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AGE ASSESSMENT OF THE DYNAMICS OF MORPHOLOGICAL REARRANGEMENT OF BONE TISSUE OF THE ARTICULAR PROCESSES OF THE HUMAN LOWER JAW DEPENDING ON THE LOSS OF THE MASTICATORY TEETH

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ABSTRACT

Aim: To analyze morphometric changes in the structure of bone tissue of the mandibular articular processes and establish their densitometric dependence on the masticatory teeth loss in people of I-II periods of adulthood.

Materials and methods: We analyzed 136 digital CT recordings of human temporomandibular joints. The research subjects were divided into three groups based on the degree of dentition defect acquisition: the first – a limited defect, the second – a final defect, and the third – a preserved dentition (control); by age into two periods of adulthood of postnatal human ontogenesis. Digital statistical analysis of the bone density is presented as M±σ (mean and standard deviation). We compared the experimental groups with the control group using nonparametric statistical analysis.

Results: Changes in the vertical dimension of occlusion due to limited masticatory teeth loss acquire variable morphometric features, causing an interrelated process of bone atrophy of the cellular part and the trabecular layer of the mandibular processes. The density of bone tissue of the cortical layer of the articular-fossa quadrant (A-Fh/q) of the articular head of the mandibular process increases on the right with limited defects and decreases with final defects. Indicators of bone densitometry of A-Fh/q on the left is characterized by a decrease with limited defects for individuals of the I-st period of adulthood and an increase in the final defects in the II-nd on the left and right.

Conclusions: Multifactorial pathomorphological compensatory processes ensure bone density, but with a change in values on the right and a decrease on the left. Morphometric values of trabecular layers, the most vulnerable areas of the neck and base of the mandibular articular processes, indicate the reconstruction of their bone tissue with limited defects; in the first period of the adulthood, they decrease with a significant predominance on the left.

KEY WORDS: bone atrophy, lower jaw, articular processes, computed tomography

INTRODUCTION

The most frequent visits to the dentist because of pain in the maxillofacial region, which occupy second place after dental pain, are disorders in the temporomandibular joints (TMJ). According to the analysis of epidemiological studies, the prevalence of TMJ pathology varies between 40-60% of the total human population. However, the number of patients receiving complex, highly specialized treatment is estimated only at 10-15%. This indicates a need for a more fundamental theoretical understanding of the etiology and diagnosis of this nosology by dentists, even at the early stages of destructive changes, which are reflected in changes in the bone density of the articular processes of the lower jaw, first of all [1-3]. After all, stagnant destructive, and inflammatory processes lead to fibrous or bone adhesion of the articular surfaces, which causes partial or complete disappearance of the articular gap, leads to limited opening of the mouth, and requires complex reconstructive operations [1, 2, 4, 5]. The development of X-ray diagnostic methods and digital analysis provided a minimally invasive diagnostic process, even with minor manifestations of pathological damage to the components of the complex TMJ disorder [6-8]. Using the above possibilities, we paid attention to the morphological rearrangement of bone tissue and its cortical and trabecular layers, primarily depending on the loss of masticatory teeth with bounded or free-end edentulous spaces in the dentition of the lower jaw [9-11].

AIM

To conduct an age-related analysis of the dynamics of morphometric variation of the trabecular layer of bone tissue of the articular processes of the lower jaw and to establish the densitometric dependence of their cortical and trabecular layers on the influence of multifactorial pathoetiological factors, in particular, the loss of the masticatory teeth.

MATERIALS AND METHODS

From the available clinical database of 18689 studies of PLC "MEDICAL 3D DIAGNOSTICS CENTER" (legal entity identification number: 41907653, location: 79010, Lviv region, Lviv, Chernihivska Str., 18, Ukraine), we selected 136 CT records of the human TMJ study, which provided appropriate information content and corresponded to the goal of this work. The research material was selected following the agreement on scientific cooperation No.

02 dated 02.10.2020 between Bukovinian State Medical University (58002, Chernivtsi, Teatralna Square, 2, Ukraine) and MEDICAL 3D DIAGNOSTICS CENTER. This is the availability of digital methods of morphological research, in particular, the method of densitometric analysis using extraoral scanning Vatech PaX-i3D Green CT (PHT-60 CFO) with an ultra-sensitive radiation detector, functions: orthopantomography, tomography, teleroentgenography, TMJ (open/closed mouth) and an additional MAR module, to reduce the number of artifacts from overlays and inclusions (Fig. 1) with Ez3D-I (5.1) software, it provided an opportunity to perform a quick, detailed analysis of the bone structure of the articular processes of the lower jaw on the left and right sides, in particular, its density in a minimally invasive and ergonomic way.

