur, surgical treatment, 3D-modeling, 3D-printing

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Introduction

Distal femur fractures (DFFs) are peripheral fractures within 15 cm of the femur [1, 2]. According to literature sources, fractures of the long bones of the limbs are the most frequent injuries and make up from 33 to 70% [3, 4] of the total number of all skeletal injuries, and in patients with polytrauma the share of long bone fractures is equal to 75–90 % [5]. DFFs make up 3–6 % of all femur fractures [2, 6–9]. Fractures of this localization, which have fused with deformation, the so-called «incorrect fusions», are generally a rather rare condition [10]. The risks of deformity during treatment depend on the nature of the fracture (extra-articular, partially articular or fully articular) and the level of fragmentation or loss of bone tissue. Commonly accepted criteria for «improper fusions» of the DFFs include deformations in the coronal and sagittal planes and a discrepancy in the length of the limbs, as well as intra-articular and multi-plane deformations [10]. Clinical symptoms begin with deformations in the coronal plane of more than 5°, sagittal — 10°, rotational — 10°–15° and limb shortening of more than 2 cm [11–15].

During the study of deformation, the evaluation of curvature using 3D modeling based on the results of CT studies is informative. Modern diagnostic preoperative technologies make it possible not only to compare the deformed and intact limb, but also to superimpose two images one on top of the other and in this way establish the peak of the deformation and its true appearance, choose the place of the osteotomy, and plan the fixation of the fragments [16, 17].

Today, the issue of adequate treatment of post-traumatic extra-articular deformities has become even more urgent due to the large number of injured people and the presence of residual displacement of fragments after providing primary care. There is a relative paucity of information regarding «malunion»of the DFFs compared to the rest of the femur and lower extremity. The available literature on DFFs is mostly focused on emergency treatment, prosthetic repair, and treatment of nonunions [1].

Purpose: following an assessment of literature and own clinical experience, to determine modern methods of treatment of post-traumatic extra-articular deformation of the distal part of the femur.

Material and methods

The study involved evaluation of available professional literature, as well as a search for publications in the electronic systems Google Scholar, PubMed, ScienceDirect, archives of specialized journals on modern tactics of treatment of post-traumatic extra-articular deformity of the femur.

For clinical analysis, 38 patients with various post-traumatic extra-articular deformities of the hip, in which the fracture line extended to the joint area during the primary injury, were selected. All of them received medical care in the Department of Musculoskeletal Trauma of the State Institution Professor M. I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine. To plan the correction of the deformity, computerized tomography (CT) was performed, and an examination was carried out according to the methods developed by us [11]. Anteversion CT of both lower extremities was used to measure rotational displacement [18]. Standard anteroposterior and lateral X-rays of the femur, hip, and knee were performed during the examination of the patients. The degree of arthrosis of the knee joint was measured according to Kellgren-Lawrence [19]. To quantify the deformity and objectively measure the length discrepancy of the lower limbs, full-length bilateral anterior-posterior radiographs of the lower limbs were performed while standing with the kneecap pointing forward [20, 21]. Anatomical posterior distal femoral angle (aPDFA according to Paley) was measured on a lateral radiograph of the femur, assessing the degree of deformation in the sagittal plane (average normative value 83°) by the ratio of the line of the sagittal distal femoral joint to the long axis of the femur [21]. The center of the turning angle was obtained radiographically for preoperative planning using a conventional radiograph, where the intersection of the proximal and distal mechanical axes was calculated [17, 20]. A clinical and biomechanical study of the recovery of the function of the damaged limb joint was conducted. Medical histories of patients with post-traumatic hip deformities, who underwent a CT scan for planning and were examined according to the methods developed by us, were studied [11].

Calculation of 3D models was carried out mostly virtually using standard computer software with 3D reconstruction, but 3D printing technology was used in 12 patients with the most complex cases of post-traumatic deformities of the lower extremities. Preoperative planning was carried out using models of the damaged and contralateral segment made by 3D printing on a scale of 1:1 [16, 17].

The type of primary injury was assessed according to the AO/OTA classification [22]. The time course of clinical data during treatment was evaluated using SF-36 and AOFAS [23].

