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COMPARATIVE ANALYSIS OF DENSITOMETRIC DETERMINATION OF BONE TISSUE IN THE CASE OF LOSS OF THE MASTICATORY TEETH OF THE MANDIBLE

ПОРІВНЯЛЬНИЙ АНАЛІЗ ДЕНСИТОМЕТРИЧНОГО ВИЗНАЧЕННЯ КІСТКОВОЇ ТКАНИНИ ПРИ ВТРАТІ ЖУВАЛЬНОЇ ГРУПИ ЗУБІВ НИЖНЬОЇ ЩЕЛЕПИ

Резюме. Проведення денситометричних досліджень спрямованих на об'єктивізацію та підвищення точності оцінки структурних параметрів кістки набувають фундаментальності у реабілітації пацієнтів із забезпеченням функціональних, протетичних та естетичних їх потреб. На сьогодні, результати аналізу щільності кісткової тканини визначають пріоритетність в обранні: чи то нової методики безпосередньої імплантації з негайним навантаженням, чи пошуку альтернативи існуючим, що ґарантують прогностичність результатів відносно до фізіологічних термінів остеогенезу, направленої регенерації кісткової тканини та іншим реконструктивним оперативним втручанням. Із 243 комп'ютерно-томографічних цифрових сканувань, отриманих екстраоральною системою Vatech PaX-I 3D Green, проаналізовано з визначенням щільності кісткової тканини в умовних одиницях сірості (УОС) у проекції відсутніх 3.7, 3.6, 4.6, 4.7 зубів та обрано 136 досліджень об'єктами даної роботи, що надають належну інформативність та вагоме пізнавальне значення. Максимальну мінералізацію кісткової тканини беззубих дистальних ділянок нижньої щелепи, як з лівої так і з правої сторони, встановлено в осіб першої групи дослідження (25-45 років) із значеннями вираженої щільності на сагітальних зрізах горизонтальних площинах у проекції 3.6 зуба M=1246,6±63,13 УОС та у проекції 4.6 зуба, де M=1158,8±47,04 УОС. Найнижчі значення щільності кісткової тканини визначено в осіб третьої групи дослідження (61-75 років) на сагітальних зрізах вертикальних площинах у проекціях 3.7 зубів, де M=736,8±42,63 УОС, та 4.7 зубів, де M=778,8±51,79 УОС. Як результат аналізу даної роботи, підтверджено гіпотезу вікової залежності зміни щільності кісткової тканини від часу втрати зубів. Встановлено, що рання втрата жувальної групи зубів, призводить до високих показників, з наростанням щільності кісткової тканини у сторону дисталізації кінцевого дефекту зубних рядів. І, навпаки, відсутність функціональної дії на кісткову тканину, призводить до зниження її щільності у віковому аспекті, а, відповідно, і спустошення трабекулярного шару, що сприяє прогресуванню атрофічних процесів.
Ключові слова: денситометрія, нижня щелепа, атрофія кісткової тканини, комп'ютерна томографія.

Expanding and deepening knowledge about the quantitative morphology of bone tissue is becoming an increasingly topical problem due to the demand of clinical medicine and dentistry in particular. Without the development of theory and practice, it becomes impossible to implement a set of health-improving measures and create optimal conditions for the rehabilitation of patients with atrophy of the mandibular bone tissue caused by the loss of the masticatory teeth.

Both morphologists and materials scientists show great interest in studying highly mineralized human body tissues, such as bone tissue and hard tooth tissue [1, 2].

Although a significant part of anatomical studies of the maxillofacial region and adjacent structures aimed at the study of their topographical and anatomical features [3] and changes in the postnatal period of human ontogenesis [4, 5], or the study of adjacent anatomical formations, the analysis of bone density is given in an overview.

Many publications are targeted at the study of the mineral composition of the bone tissue of the upper and lower jaws and teeth in both humans and laboratory animals against the background of various influences of damaging factors [6].

From these positions, it is important to note the place of radiological methods in paraclinical research,

which allow us to establish the features of the topography of the structures of the mandible [7], obtain information about the structure of the external and internal cortical plates and conduct a densitometric assessment, which indicates qualitative characteristics that reflect the type of bone density, even in its age dynamics.