CT digital scans were analyzed using Hewlett-Packard Z4 G4 Workstation computer equipment with an Intel Xeon W-2104 central processor, Nvidia GeForce GTX 1660 GPU, 32 GB of RAM, and Windows 10 Pro for Workstations software (version 1903, product code 00391-70000-00000-AA381).

The method of statistical selection was used to distribute the study material by age for two periods (I-II) of adulthood of postnatal human ontogenesis (I-st period of adulthood - men aged 22-35 years, women aged 21-35 years; II-nd period – men aged 36-60 years, women aged 36-55 years) [12]. Depending on the pathoetiological factor, the selected material was distributed according to the degree of acquisition of a dentition defect of the lower jaw (LJ) by patients into three groups, namely: the first group - limited dentition defect, the second group is an existing final defect, the third group is individuals with preserved dentition, the control group (Table 1).

To determine bone density, we selected quadrants that were primarily subject to pathological changes

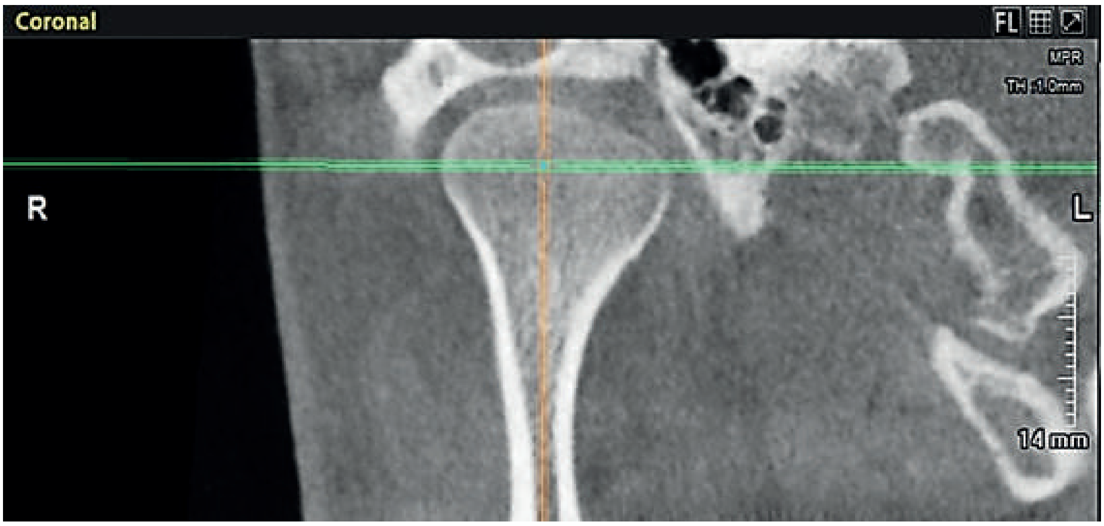

Fig. 1. Settings. In the coronal plane (investigated option window), the sagittal axis is located along the vertical axis of the articular process, centered perpendicular and in the middle of its macrostructure.

Table 1. Grouping data when studying qualitatively homogeneous aggregates – quantitative indicators that determine bone density in conventional grayscale units (CGU) of the articular processes of the lower jaw due to partial/complete loss of the lateral/masticatory teeth, n= 136.

Group name/age period		Number of observations	Articular processes of the lower jaw	
			A - right side	B - left side
First group: Limited dentition defect	I adulthood	26	13	13
	II adulthood	22	11	11
Second group: Final dentition defect	I adulthood	16	8	8
	II adulthood	24	12	12
Third group: Preserved dentition - control group	I adulthood	26	13	13
	II adulthood	22	11	11
Total number of objects under study	I adulthood	68	34	34
	II adulthood	68	34	34

(Fig. 2), in particular:

- A-Fh/q - articular-fossa quadrant of the articular head of the mandibular process;
- A-Pn/q - anteroposterior quadrant of the neck of the mandibular process;
- A-Pb/q - anteroposterior quadrant of the base of the mandibular process;
- c/g – control group, quadrant of the mandibular angle.

When conducting medical research, it is often necessary to use statistical analysis methods of data presented in semi-quantitative, semi-qualitative, and qualitative forms, which forces us to direct our choice to use nonparametric evaluation criteria.