The research materials were reviewed and approved by the local Bioethics Committee at the State Institution Professor M. I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine (Protocol No. 222 dated 20.12.2021).

Results and their discussion

Assessment of scientific information sources

According to the results of a clinical study conducted by M. K. Zehntner et al. [24], symptomatic complications of femur fractures during treatment occurred with varus/valgus deformity of more than 5° in 26 % of cases, procurvation or recurvation of more than 5° — 22 %, rotational deformity of more than 5° — 19 %. Rotational deformations of the diaphysis of the femur (including its distal third), which exceeded 15°, were recorded in 20–30 % of patients after treatment with an intramedullary rod [25, 26]. During minimally invasive periosseous osteosynthesis of DFFs, the frequency of rotational fusions over 10° reached 35–43 % [14, 18, 27]. Varus collapse of more than 5° was observed in 42 % of patients who were only fitted with a lateral condyle support plate [28]. Arthritic complications of the knee joint after intra-articular distal fractures of the femur were observed in 23–36 % [29–31]. However, in addition to intra-articular deformation, among the reasons for such high rates of complications are: mechanical damage during a traumatic event, death and dysfunction of chondrocytes, as well as an inflammatory cell-mediated response [29, 31]. DFFs are a relatively common injury that is accompanied by numerous potential complications. M. Zlowodzki et al. [32] analyzed 1,670 DFFs and determined the frequency of secondary surgical interventions for all reasons at the level of 16.8 %, including 6 % of nonunions, while post-traumatic femoral deformities were not separately identified.

Post-traumatic deformation of the DFFs leads not only to dysfunction of the patient's lower limb, but also to cosmetic and esthetic problems. All types of femoral deformity can cause changes in knee joint biomechanics or contact pressure and lead to the development of post-traumatic arthrosis. Patients usually notice rotational deformities of 15° or more, associated with damage to the articular cartilage, distortion of the biomechanics of the knee joint, and a general decrease in function [12, 14]. The rotational malposition of the femur also makes it difficult to climb stairs, run or play sports [12].

Evaluation of deformation of any degree using 3D modeling showed that displacement of the reference axis back under conditions of supracondylar rotation of more than 30°–45° results in an incorrect location in the frontal plane of the orientation of the knee joint [33]. In addition, knee-femoral contact pressure increases non-linearly with increasing rotational deformations above 20° [34]. In the case of deformation in the coronal plane, varus or valgus curvature of the DFF triggers an increase in contact forces in the medial or lateral parts of the knee, respectively, and can cause the progression of changes in the articular cartilage and premature osteoarthritis [17, 21, 35]. Deformation in the sagittal plane results in *genu curvatum* or *genu procurvatum*, causing pain, loss of knee flexion/extension, feeling of instability and muscle weakness [11, 17, 36]. In addition, distal femoral curvature can lead to lameness due to limitation of the swing phase of walking, while recursion deformity can cause rearward thrust and painful walking [37]. Symptomatic leg length discrepancies of more than 2 cm are associated with quadriceps weakness, gait asymmetry, a sense of imbalance, and low back pain [11, 38]. Finally, intra-articular deformities can potentially lead to direct mechanical destruction of the involved articular surface and contribute to the reported 23–36 % incidence of post-traumatic arthrosis after intra-articular distal femoral fractures [29, 30, 39].

Primary prophylactic measures to prevent the formation of femoral deformity include timely fusion of the fracture and restoration of the length and axis of the limb, elimination of rotational displacement. Rotational deformities are a common type after treatment of femoral fractures. Methods for evaluating the intraoperative and postoperative rotational profile have been developed. Many of them are based on comparison with the intact contralateral femur [16, 40]. Prevention of deformation in the coronal plane is possible with the help of correct restoration of the mechanical axis [41]. In standard cases, this is a line that passes through the middle of the tibial axis of the fully extended knee, and the valgus angle of 5°–7° corresponds to the average difference between the anatomical intramedullary axis of the femur and the mechanical axis of the lower extremity [42]. Prevention of deformation in the sagittal plane is the most difficult. Recurvature of the distal condylar segment occurs due to the deforming force of the calf muscle, which must be compensated for [43]. The risk of leg-length discrepancy due to femoral shortening or, less commonly, femoral lengthening can be reduced by one of two methods if direct fracture reduction cannot be achieved for comparison, which is often the case with multifragmentary fractures. Comparison of limb length based on palpation at the level of the patella, calcaneal pads, or medial bones can provide an approximate estimate of symmetrical limb length. This depends on the symmetrical arrangement of the femoral heads relative to the axis of the operating table and can be performed with the contralateral limb. The objective use of an intraoperative X-ray contrast ruler to measure the contralateral and ipsilateral femur at proximal and distal reference points (i. e., from the greater trochanter to the medial condyle of the femur, the distal surface of the joint) provides the most accurate representation of symmetrical femoral length.