In turn, the authors [8] note that ultrasound (US), magnetic resonance imaging (MRI) and computed tomography (CT) of the craniofacial region have related applications and are used both for the initial assessment of intracranial anomalies, and for determining 3D and transverse parameters of structures of the maxillofacial region and changes in bone quality with the determination of quantitative density indicators in conventional grayness units, but they are characterized by differences in the volume of diagnostic parameters and availability.

The study of quantitative morphology (density) of bone tissue requires reproducing the model of mathematical reconstruction of X-ray images of objects, which is formed by calculating the degree of attenuation of X-ray radiation at the exit from the thin layer of the object under study. Therefore, with the help of CT, it became possible to avoid superposition and summation of individual elements of the object, that is, the superposition of artifacts, by isolating a thin layer. Thinner sections give a higher spatial resolution and enable more detailed analysis and reconstruction of the image in the needed projections, respectively, to determine the sequence of changes in bone density even in thin cortical layers.

Conducting such studies becomes fundamental in the rehabilitation of patients with functional, prosthetic and aesthetic needs. Densitometric analysis of bone tissue determines the priority in choosing new methods of direct implantation with immediate load [9], as a result of the search for an alternative to existing ones and guarantees the predictability of the result regarding the physiological terms of osteogenesis or directed bone regeneration and other reconstructive surgical intervention [10].

The **aim of the study** is to analyze densitometric assessment of the bone tissue of the human lower jaw, in the case of the masticatory tooth loss between the right and left sides in four age groups from 25 to 75 years.

Material and methods. The study processed 243 computed tomography cone-digital scans with standardized X-ray diagnostic software Ez3D-I Original ver.5.1.9.0, used for visualization of multimodal and multidimensional images, using Hewlett-SNCPUM1 computer equipment with 16.0 GB RAM, 10 Pro system software for Workstations, 2019:00391-70000-00000-AA425. Using the tools of the horizontal optional panel, in particular the «profile» interface keys, bone density was determined with interpretation in conventional grayness units (CGU) in the projection of missing 3.7, 3.6, 4.6, 4.7 teeth and 136 studies were selected as the objects for this work, which have the proper informative content and significant cognitive importance.

The material was divided according to the age into four groups for each side, namely: the first group (I) – 25-45 years, n= 14; the second group (II) – 46-60 years, n=20; the third group (III) 61-75, n=17; the fourth group (IV) – 25-75 years, n=17, persons with preserved dentition (control group).

Digital statistical analysis is performed with the StatSoft Statistica 10.0 software and presented as M ± m (average value and error of the average). Using nonparametric methods of statistical analysis, the study groups were compared with the control group using the Mann-Whitney U test. Comparison of groups by age – using the multidimensional the Kruskal-Wallis test, as an alternative intergroup analysis of variance, which is used to compare three or more samples, in order to test null hypotheses according to which different samples were taken from the same distribution with similar medians. The differences between the groups were considered to be reliable at the significance level $p<0.05$.

Research results. The vagueness of pathological processes occurring, at first glance, in inert tissue is interpreted by the fact that changes occur slowly, in the direction of mineralization and vice versa, without being accompanied by accentuating symptoms for a long time. Even with minimal external influence, functional disorders caused by the loss of the masticatory teeth lead to exhaustion of the trabecular layer in age-related growth, and, accordingly, bone density.

The value of densitometric determination of bone tissue as a functionally active connective tissue, a depot of micro- and macronutrients, and, at the same time, the manifestation of gradual pathological changes that are observed even in a «conditionally» healthy person, which are presented in Table 1-2, characterize its density on the left and right sides of the lower jaw.

The maximum mineralization of bone tissue in the toothless distal areas of the lower jaw, both on the left and right sides, is observed in individuals of the first study group with values of pronounced density on sagittal sections of horizontal planes (HP) in the projection of 3.6 tooth M=1246.6±63.13 CGU and in projection of 4.6 tooth, where M=1158.8±47.04 CGU (Fig. B, D).

