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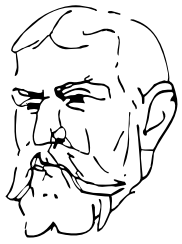

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ORIGINAL ARTICLES

ORIGINAL ARTICLE

THE RELATIONSHIP OF CLINICAL AND MORPHOLOGICAL DATA IN COMMINUTED FRACTURES OF THE LOWER JAW

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ABSTRACT

The aim is to establish the relationship between some clinical, physiological and morphological parameters in patients with the consequences of an acute injury considering the features of pathological and reparative changes in the bone fragments of the lower jaw formed during a fracture using clinical and morphological methods.

Materials and methods: The material of the study was bone fragments of the lower jaw, removed during osteosynthesis operations in 20 patients with traumatic comminuted fractures. Also, the material of the study was the data obtained during the examination of the above patients. Morphological parameters characterizing the state of the fragments tissues removed during surgical treatment of fractures of the lower jaw and clinical parameters characterizing the patient's condition in cases of traumatic fractures of the lower jaw treatment were identified for frequency and correlation analysis. Different of frequency of individual indicators' gradations cases was determined by the χ-square test, correlations between parameters (correlations of pairs of parameters "clinic – morphology", "clinical and laboratory data – morphology") – by calculating the Pearson association coefficient.

Results: The main pathological and reparative changes are determined in the bone fragments of the lower jaw after a traumatic fracture: osteomedullary ischemic necrosis (traumatic bone infarction), nonspecific productive inflammation, endosteal and periosteal bone regenerates. The severity and frequency of pathological and reparative changes in the bone fragments of the lower jaw vary, leading to various correlations between clinical and morphological indicators of the fragment tissues conditions. Reliable correlations were established between individual clinical and morphological indicators of the state of bone fragments corresponding to the values of the association coefficient in the range of 0.3-0.7, in particular: in the pair "age of the patient" – "endosteal regenerates" – the dependence is negative, of medium strength, significant ($p<0.05$); in the pair "age of the patient" – "periosteal regenerates" – the dependence is negative, of medium strength, significant ($p<0.05$); in the pair "fragment surface area" – "osteonecrosis" – the relationship is negative, weak, significant with the probability of error in assessing the value $|r_a|$ $p<0.1$; in the pair "locus of a fracture in the lower jaw" – "type of inflammation in the bone marrow" – the dependence is positive, of medium strength, highly reliable ($p<0.01$).

Conclusions: A comprehensive clinical and morphological examination made it possible to calculate quantitative data that characterize the frequency parameters of the occurrence of certain pathological changes in the bone fragments of the lower jaw after a fracture and the features of individual clinical and morphological parameters conjugation in patients with the consequences of a mechanical jaw injury. The obtained data on the correlation dependences of the type "clinic – morphology" can be used to predict the severity of morphological parameters according to the known values of clinical parameters in patients with the consequences of mandibular fractures.

KEY WORDS: mandibular fracture, bone splinters, clinical indicators, morphological indicators, frequency analysis, correlation analysis

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INTRODUCTION

A characteristic feature of mandibular fractures is a high likelihood of complications [1, 2], primarily of an inflammatory nature. According to the literature, their incidence reaches 37.2% [3]. In 16.8% of cases, patients develop chronic traumatic osteomyelitis with sequestration of bone fragments and the formation of false joints, extensive post-traumatic defects and jaw deformities [4]. Comminuted fractures, often accompanied by ruptures of the mucous membrane, damage of the teeth, alveolar process, are most susceptible to complications in the form of inflammatory processes [5]. According to numerous studies, such injuries are accompanied by the highest frequency of postoperative complications and represent the greatest difficulty for surgical treatment [6].

It is logical to assume that bone tissue, bone marrow, mandibular periosteum, paraosseous soft tissues undergo characteristic changes after a fracture, including traumatic-ischemic, dystrophic, inflammatory and reparative ones. The authors studied dynamics of such changes in fragments of long bones during osteotomies in the experiment [7, 8]. However, there is no mention of the research on the relationship between clinical indicators characterizing the condition of patients with mandibular fractures and morphological indicators reflecting the state of fragment tissues in the literature.