A detailed history may be the most important tool in the evaluation and diagnosis of distal femoral deformities. It should begin with questions about initial health status, smoking status, drug use, comorbidities, housing status, the level of physical activity prior to injury, occupation, and hobbies. This will help to better assess patients' expectations of outcomes and inform the direction of further discussions regarding managing realistic expectations. During the initial consultation about the deformity, the mechanism of injury must be established and the treatment process discussed in detail. The timeline should include timing of surgery, time to full weight bearing of the lower extremity, initial identification of gross deformity or symptoms associated with malunion, and timing and duration of rehabilitation. Any prolonged wound healing, open fracture, drainage, postoperative oral antibiotic therapy, or additional surgery, procedure, or postoperative access treatment should be documented and the patient informed of the potential risk of fracture nonunion.

After taking a thorough history, the physical examination should begin with a review of the patient's general appearance, hygiene, and body condition. A full walking examination should be performed and the lower extremities should be assessed simultaneously in the supine and standing position, noting the location and appearance of cuts or wounds. Gross deformities may be obvious, but the patient may point to more subtle symptoms of the deformity. It is necessary to pay attention to the position of the feet in relation to each other, both lying down and standing. Quadriceps atrophy may be apparent, but measurement of thigh circumference at a given reference point (10 cm above the upper pole of the kneecap) will provide a more objective measure. Rotational deformities can be further examined by analyzing the internal and external rotation of the hip while sitting. Testing the acetabulum angle is a reliable method of objectively measuring bilateral femoral anteversion and any rotational abnormalities [11, 17, 44]. It is performed with the patient lying on his stomach by palpating the large acetabulum with the knee joint bent to 90°.

Leg length can be measured in the supine position on an examination table by comparing the position of the heel pads and medial malleolus during full knee extension and by comparative palpation of the patella with the knee in equal 90° flexion. Any ipsilateral knee flexion contracture or sagittal deformity should be noted, as this may increase perceived limb inequality [45].

Isolated rotational deformations are eliminated using various techniques. When planning the correction of this type of deformity, the degree of axial derotation is determined using CT or anteversion CT of both lower extremities. Fixation of a derotational osteotomy of the femur can be performed using an intramedullary rod, a distal fixation plate of the femur, or an external fixation device, depending on the patency of the canal, the level of the osteotomy, the available equipment, and the quality of the bone [46–48]. The site for the derotational osteotomy can be chosen according to surgeon preference and soft tissue suitability without definitive preference for one technique. This is done through the supracondylar zone of the bone metaphysis or metadiaphyseal junction, or through the site of a previous fracture [46–48]. Postoperative CT revealed less than 4° of residual deformity in all patients. The average time to consolidation was 10–12 months. [48].

The ultimate goal of correction of coronal plane deformation is to restore the mechanical axis of the lower limb to the normative value [39]. The degree of correction is determined by the need to restore the center of the mechanical axis to the center of the knee joint [42]. It is determined with the help of mathematical modeling, which makes it possible to more fully assess the deformation and condition of the joints, that is, to carry out adequate treatment planning. Additional opportunities for planning are provided by visualization of the damaged segment with the help of a three-dimensional model in real size, made by the method of 3D printing on a scale of 1: 1 [49, 50]. Options for correction of the coronal plane include: medial wedge-shaped osteotomy or lateral with a closing wedge (varus deformity); medial osteotomy with a closing wedge or lateral with an opening one (valgus deformity); dome-shaped osteotomy, scythe in the sagittal plane, double scythe and bone plastic according to the Ilizarov method with gradual correction [20, 51, 52]. The pros and cons of open and closed wedge osteotomy are well described and often extrapolated from native knee deformities or the literature on high tibial osteotomy