The lowest values of bone density were determined in individuals of the third study group on sagittal sections of vertical planes (VP) in projections of 3.7 tooth, where M=736.8±42.63 CGU, and 4.7 tooth, where M=778.8±51.79 CGU (Fig. A, C).

We confirmed the high reliability of the results during an intergroup dispersed comparative analysis by age using the multidimensional Kruskal-Wallis test, with a significance level of $p<0.05$.

However, the values in vertical planes (VP), where p=0.299 in the projection of 3.6 tooth and p=0.359 in the projection of 4.6 tooth of intergroup comparison, focus on their variability.

Table 1

Quantitative indicators of densitometric determination (CGU) of mandibular bone tissue on the left side on sagittal sections in the vertical (VP) and horizontal (HP) planes, due to the loss of the masticatory teeth in people aged 25-75 years, n=51

Study groups, years	3.7 tooth projection/ *value of M (CGU), m (±)*		3.6 tooth projection/ *Value of M (CGU), m (±)*	
	VP	HP	VP	HP
I (25-45) n=14	889.7±54.36	1200.6±67.14	879.5±70.86	1246.6±63.13
II (46-60) n=20	798.6±29.25	1075.3±40.97	801.5±39.00	1088.7±39.22
III (61-75) n=17	736.8±42.63	907.6±39.47	766.9±46.13	980.9±39.73
p	0.041	0.000	0.298	0.001

Table 2

Quantitative indicators of densitometric determination (CGU) of mandibular bone tissue on the right side on sagittal sections in the vertical (VP) and horizontal (HP) planes, due to the loss of the masticatory teeth in people aged 25-75 years, n=51

Study groups, years	4.6 tooth projection/ *value of M (CGU), m (±)*		4.7 tooth projection/ *Value of M (CGU), m (±)*	
	VP	HP	VP	HP
I (25-45) n=14	880.6±38.24	1158.8±47.04	980.1±38.57	1140.1±55.19
II (46-60) n=20	812.9±54.16	1064.5±33.15	891.5±43.34	1041.9±33.25
III (61-75) n=17	783.8±49.78	947.0±42.66	778.8±51.79	893.8±35.88
p	0.359	0.002	0.009	0.000