THE AIM

The aim is to establish the relationship between some clinical, physiological and morphological parameters in

Table I. Clinical parametric and nonparametric parameters characterizing the patient's condition in cases of traumatic fractures of the lower jaw treatment

Parametric parameters			
Clinical parameters	**Number of recorded cases**	**Median**	**Mean value and standard error**
Age of the patient at the time of injury, years	20	39.00	40.05±3,03
Duration of injury, days	20	12.00	11.40±1.55
Injury index, points	20	11.50	11.45±0.65
Fragment surface area, mm×mm	19	15.00	21.76±3.77
Rheographic index	20	0.65	0.695±0.046

Nonparametric parameters			
Clinical parameters	**Description of parameter gradations**	**Number of recorded cases**	**Frequency of occurrence in the material**
Nature of injury	Low degree: low energy	4	20.0 %
	High degree: high energy	16	80.0 %
Locus of fracture in the lower jaw	Low degree: fracture of the articular process or in the area of the jaw angle	11	55.0 %
	High grade: fracture in the jaw body	9	45.0 %
Treatment result	Low grade: complete union or delayed consolidation	13	65.0 %
	High grade: pseudarthrosis or bone defect	7	35.0 %

patients with the consequences of an acute injury considering the features of pathological and reparative changes in the bone fragments of the lower jaw formed during a fracture using clinical and morphological methods.

MATERIALS AND METHODS

The material of the study was bone fragments of the lower jaw, removed during osteosynthesis operations in 20 patients with traumatic comminuted fractures. Fragments were repositioned during the operation, small fragments were removed (used for histological examination) and other fragments were fixed with mini-plates on the surface of the damaged bone.

All examined patients were traumatized by high-energy trauma (gunshot wounds, traffic accidents, industrial injuries). Comminuted fractures in the area of the angle and condylar process of the jaw were open in 11 (55%) cases and closed in 9 (45%) cases.

Before the operation, the patients underwent clinical, laboratory and X-ray studies, as well as tissue rheography of the damaged area. According to the rheography data, a decrease of the rheographic index was determined by more than 50% (rheographic index = 0.28-0.31 ohm) [9].

During patient examination, we took into account 10 main clinical and biological indicators of the state of tissues in the area of damage: the general status of the patient, the duration of the injury, the number of fragments of the lower jaw in the area of the fracture, the number of sources of extraosseous circulation of the larger fragment, the size of the large fragment, the degree of rupture of the oral mucosa and exposure bones, displacement of fragments, etiology of injury, volume of diastasis between the contact surfaces of fragments, impaired blood circulation of the bone according to rheography. We evaluated these main indicators according to the degree of their clinical severity in points (0-1-2) and then summarized the scores. The resulting scores were called the "injury index" [10]. The maximum surface area of the fragments was calculated by multiplying the two parameters of the length of the fragments obtained by measurements on the radiograph.

The removed fragments were usually used without grinding for histological examination. The tissues were fixed with 10% formalin, the pieces were decalcified with 5% nitric acid, and embedded in celloidin. The resulting sections with a thickness of 10 μm were stained with hematoxylin and eosin, hematoxylin-picrofuchsin according to van Gieson. The slides were examined using an Olympus BX-41 microscope (Japan).

To carry out frequency and correlation analysis, the authors identified a number of morphological parameters characterizing the state of the fragments tissues removed