[20, 53–56]. It is important to consider that a closing wedge osteotomy provides better bone contact for stability and fusion [56], but at the cost of potential femoral shortening [52]. Supracondylar dome and oblique sagittal osteotomies of the femur have the potential to improve bone contact without significantly changing the length of the limb, although their documented use for DFF deformities is lacking [20, 52, 54, 55]. For natural varus or valgus deformations of the DFF, resulting in ipsilateral osteoarthritis of the knee joint, it is recommended to perform correction in the coronal plane [56]. Although a rare but serious complication, peroneal nerve palsy may be associated with correction of severe valgus deformity. Therefore, it is necessary to consider simultaneous prophylactic decompression of the peroneal nerve in patients with severe chronic valgus deformities [57, 58].

Many of the above principles for correction in the coronal plane are used in the case of deformations in the sagittal plane *(procurvatum/recurvatum)*. Before surgical intervention, the degree of deformation should be determined and the necessary correction should be quantified, and its assessment should be carried out during the operation.

Own experience using 3D visualization and 3D printing

The well-known Latin proverb Qui bene diagnostic bene curat means «He who diagnoses well, cures well». This is completely relevant for post-traumatic deformations of long bones. Emphasizing the need for a systematic approach to the treatment of patients with this abnormality, it is important to remember the need for a detailed analysis of the deformed segment, which can be facilitated by the use of various modern technologies, for example, 3D initialization. In particular, the results of the application of the developed modern treatment tactics for post-traumatic extra-articular deformation of the femur were evaluated. For 3D printing of her damaged segment, its image was virtually superimposed on the impression of the contralateral one, rotated by 180°, followed by evaluation of the combined image. It has been established that such a technique provides additional information that facilitates surgical intervention planning [16]. Even conducting an adequate X-ray examination and CT scan with calculation of deformation angles in different planes may sometimes not provide all the necessary information (Fig. 1).

The calculation of deformation angles in different planes can be partially obtained by comparing the damaged and contralateral segments, using the technique of superimposing their virtual 3D models on each other (Fig. 2).

Even more information can be obtained using 3D printing (printing on a scale of 1:1) of the damaged (Fig. 3) and contralateral (Fig. 4, a) segments with rotation of the latter by 180° relative to the longitudinal axis (Fig. 4, b).

The presence of a model of the damaged segment printed on a 3D printer also makes it possible to simulate a surgical intervention and evaluate its probable result (Fig. 5).

All patients, in whose treatment at the stage of preoperative planning a CT examination with the proposed 3D modeling technique was performed, were subsequently operated on taking into account the individual characteristics of the deformity. After each stage of surgical treatment, a course of individual rehabilitation treatment was carried out, taking into account the muscle imbalance of the limbs and lower back, which made it possible to obtain positive dynamics of the functional results of the operated patients within 12 months according to the survey data on the SF-36 and AOFAS scales.

A clinical example

A 22-year-old patient S. was admitted on 04.01.2019 with a fragment fracture of the lower third of the left femur, which fused with residual deformation (*varus* 15°, *antecurvatio* 23°, internal rotation 14°), the condition after repeated surgical interventions for wounds of the left thigh, mixed, flexion-extension contracture of the left knee joint, equino-adducto-polo-varus deformity of the left foot, neuropathy of the fibular nerve, shortening of the left lower limb by 3.5 cm, impaired support and walking function. The injury was caused by being crushed by a cargo container in the port of Odesa (Fig. 1).