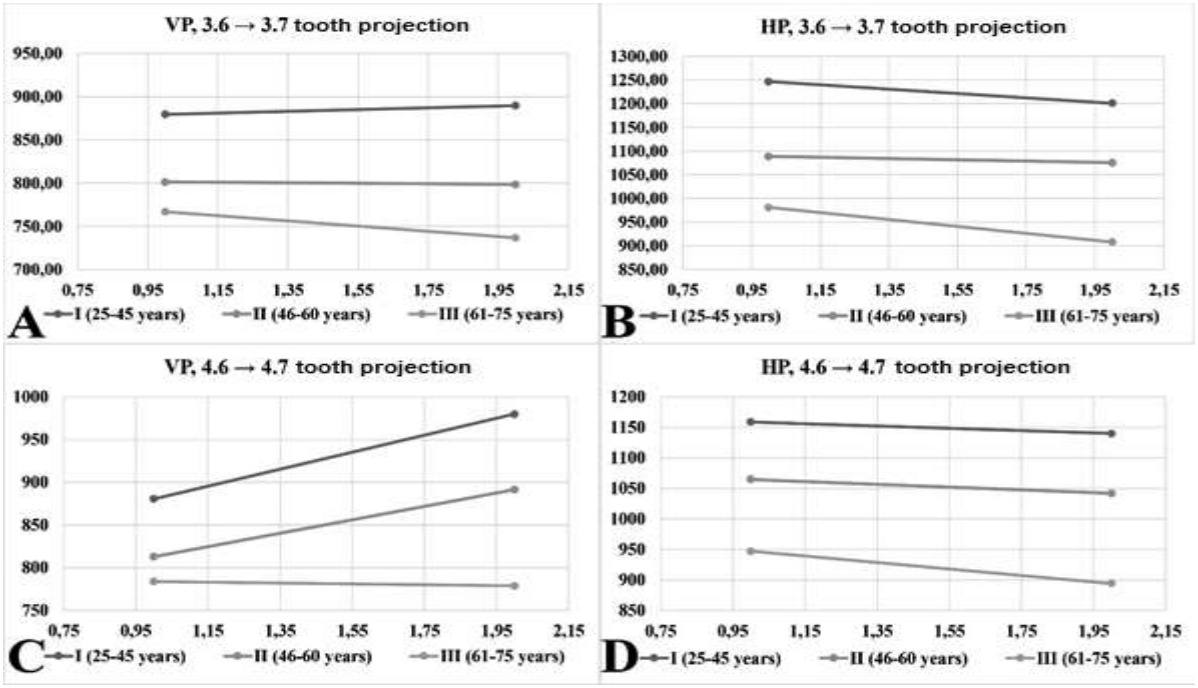

Fig. A, B, C, D. Graphical analysis of densitometric determination (CGU) of mandibular bone tissue on sagittal sections in the vertical (VP) and horizontal (HP) planes, due to the loss of the masticatory teeth in people aged 25-75 years, n=102

Table 3

Comparison of quantitative indicators of densitometric determination (CGU) of mandibular bone tissue on sagittal sections in the vertical (VP) and horizontal (HP) planes, due to the loss of the masticatory teeth in people aged 25-75 years, n=136

Region of determination, study (S) / control (C)		VP / value *M*, *m* (±), p		HP / value *M*, *m* (±), p	
		value of M (CGU), m (±)	value level, p	value of M (CGU), m (±)	value level, p
3.7 tooth projection	S	803.1±24.78	0.000	1053.3±31.89	0.038
	C	587.1±31.94		935.5±31.68	
3.6 tooth projection	S	811.6±29.37	0.003	1096.2±30.13	0.113
	C	648.2±49.56		1008.4±33.44	
4.6 tooth projection	S	821.9±28.70	0.004	1050.9±25.74	0.300
	C	675.5±43.52		977.4±47.10	
4.7 tooth projection	S	878.0±28.28	0.023	1019.0±26.84	0.428
	C	725.0±55.35		959.3±54.14	

The results obtained directed our attention to further clarify the comparative analysis and establish a possible pattern of changes in bone density caused by the loss of the masticatory teeth, according to the average number (M) of the study groups and control groups using the statistical nonparametric Mann-Whitney U test (Table 3).

We have proved (see Table 3) the regularity of manifestation of signs of changes in bone density on toothless segments of the lower jaw in the projection of 3.7, 3.6, 4.6, 4.7 teeth, both on the left and right sides, on sagittal sections in the vertical plane, with a high significance level of the results $p<0.05$.

Analysis of the obtained densitometric values on sagittal sections in the vertical plane indicates a slight variability in the results with a significance level of $p>0.05$ in the projections of 3.6, 4.6 and 4.7 teeth, but at the same time, it expresses a change in bone density, which depends on the time of tooth loss and the constitutional type of a person, which we presented in the discussion of the results.

Discussion. Bone tissue, like any structural unit of the body's systems, undergoes ageing processes, in a certain age aspect, which is a normal physiological process. Also, it easily undergoes changes throughout life under the influence of etiopathogenic factors, stimulating the processes of its remodeling, which can be interpreted by both physiological and pathological factors [11]. After all, the rates of bone resorption and restoration determine one or another vector of course mechanisms that lead to loss-restoration of bone mass and its structural changes.

In turn, the meta-analysis conducted by the authors [12] provides data on the possibility of influencing changes in bone density by endogenous correction with the achievement of rapid predicted results [13].

It would seem that all the tasks set are solved, but the «control» of the neurohumoral chain expresses its influence on the remodeling processes [14, 15], so the problems remain for a long time, and the patient already needs to restore proper function by means of dental rehabilitation techniques.

In our study, we draw attention to changes in bone tissue that occur when the masticatory teeth are lost. The absence of indirect «constant pressure», which is transmitted through the periodontium from the roots of the teeth, leads the bone tissue to a state of relative metabolic rest, and accordingly, to its exhaustion. Reduction of the osteoblast and osteocyte forming cells that maintain the level of ionic concentration in the bone interstitial fluid and directly reflects osteonic structure and its volume. Bone tissue «without activity» changes by the average vector of the existing or acquired static load and forms the maximum densitometric values in the direction of the force action.