Digital statistical analysis of the bone density of the articular processes of the lower jaw, depending on the loss of the masticatory teeth, presented as M±σ (mean value and standard deviation). Using nonparametric statistical analysis methods, we compared the experimental groups with the control group using the Mann-Whitney U test.

Comparison of groups with each other was conducted using the multidimensional Kruskal–Wallis test as an alternative intergroup analysis of variance, which compares three or more samples to test null hypotheses according to which different samples were taken from the same distribution with similar medians. The obtained differences between the groups were considered reliable as the change in the density of bone tissue has a multifactorial patho-etiological dependence described in this paper.

All the studies were conducted after patients familiarized themselves with and signed informed consent to participate in research in compliance with the main provisions of the GCP (1996), the Council of Europe Convention on Human Rights and Biomedicine (dated 04.04.1997), the World Medical Association Declaration of Helsinki on ethical principles for conducting scientific medical research involving human subjects (1964-2013), order of the Ministry of Health of Ukraine No. 690 dated 23.09.2009 № 616 dated 03.08.2012.

RESULTS

For dynamic assessment of the bone density, we identified "areas" that were primarily exposed to pathoetiological factors to change densitometric values in the direction of increasing and decreasing. Such studied quadrants are the vertex of the cortical layer (M/cort) of the articular head of the articular-fossa surface (A-Fh/q) and, accordingly, the trabecular (spongy) bone (SD/sp), which was measured subcortically to a length of one millimeter parallel to the axis.

Attention is paid to the places of attachment and the vector of the masticatory muscle force, which play a crucial consistent role in the series of irreversible pathological changes, with their morphometric analysis. Antero-posterior quadrant of the neck of the mandibular process (A-Pn/q) gives an idea of the restructuring of bone tissue based on the spongy matrix. Therefore, the constructed algorithm covers morphometric studies (M/mph) for measuring between cortical layers and determining the density of the spongy layer (SD/sp), followed by average values in tables for statistical processing and analysis (Table 2, 3, 4, 5). The same algorithm was followed in the study of the anteroposterior quadrant of the base of the mandibular process (A-Pb/q).

It is generally accepted that the angle of the lower jaw has a stable value relative to its morphological rearrangement. For comparison and more comprehensive objectivity, we determined the density of the cortical layer at the edge of the lower jaw angle (c/g), along the length of a line of four millimeters, in the plane of the sagittal section.

No less and priority role is given to the morphometric study of the trabecular layer of bone tissue since the loss of the masticatory teeth leads to its atrophy and gives an understanding of the objectivity of bone tissue rearrangement depending on tooth loss as a vector pathoe-

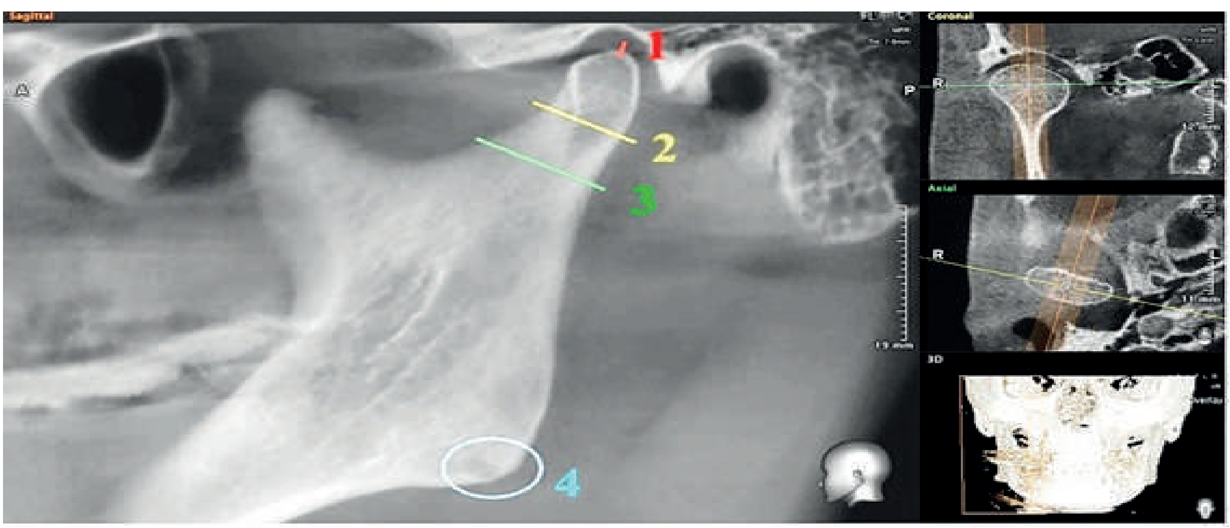

Fig. 2. Settings. In the coronal plane (investigated option window), the sagittal axis is located along the vertical axis of the articular process, centered perpendicular and in the middle of its macrostructure.