The patient's profession is not associated with excessive physical exertion. The SF-36 scale was used

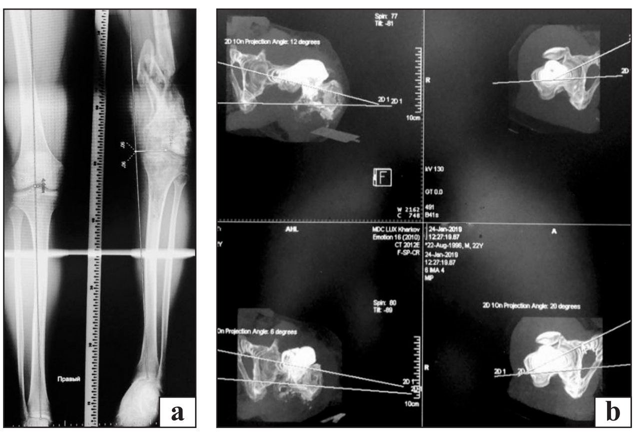

Fig. 1. X-rays and CT scans of patient S. after calculating the angles of deformation in direct (a) and axial (b) projections

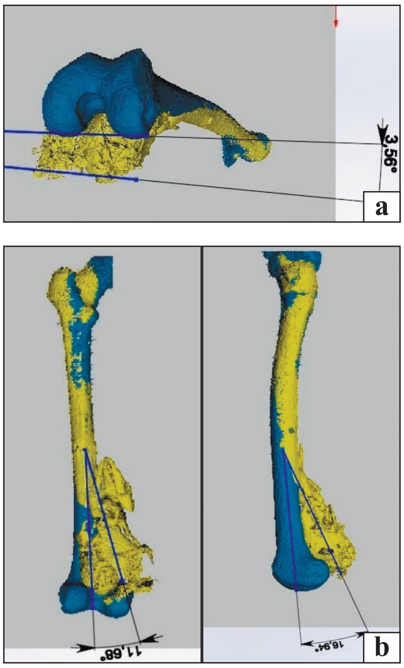

Fig. 2. CT scans of patient S. after overlaying virtual 3D models of the damaged segment on the contralateral one and calculating the corresponding deformation angles in the axial (a), direct (b) and lateral (c) projections

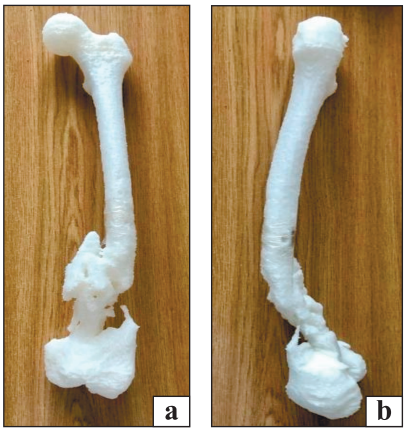

Fig. 3. General view of the printed model of the damaged segment of patient S. from the front (a) and side (b)

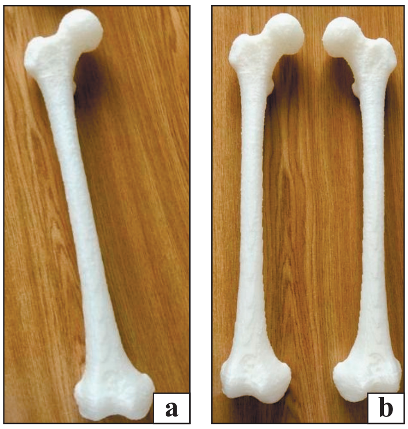

Fig. 4. General view of the printed model of the contralateral segment of patient S. before 180° rotation (a) and after it (b)

to assess the patient's vital signs before the operation; the results are shown in Table 1.

As a result of the observation, we obtained estimates of the patient's life indicators, presented in Table 2.

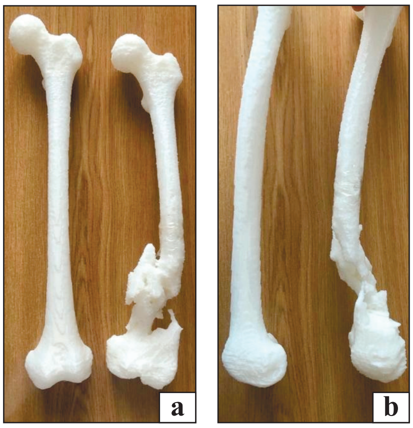

Fig. 5. Comparison of both segments of patient S. General view of the 3D-printed model of the damaged segment and the model of the contralateral segment: front view (a) and side view (b)

Fig. 6. Radiographs of patient S. at the stage of treatment (bone plastic surgery)

Fig. 7. Radiographs of patient S. at the stage of treatment (revision, debridement, spacer)

The patient underwent comprehensive treatment aimed at healing skin defects — bandages, remounting of the EFD, repair of the defect with a free skin flap. Further treatment was carried out using the developed 3D modeling technique. After careful preoperative planning, surgical intervention was performed — revision of the deformity zone, osteotomy, alignment of the femoral axis, fixation with DFP (Synthes), bone auto-/alloplasty (Fig. 6).