It also attracts attention that bone density depends not only on mineral saturation, but also on special micro- and macroarchitectonics, which is the result of adaptive bone restructuring processes that constantly occur under the influence of mechanical and biological factors, and is realized by osteoclasts and stem osteogenic cells, that is, stromal fibroblasts of the bone marrow. A sharp decrease in the volume of osteons, respectively, and bone marrow spaces in the area of previous surgical or reconstructive interventions, indicates low vascularization and a decrease in the area of the biologically active bone surface, and therefore a slowdown in the processes of its adaptive restructuring [16, 17].

In our study, we took into account the subjective and clinical anamnesis, which excludes the abovementioned somatic categories of persons from the analysis and provides an opportunity to interpret the results of the work as a proper pattern of bone tissue restructuring caused by the loss of the masticatory teeth.

Conclusions. 1. Atrophy of the bone tissue of the lower jaw, caused by the loss of the masticatory teeth, varies by the average vector of the existing or acquired static load and accumulates the maximum densitometric values in the direction of action of the force and their reduction, directly proportional to the time of acquisition of secondary defects of the dentition. 2. A pattern of manifestation of signs of changes in bone density by age was established on toothless segments of the lower jaw in the projection of 3.7, 3.6, 4.6, 4.7 teeth, on sagittal sections of the vertical plane, with a high confirming significance level of the results $p<0.05$. 3. The obtained values are fundamental and can be used to change existing classifications by type of bone density.

Prospects for further research. At the core of the conducted densitometric analysis, the topical study should be proceeded to determine the dynamics of morphological restructuring of bone tissue, depending on the time of acquisition of terminal defects of dentition and gender, in different age groups with in-depth statistical analysis and the development of a three-dimensional model for template application in practical dentistry, in particular, maxillofacial surgery.

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COMPARATIVE ANALYSIS OF DENSITOMETRIC DETERMINATION OF BONE TISSUE IN THE CASE OF LOSS OF THE MASTICATORY TEETH OF THE MANDIBLE

Abstract. Conducting densitometric studies aimed at objectifying and improving the accuracy of estimating the structural parameters of the bone become fundamental in the rehabilitation of patients to meet their functional, prosthetic and aesthetic needs. Today, the results of bone density analysis determine the priority in choosing a new method of direct implantation with immediate load or search for an alternative to existing ones that guarantee the predictability of the result concerning the physiological terms of osteogenesis, directed bone regeneration and other reconstructive surgical interventions. Based on 243 computed tomographic digital scans taken by the VaTech PaX-I 3D Green extraoral system, bone density was analyzed in conventional grayness units (CGU) in the projection of the missing 3.7, 3.6, 4.6, 4.7 teeth and 136 studies were selected as objects for this work, which provide proper information and significant cognitive importance. The maximum mineralization of bone tissue in the toothless distal areas of the lower jaw, both on the left and right sides, was established in individuals of the first study group (25-45 years) with values of pronounced density on sagittal sections of horizontal planes in the projection of 3.6 tooth M=1246.6±63.13 CGU and in projection 4.6 tooth, where M=1158.8±47.04 CGU. The lowest values of bone density were determined in individuals of the third study group (61-75 years) on sagittal sections of vertical planes in projections of 3.7 tooth, where M=736.8±42.63 CGU, and 4.7 tooth, where M=778.8±51.79 CGU. The result of the analysis of this work confirms the hypothesis of age-related dependence of changes in bone density on the time of tooth loss. It was found that early loss of the masticatory teeth leads to high indicators, with an increase in bone density towards distalization of the terminal defect of dentition. Conversely, the lack of functional action on bone tissue leads to a decrease in its density in the age aspect, and, accordingly, the exhaustion of the trabecular layer, which contributes to the progression of atrophic processes.

Key words: densitometry, lower jaw, bone atrophy, computed tomography.

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