Table 2. Results of quantitative and qualitative indicators that determine the density (CGU) and morphometric values of bone tissue of the articular processes of the lower jaw on the right side of the I-st the period of adulthood in postnatal human ontogenesis, due to partial/complete loss of the lateral/masticatory teeth, n= 34.

Marking	Research areas	Control group (preserved dentition) M±σ	Limited dentition defect M±σ	Final dentition defect M±σ	p1	p2	p3
	n	13	13	8			
A-Fh/q	M/cort	1149±398.1	1225±312.8	1095±158.7	0.412	0.828	0.169
	SD/sp	668.7±227.4	590.6±244.5	737.8±319.8	0.457	0.515	0.169
A-Pn/q	SD/sp	849.6±260.1	708.2±302.0	616.8±235.6	0.209	0.083	0.347
	M/mph	4.438±1.274	4.438±1.570	4.850±1.174	0.878	0.328	0.717
A-Pb/q	SD/sp	882.1±195.3	910.4±329.3	658.7±160.5	0.457	0.017	0.021
	M/mph	4.992±0.867	4.515±1.852	4.913±1.374	0.191	0.664	0.492
c/g	cort.	2313±806.2	2490±615.8	2107±440.9	0.305	0.942	0.278

Table 3. Results of quantitative and qualitative indicators that determine the density (CGU) and morphometric values of bone tissue of the articular processes of the lower jaw on the left side of the I-st period of adulthood in postnatal human ontogenesis, due to partial/complete loss of the lateral/masticatory teeth, n= 34.

Marking	Research areas	Control group (preserved dentition) M±σ	Limited dentition defect M±σ	Final dentition defect M±σ	p1	p2	p3
	n	13	13	8			
A-Fh/q	M/cort	1062±337.8	1047±288.6	1139±164.9	0.939	0.515	0.664
	SD/sp	621.6±229.5	582.5±265.5	526.3±272.0	0.739	0.366	0.664
A-Pn/q	SD/sp	720.3±354.2	659.4±314.9	526.7±143.7	0.858	0.247	0.278
	M/mph	4.500±0.936	4.346±1.133	4.813±1.093	0.473	0.294	0.385
A-Pb/q	SD/sp	888.0±406.4	775.6±385.8	709.0±154.9	0.489	0.515	1.000
	M/mph	4.723±1.182	4.692±1.614	4.838±1.038	0.818	0.971	0.690
c/g	cort.	2227±667.4	2348±523.6	2151±319.1	0.293	0.800	0.311

Table 4. Results of quantitative and qualitative indicators that determine the density (CGU) and morphometric values of bone tissue of the articular processes of the lower jaw on the right side of the II-nd period of adulthood in postnatal human ontogenesis, due to partial/complete loss of the lateral/masticatory teeth, n= 34.

Marking	Research areas	Control group (preserved dentition) M±σ	Limited dentition defect M±σ	Final dentition defect M±σ	p1	p2	p3
	n	11	11	12			
A-Fh/q	M/cort	1148±185.7	1032±271.3	1184.1±330.2	0.251	0.580	0.243
	SD/sp	650.1±214.0	546.6±238.0	692.2±204.5	0.309	0.623	0.157
A-Pn/q	SD/sp	787.0±285.1	669.8±231.3	746.8±186.8	0.309	0.689	0.356
	M/mph	4.345±1.667	4.273±1.003	4.417±1.129	0.922	0.854	0.854
A-Pb/q	SD/sp	810.4±299.5	739.9±321.7	694.8±198.2	0.251	0.132	0.806
	M/mph	4.982±2.180	4.673±0.957	4.883±1.564	0.948	0.975	0.782
c/g	cort.	2122±562.3	1926±230.8	2028±349.0	0.491	0.902	0.296

Table 5. Results of quantitative and qualitative indicators that determine the density (CGU) and morphometric values of bone tissue of the articular processes of the lower jaw on the left side of the II-nd period of adulthood in postnatal human ontogenesis, due to partial/complete loss of the lateral/masticatory teeth, n= 44.