The varus component of the deformation (in the coronal plane), antecurvation (procurvation in the sagittal plane) and rotational displacement have also been eliminated.

An early purulent complication in the period up to 4 weeks determined the performance of surgical intervention: revision, debridement, installation of a spacer with antibiotics (Copal G + Vx2) (Fig. 7).

Five months after the revision intervention, clinical and laboratory signs of infection were not detected. However, neuropathy manifested itself clinically as severe motor-sensory distal neuropathy of *n. peroneal* and *n. suralis* and moderate distal neuropathy of *n. tibialis*. A formed equinus setting of the foot was detected. This required further treatment (Fig. 8).

At the time of the follow-up examination (5 months after the operation), the patient was walking with the support of a stick. He felt insecure when walking long distances (more than 500 m). He received functional rehabilitation of the knee joint. Results 5 months after the operation are presented in Table 3.

Assessment of the patient's vital signs 5 months after the operation is given in Table 4.

After the study, the next stage of surgical treatment was performed — bone cement was removed from the distal part of the left femur, decortication was performed, bone autoplasty with a graft from the right fibula of the contralateral limb (Fig. 9), and after 2 months an achylotomy (with a lengthening of 10 cm) and a triple arthrodesis of the left foot were performed (Fig. 10).

During the routine examination, the formation of the bone regenerate of the femur, the function of the two-legged stance and the knee joint were monitored (Fig. 10).

After the formation of the bone block and three-joint arthrodesis, the patient was able to stand and walk on two supports (Fig. 11).

At the time of the control examination in 9 months, X-ray determined a hypertrophic bone

Table 1

Results reported by the patient before surgical treatment (according to SF-36)

Question No.		Score	Estimated SF-36 score
1’		3	3.4
2		3	2
3	A	1	1
	B	1	1
	C	1	1
	D	2	2
	E	2	2
	F	1	1
	G	2	2
	H	2	2
	I	2	2
	J	3	3
4	A	2	2
	B	2	2
	C	1	1
	D	2	2
5	A	1	1
	B	1	1
	C	2	2
6’		2	4
7’		3	4.2
8’		3	4
9	A’	2	5
	B	3	3
	C	4	4
	D’	3	4
	E’	3	3
	F	3	3
	G	5	5
	H’	4	3
	I	5	5
10		3	3
11	A	5	5
	B’	1	5
	C	5	5
	D	2	5

Table 2

Patient vital signs results (according to SF-36)

Indicator	Estimated score	Normalized score
Physical functioning (PF)	(((1 + 1 + 1 + 2 + 2 + 1 + 2 + 2 + 2 + 3) – 10)/20) • • 100 = 35	35
Role physical functioning (RP)	((2 + 2 + 1 + 2 – 4)/4)) • • 100 = 75	75
Bodily pain (BP)	((4,2 + 4 – 2)/10)) • 100 = = 62	62
General health (GH)	((3,4 + 5 + 5 + 5 + 5 – 5)/ 20) • 100 = 92	92
Vitality (VT)	((5 + 3 + 5 + 5 – 4)/20) • • 100 = 70	70
Social functioning (SF)	((4 + 3 – 2)/8) • 100 = = 62.5	62.5
Role emotional functioning (RE)	((1 + 1 + 2 – 3)/3) • 100 = = 33.3	33.3
Mental health (MH)	((3 + 4 + 4 + 3 + 3 – – 5)/25) • 100 = 68	48

callus; the patient largely restored the range of motion in the knee joint, walked independently without additional support (Fig. 12). The results of the patient survey 9 months after the operation is presented in Table 5, indicators of life in Table 6.