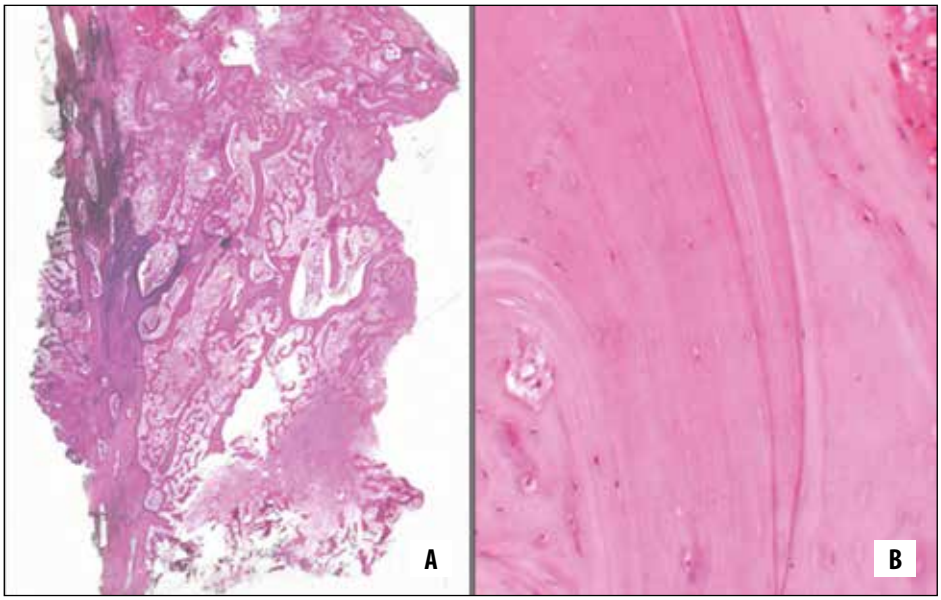

Fig. 1A. General view of a fragment of the articular process of the lower jaw: periosteal regenerate on the surface of the cortex; hemorrhages, fibrosis and endosteal regenerates in spongiosis. Stained with hematoxylin and eosin, × 20.
Fig. 1B. Large interstitial osteonecrosis in the cortex. Stained with hematoxylin and eosin, × 150.

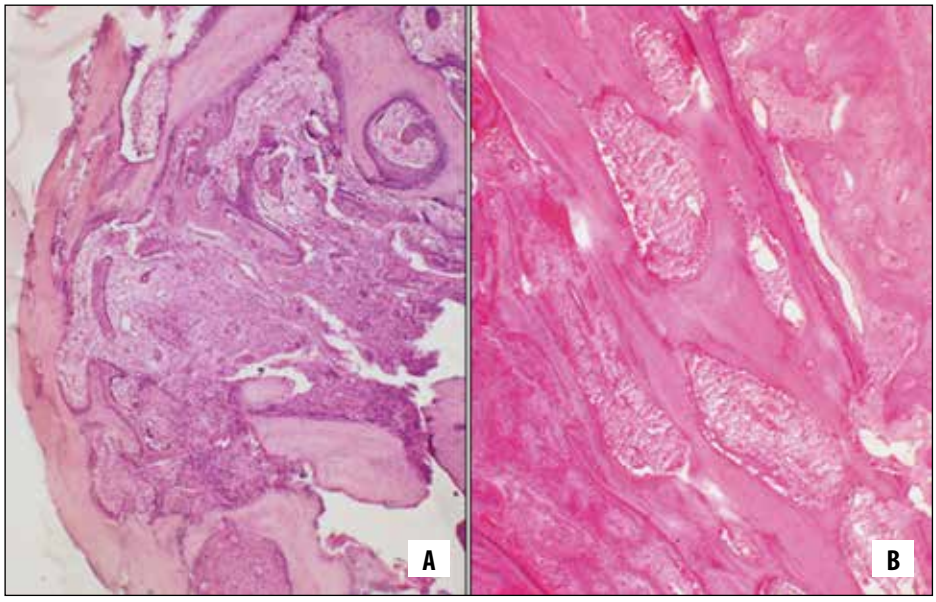

Fig. 2A. Large focal osteomedullary necrosis and endosteal regenerates. Stained with hematoxylin and eosin, × 30.
Fig. 2B. Cortex osteonecrosis restructuring: extensive resorption cavities, endosteal regenerate, periosteal regenerate. Stained with hematoxylin and eosin, × 30.

during surgical treatment of fractures of the lower jaw and clinical parameters characterizing the patient's condition in cases of traumatic fractures of the lower jaw treatment. Different of frequency of individual indicators' gradations cases was determined by the χ-square test, correlations between parameters (correlations of pairs of parameters "clinic – morphology", "clinical and laboratory data – morphology") – by calculating the Pearson association coefficient.