Marking	Research areas	Control group (preserved dentition) M±σ	Limited dentition defect M±σ	Final dentition defect M±σ	p1	p2	p3
	n	11	11	12			
A-Fh/q	M/cort	988.8±255.5	926.4±179.5	1064±153.7	0.341	0.580	0.091
	SD/sp	558.2±281.2	461.2±128.1	619±257.2	0.094	0.902	0.085
A-Pn/q	SD/sp	609.0±325.5	501.4±119.8	673.8±218.7	0.844	0.356	0.043
	M/mph	4.482±1.492	4.764±1.177	4.358±1.355	0.512	0.782	0.460
A-Pb/q	SD/sp	748.4±385.1	542.9±178.8	691.4±260.8	0.168	0.758	0.140
	M/mph	4.855±1.569	5.236±1.510	5.067±1.624	0.325	0.806	0.926
c/g	cort.	2061±311.9	1873±252.0	2133±334.3	0.123	0.623	0.027

Notes:
p1-comparison: Control group (preserved dentition) with a limited dentition defect;
p2-comparison: Control group (preserved dentition) with a final dentition defect;
p3-comparison: limited dentition defect with final dentition defect.

tiological factor.

Morphometric values of the most vulnerable areas of the neck and base (A-Pn/q, A-Pb/q) of the articular processes of the lower jaw with limited dentition defects indicate the reconstruction of their bone tissue, in particular, in the I-st period of adulthood of postnatal human ontogenesis (PO) and they are characterized by a decrease with a significant predominance on the left side. With a change in the vector of muscle strength, there is a morphological restructuring of the height of the processes, namely, the distance from their base to the neck, in the negative direction due to the loss of occlusal ratios. A change in the vertical dimension of occlusion due to a limited loss of chewing teeth stipulates quick adaptation to new conditions of reducing pressure on the joints, causing an interrelated process of bone atrophy of both the cellular part and the trabecular layer of the mandibular processes.

With the final dentition defects of the lower jaw, chewing pressure is formed in the middle, pushing the jaws to the front in order to grind food. This distribution of pressure on the articular processes, in turn, causes a change in the angle of the lower jaw as a compensatory resistance to pathomorphological processes with a significant increase in their morphometric values in the A-Pn/q, A-Pb/q of the studied quadrants.

Synchronous pathomorphological, compensatory processes provide bone density, but with a change in values on the right side and a decrease on the left in both human age periods (Fig. 3).

Attention is drawn to the increasing bone density of the cortical layer of A-Fh/q of the studied quadrant of the right side, with limited dentition defects and a decrease in its values with final dentition defects. The synchronicity of the decrease in bone density on the left side of A-Fh/q is characterized by a sharp decrease in limited dentition defects of the I-st period of adulthood of the human PO and its increase in the final dentition defects of the II-nd period of adulthood for both the left and right sides.

Comparison of the results of the constant density of the studied quadrant of the cortical layer of bone tissue of the lower jaw angle (c/g) in the I-st period of adulthood of PO is confirmed by a conditional pattern growth-decline. In II-nd period of adulthood of human PO, on the contrary, decline-growth of its density is on the left and right sides of the jaw.

Multifactorial pathoethological dependence does not make it possible to establish the reliability of differences between the comparison groups p1, p2, and p3 (see. Note below Table I–V) with a constant expression $p<0.5$ since the change in bone density depends on the somatic state of the body, its coenzyme capacity, hormonal regulation and the time of manifestation of etiological factors, as described above.

This paper details individual values that reveal bone tissue's behavior (restructuring) caused by the loss of individual chewing teeth or their groups. They have significant informative value during the planning and conducting of reconstructive surgical interventions, particularly osteosynthesis.

DISCUSSION

Attention is drawn to the morphometric and densitometric examination of TMJ using minimally invasive methods of CT in maxillofacial surgery for the manufacture of navigational surgical templates and patient-specific retainers using CAD/CAM technologies in patients with a mandibular head fracture, which enables improving the anatomical and functional results of their