Thus, we can trace the time course of the patient's condition before surgical treatment and 5 and 9 months after it (Table 7).

Table 3

Results reported by the patient 5 months after surgical treatment (according to SF-36)

Question No.		The score indicated by the patient	Estimated SF-36 score
1'		2	4.4
2		1	2
3	A	1	1
	B	2	2
	C	2	2
	D	2	2
	E	2	2
	F	2	2
	G	2	2
	H	3	3
	I	3	3
	J	3	3
4	A	1	1
	B	2	2
	C	1	1
	D	2	2
5	A	2	2
	B	1	1
	C	2	2
6'		2	4
7'		1	6
8'		2	4
9	A'	2	5
	B	4	4
	C	5	5
	D'	2	5
	E'	3	3
	F	5	5
	G	5	5
	H'	2	5
	I	5	5
10		3	3
11	A	5	5
	B'	1	5
	C	5	5
	D'	2	4

Eight indicators of the patient's quality of life reflect different areas of his life. Based on them, it is possible to draw conclusions about his condition at various stages of the treatment process.

In particular, an obvious positive time course of physical functioning was determined, which became twice as good as before surgical treatment. At the intermediate stage, a decline in role-based physical functioning is indicated, i.e. the patient began to limit daily workload: work, everyday duties (due to the orthopedic regimen prescribed by the doctor at the postoperative stage); positive time course of pain

Fig. 8. Appearance of the left lower limb of patient S.: radiographs of the left lower limb in two standard orthogonal projections (a), appearance after repeated surgical interventions (b)

Table 4

Results of the patient's health status 5 months after surgery (according to SF-36)

Indicator	Estimated	Normalized score
Physical functioning (PF)	((1 + 2 + 2 + 2 + 2 + 2 + + 2 + 3 + 3 +3 – 10)/20) • • 100 = 60	60
Role physical functioning (RP)	((1 + 2 + 1 + 2 – 4)/4) • • 100 = 50	50
Bodily pain (BP)	((6 + 4 – 2)/10) • 100 = 62	80
General health (GH)	((4,4 + 5 + 5 + 5 + 4 – 5)/ 20) • 100 = 92	92
Vitality (VT)	((5 + 3 + 5 + 5 – 4)/20) • • 100 = 70	70
Social functioning (SF)	((4 + 3 – 2)/8) • 100 = 62.5	62.5
Role emotional functioning (RE)	((2 + 1 + 2 – 3)/3) • 100 = = 66.7	66.7
Mental health (MH)	((4 + 5 + 5 + 5 + 5 – 5)/25) • • 100 = 76	76

Fig. 9. Radiographs of patient S.: removal of bone cement from the distal part of the left femur, decortication, bone autoplasty with a graft from the right fibula of the contralateral limb

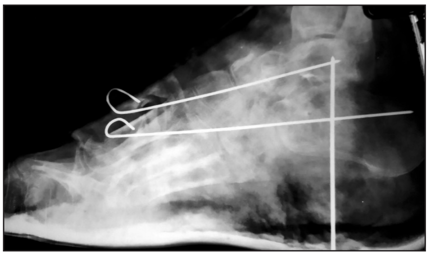

Fig. 10. Radiographs of patient S. at the stage of treatment (achillotomy (with 10 cm extension) and triple arthrodesis of the left foot)

sensitivity were recorded, which favorably affected the outcome of treatment.

Thus, timely and comprehensive planning of surgery in patients with DFF injuries allows to prevent the formation of post-traumatic deformity, and in case of its presence, to implement better treatment and rehabilitation of the patient, which can improve life indicators.