RESULTS

Analyzing the clinical data of the group of patients shown in table I, the authors found out that most of the reported cases corresponded to high-energy trauma, were localized in the posterior parts of the jaw. They led to complete fusion or delayed consolidation of fragments after installation of fixators.

Histological examination of the removed fragments of the lower jaw revealed a number of characteristic pathological changes in the bone marrow and bone tissue, the extent and severity of which varied from case to case and reflected a topographically complex combination of dyscirculatory, reactive-inflammatory and reparative changes in the tissues of the jaw after an acute injury (Fig. 1A). So, we found osteonecrosis of various sizes in all studied fragments, localized in the cortex and spongiosa crossbeams, regardless of the fracture location. However, in some cases, there were signs of ongoing pathological restructuring, in the cortex tissue subjected to ischemic damage with the formation of extensive resorption lacunae. Distribution of osteonecrosis area was uneven: sometimes there were necroses in the form of small groups of empty osteocytic lacunae – up to 20 objects. Such changes were characterized as small interstitial osteonecrosis. Groups of empty osteocytic cells with several tens of lacunae localized in the cortex and spongiosis were designated as large interstitial osteonecrosis (Fig. 1B). Finally, areas of bone marrow and bone tissue with dimensions of 2 mm or more were

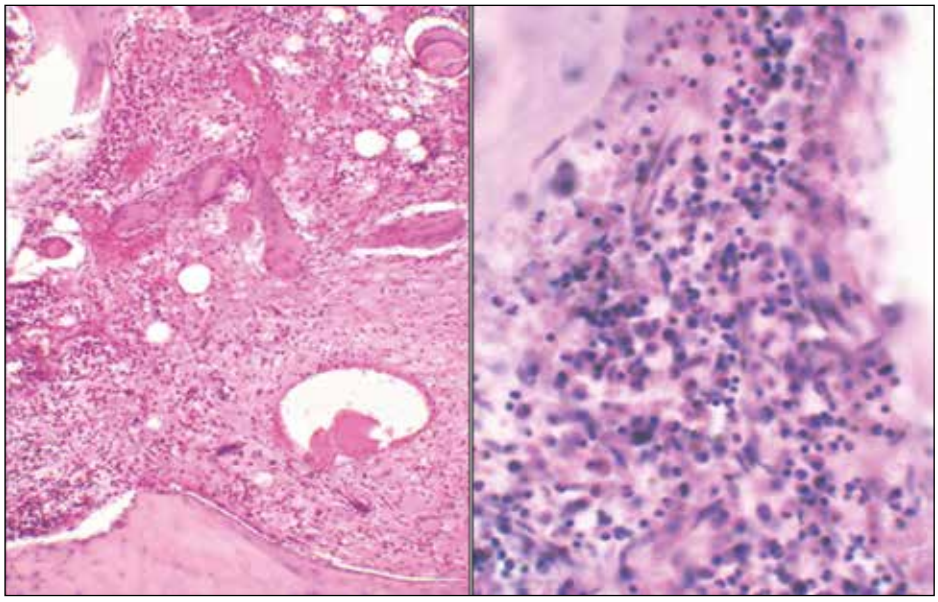

Fig. 3A. Loose leukocyte infiltration in the bone marrow. Stained with hematoxylin and eosin, × 30.
Fig. 3B. Intensive leukocyte infiltration with a predominance of mononuclears in the bone marrow. Stained with hematoxylin and eosin, × 300.

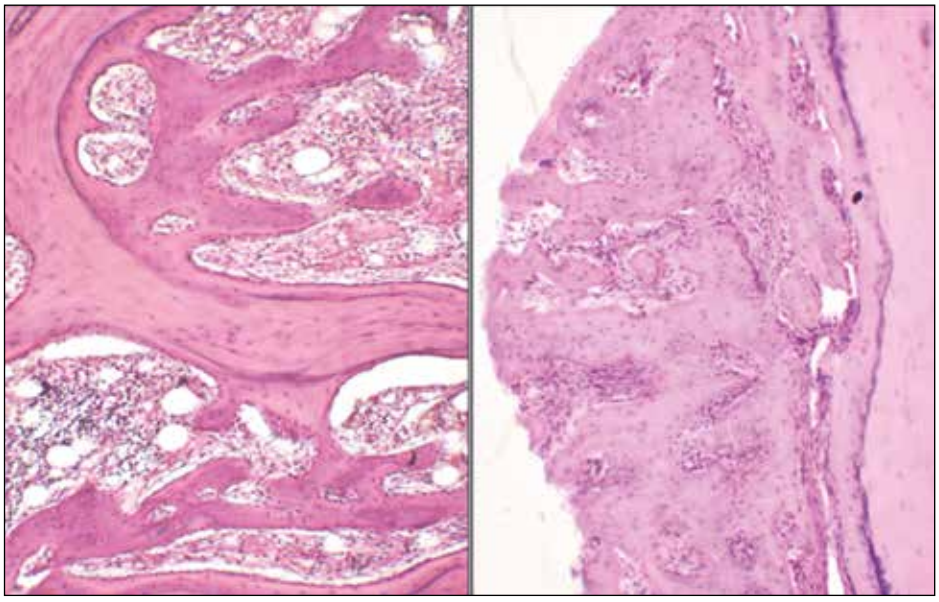

Fig. 4A. Endosteal regenerates, spongiosis bars in a state of osteonecrosis. Stained with hematoxylin and eosin, × 75.
Fig. 4B. Periosteal regenerate with signs of moderate compaction on the surface of the cortex containing osteonecrosis. Stained with hematoxylin and eosin, × 75.

regarded as focal osteonecrosis. Necrotized bone marrow in them was often replaced by immature fibrous tissue, while the areas with empty osteocytic lacunae persisted (Fig. 2A). Enlarged resorption cavities with an increased number of multinuclear osteoclasts on the walls were often determined in the cortex where osteonecrosis occurred. (Fig. 2B).

Among the immature fibrous tissue occupying the bone marrow spaces of the studied bone fragments of the lower jaw, there were accumulations of leukocytes, macrophages and plasma cells, and these inflammatory infiltrates had a different density and, more often, a small-focal distribution. Low-density, small-focal infiltrates corresponded to productive-infiltrative inflammation of low activity (Fig. 3A), denser, confluent accumulations of infiltrate cells corresponded to productive inflammation of high activity (Fig. 3B).

An important manifestation of bone tissue repair processes are endosteal and periosteal bone regenerates, which were most pronounced in fragment tissue areas adjacent to the fracture surface. Endosteal regenerates were usually more voluminous and resembled small-beam reticulated stratifications on the endosteal surface of a partially necrotic cortex and necrotic bone bars (Fig. 4A). Periosteal bone regenerates were usually inferior in size to endosteal ones, often had an insignificant thickness and were more or less compacted. Sometimes, the surfaces of their crossbars were covered with a palisade of active osteoblasts, and sometimes – with flattened, less active cells (Fig. 4B).

The data in table II indicate that osteonecrosis was somewhat more common in the form of small and large interstitial objects than macrofocal osteonecrosis. Cases with productive high-grade inflammation in the bone marrow of splinters were less common than cases with no or low-grade inflammation. Cases with endosteal and periosteal bone regenerates of a high degree of severity were found in the biopsy material of the fragments more often than cases with a low degree of these signs.

Table II. Morphological parameters characterizing the state of the fragments tissues removed during surgical treatment of fractures of the lower jaw

Morphological parameters	Description of parameters gradations	Number of recorded cases	Frequency of occurrence in the material
Osteonecrosis	Low grade: interstitial small and large osteonecrosis	11	55.0 %
	High grade: large focal osteonecrosis	9	45.0 %
Inflammation in the bone marrow	Low grade: no inflammation or inflammation of low activity	9	60.0 %
	High grade: high activity inflammation	6	40.0 %
Endosteal regenerates	Low degree: absent or minimal	7	43.7 %
	High degree: well expressed	9	56.3 %
Periosteal regenerates	Low degree: absent or minimal	5	35.7 %
	High degree: well expressed	9	64.3 %