Fig. 11. Results of the clinical and CT examination of patient S. at the follow-up examination: a) CT scan of the left hip, formation of bone regenerate of the femur; b) restored two-legged standing and function of the knee joint

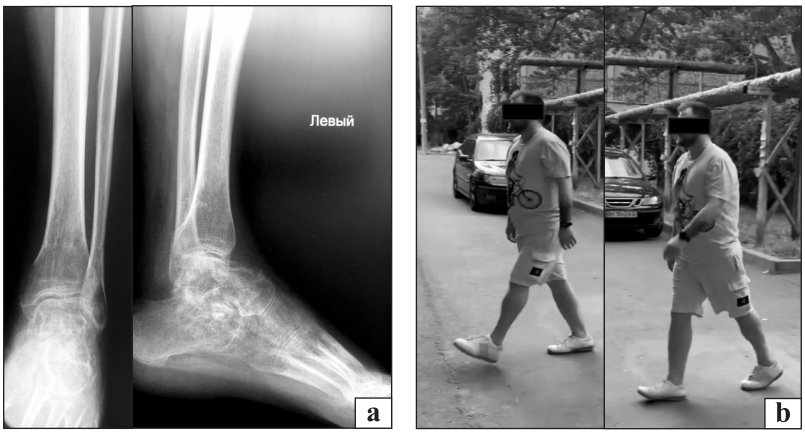

Fig. 12. The results of the clinical and X-ray examination of patient S. at the follow-up examination: a) X-ray of the left foot, formation of a bone block and three-joint arthrodesis; b) restoration of two-legged standing and walking

Table 5

Results reported by the patient 9 months after surgical treatment (according to SF-36)

Question No.		Score	Estimated SF-36 score
1’		1	5
2		1	1
3	A	2	2
	B	3	3
	C	3	3
	D	2	2
	E	3	3
	F	2	2
	G	3	3
	H	3	3
	I	3	3
	G	3	3
4	A	2	2
	B	2	2
	C	2	2
	D	2	2
5	A	2	2
	B	2	2
	C	2	2
6’		1	5
7’		1	6
8’		1	6
9	A’	1	6
	B	5	5
	C	6	6
	D’	2	5
	E’	2	5
	F	6	6
	G	6	6
	H’	2	5
	I	6	6
10		5	5
11	A	5	5
	B’	1	5
	C	5	5
	D’	1	5

Table 6

Results of the patient's health status 9 months after surgery (according to SF-36)

Indicator	Estimated	Normalized score
Physical functioning (PF)	(((2 + 3 + 3 + 2 + 3 + 2 + 3 + 3 + 3 + 3) – 10)/20) • • 100 = 85	85
Role physical functioning (RP)	((2 + 2 + 2 + 2 – 4)/4)) • • 100 = 100	100
Bodily pain (BP)	((6 + 6 – 2)/10)) • 100 = 100	100
General health (GH)	((5 + 5 + 5 + 5 + 5 – 5)/20)• • 100 = 100	100
Vitality (VT)	((6 + 5 + 6 + 6 – 4)/20) • • 100 = 95	95
Social functioning (SF)	((5 + 5 – 2)/8) • 100 = 100	100
Role emotional functioning (RE)	((2 + 2 + 2 – 3)/3) • 100 = 100	100
Mental health (MH)	((5 + 6 + 5 + 6 + 5 – 5)/25) • • 100 = 56	88

Table 7

Comparative results of patient’s health status after treatment (according to SF-36)

Indicator	Before surgical treatment	After 5 months	After 9 months
Physical functioning (PF)	35,0	60,0	85,0
Role physical functioning (RP)	75,0	50,0	100,0
Біль (BP)	62,0	80,0	100,0
General health (GH)	92,0	92,0	100,0
Vitality (VT)	70,0	70,0	95,0
Social functioning (SF)	62,5	62,5	100,0
Role emotional functioning (RE)	33,3	66,7	100,0
Mental health (MH)	48,0	76,0	88,0

Conclusions

3D printing is the most informative method of visualization that allows medical practitioners to assess the deformation of the femur and the condition of adjacent joints, to carry out adequate planning of surgical intervention. This technique is used to simulate a surgical intervention and estimate the likely results. The use of 3D modeling during the planning of corrective surgery allows the surgeon to increase the accuracy of the correction and significantly reduce the time of the operation.

Well-known and improved by the authors methods of individually selected rehabilitation, used today in the treatment of post-traumatic extra-articular deformation of the femur contribute to faster recovery, avoidance of potential complications and the achievement of positive results of functional treatment of such patients.

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MODERN TREATMENT OF POST-TRAUMATIC EXTRA-ARTICULAR DEFORMITY OF THE FEMUR

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