Table III. Correlations between the clinical parameters of patients and the morphological parameters of affected tissues of the fragments removed during the surgical treatment of mandibular fractures (gradations of parameters – see tables I, II)

Clinical parameters	Morphological parameters	n, number of recorded cases with values of both parameters	Pearson's tetrachoric coefficient of association (association coefficient) r_a	Estimation of the significance r in k=n-1 by Student's criterion, the error significance
Patient's age *	Osteonecrosis n	20	+0.219	>0.05
	Type of inflammation in the bone marrow n	15	+0.218	>0.05
	Endosteal regenerates n	16	-0.524	<0.05
	Periosteal regenerates n	14	-0.559	<0.05
Age of injury **	Osteonecrosis	20	-0.287	>0.05
Injury index ***	Periosteal regenerates	14	+0.244	>0.05
Fragment surface area ****	Osteonecrosis	19	-0.382	<0.1
	Periosteal regenerates	13	-0.386	>0.05
Rheographic index *****	Osteonecrosis	20	+0.285	>0.05
Nature of injury °	Osteonecrosis	20	-0.302	>0.05
Locus of fracture in the lower jaw	Type of inflammation in the bone marrow	15	+0.667	<0.01
	Periosteal regenerates	13	-0.300	>0.05
Treatment result °	Periosteal regenerates	14	+0.344	>0.05

Notes: * – gradations: "low" – less than 40 years old, "high" – equal to or more than 40 years old; ** – gradations: "low" – less than 10 days, "high" – more than 10 days; *** – gradations: "low" – less than or equal to 11 points, "high" – more than 11 points; **** – gradations: "low" – less than 15 mm2, "high" – more than 15 mm^2; ***** – gradations: "low" – less than or equal to 0.65, "high" – more than 0.65; ° – gradations of clinical nonparametric parameters see table 1; n – gradations of morphological nonparametric parameters see table II.

The results of the correlation analysis of relationships (table III) indicate that most of the correlation pairs "clinic – morphology" have absolute values in the range of weak $0.3<|r_a|<0.5$, or very weak $|r_a|<=0.5$, or the values of the association coefficient were not reliable. A couple of indicators with the highest values of the association coefficient deserve discussion:

- in the pair "age of the patient" – "endosteal regenerates" – the dependence is negative, of medium strength, significant ($p<0.05$);
- in the pair "age of the patient" – "periosteal regenerates" – the dependence is negative, of medium strength, significant ($p<0.05$). In both cases, this means that older patients are more likely to have low grade regenerates;
- in the pair "fragment surface area" – "osteonecrosis" – the relationship is negative, weak, significant with the probability of error in assessing the value $|r_a|$ $p<0.1$. This means that large-focal osteonecrosis is more common in smaller fragments compared to larger fragments;

- in the pair "locus of a fracture in the lower jaw – "type of inflammation in the bone marrow" – the dependence is positive, of medium strength, highly significant ($p<0.01$). This means that we observe productive inflammation of high activity or exudative inflammation more often when a fracture is localized in the area of the body lower jaw in the bone marrow.

DISCUSSION

The histological study showed that the severity of pathological changes in the bone fragments of the lower jaw is different, can be presented and taken into account in the form of separate gradations, and the frequency of cases of each gradation in the array of the studied clinical and morphological material varies [11]. The most permanent histological changes in the bone fragments of the lower jaw are traumatic-ischemic osteonecrosis, nonspecific productive inflammation in the fibrous bone marrow, endosteal and periosteal bone regenerates. Morphological gradation indicators, reflecting the severity of these pathological and reparative changes in the tissues of the fragments, can correlate differently and significantly only with some clinical indicators, determining their different diagnostic value.

A traumatic bone fracture always leads to impaired blood supply at the ends of the fragments. This is due to mechanical damage to the vascular networks of the cortex and bone marrow. In the case of a high-energy fracture, if there is a significant displacement of the fragments and the intraorgan branches of the main feeding artery can be torn, quite extensive zones of ischemic necrosis appear at the ends of the long bone fragments, which we designated as traumatic bone infarcts [12-16]. The presence of extensive osteonecrosis reflects the decompensated nature of impaired blood supply to bone tissue and bone marrow fragments. Pathological changes in the tissues of the lower jaw after its traumatic fracture have not been studied before, although their results are important for understanding the viability of bone tissue. Variations in the size of osteomedullary necrosis are probably associated with the degree of damage to the sources of blood supply to the bone tissue: the main supply artery, metaphyseal and periosteal vessels. Restoration of the blood supply to the fragment occurs both through the preserved blood vessels due to recirculation from the preserved sources, and through the vessels growing into the focus of osteomedullary necrosis, i.e. in the process of revascularization necrosis. The development of both endosteal and periosteal bone regenerates is impossible without at least partial restoration of the blood supply to the fragments.

The revealed correlation dependences in pairs of indicators "clinic – morphology" suggest a certain author's comment. The negative dependence of the average strength between the age of the patient and the severity (in fact, the volume) of endosteal and periosteal bone regenerates: the higher the age, the smaller the volume of bone regenerates, indicates the quantitative age-related features of the reparative reaction in certain age periods, and seems natural. It is likely that the decrease in the size of bone regenerates in mandibular fragments is associated with age-related reduction of the microvasculature of the mandible tissues, although angiomorphological study was not the subject of this work. The negative relationship between the size of the fragments and the size of osteonecrosis (in the series: small, large interstitial, large-focal) indicates a greater damage, in terms of ischemic impact on them, of small bone fragments compared to larger fragments. The positive dependence of the average strength between the fracture locus (from low to high in the series: articular process – jaw angle – jaw body) and the type (in fact – morphological signs) of inflammation in the bone marrow of the bone fragment can be explained by more intense blood supply to the bone tissue of the jaw body.

From the results of the correlation analysis carried out in this paper, such facts as, for example, a very weak relationship between the "prescription of injury", on the one hand, and "endosteal regenerates" and "periosteal regenerates", on the other hand, seem to be informative and previously unobvious. This can be explained by unequal formation rate of regenerates of various sizes at different time after injury in individual patients. Very weak dependencies with unreliable values of the association coefficient exist between the "injury duration", "injury index", "rheographic index", "injury character" (+/- high-energy injury) – on the one hand, and a number of morphological indicators of the state of bone fragments – on the other hand.

In our clinical and morphological study, we calculated quantitative data that characterize the frequency parameters of the occurrence of certain pathological changes in the bone fragments of the lower jaw after a fracture and the features of individual clinical and morphological parameters conjugation in patients with the consequences of a mechanical jaw injury. The obtained data on the correlation dependences of the type "clinic – morphology" can be used to predict the severity of morphological parameters according to the known values of clinical parameters in patients with the consequences of mandibular fractures.

CONCLUSIONS

1. The main pathological and reparative changes are determined in the bone fragments of the lower jaw after a traumatic fracture: osteomedullary ischemic necrosis (traumatic bone infarction), nonspecific productive inflammation, endosteal and periosteal bone regenerates.
2. The severity and frequency of pathological and reparative changes in the bone fragments of the lower jaw vary, leading to various correlations between clinical and morphological indicators of the fragment tissues conditions.
3. Reliable correlations were established between individual clinical and morphological indicators of the state of bone fragments corresponding to the values of the association coefficient in the range of 0.3-0.7, in particular: in the pair "age of the patient" – "endosteal regenerates" – the dependence is negative, of medium strength, significant

($p<0.05$); in the pair "age of the patient" – "periosteal regenerates" – the dependence is negative, of medium strength, significant ($p<0.05$); in the pair "fragment surface area" – "osteonecrosis" – the relationship is negative, weak, significant with the probability of error in assessing the value $|r_a|$ $p<0.1$; in the pair "locus of a fracture in the lower jaw" – "type of inflammation in the bone marrow" – the dependence is positive, of medium strength, highly reliable ($p<0.01$).

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Conflict of interest:

The Authors declare no conflict of interest.

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