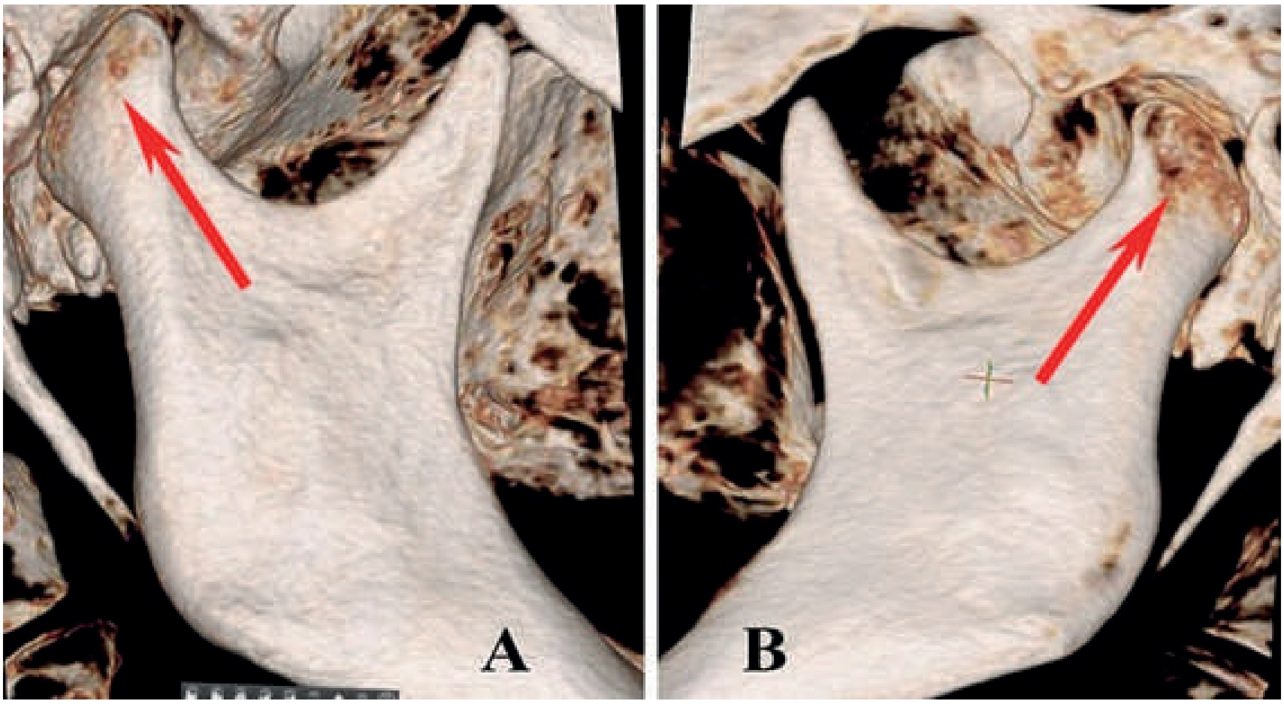

Fig. 3. 3D reconstruction model of the articular processes of the lower jaw: A) the right articular process of the LJ of the normal morphological structure of its cortical layer; B) the left articular process of the LJ with the manifestation of pronounced destructive changes in its cortical layer. X-ray positioning "closed mouth".

surgical treatment, namely, increasing the accuracy of restoring the anatomical shape of the head, reducing the frequency of occlusal disorders and secondary displacements, as well as increasing the maximum range of movements of the lower jaw [13].

The authors [14] point out the importance of using not only the methods but also the areas (points) of bone tissue of the articular processes that will provide the most stabilizing and restoring results of TMJ integrity.

Updated results of clinical observations [15] confirm the importance of understanding the anatomical features of the articular processes in achieving a proper anatomical reduction of the lower jaw during surgical planning, which becomes the method of choice and reduces the time of surgery and morphological rehabilitation.

Loss of the bone density of the articular processes is a convenient platform for even a primary infection, with the subsequent development of septic lesions of the entire TMJ complex and their spread to adjacent areas [16-18].

The asymptomatic course of pathological processes such as osteopenia or osteoporosis of the bone tissue of the lower jaw processes in the early stages is available for diagnosis by CT methods, focusing on the values presented by us, even without bone sampling.

The unjustified ergonomics of methods [19, 20] determining the mineral saturation of micro- and macronutrients takes on a historical vector. After all, the minimal invasiveness of digital radiography in densitometric and morphometric research can offer reduced radiation doses and the advantages of image analysis, which increases sensitivity and reduces the error resulting from the subjective analysis.

Another important argument for the need to study bone density, according to the author [21, 22], for most specialists working in medicine, may be helpful that the latter is an unknown, overly variable structure in the human body. According to the World Health Organization, bone mineral density disorders are the fourth most common globally – after cardiovascular diseases, cancer, and diabetes.

We know the works of Kulinchenko RV (2012-2016), which reflect the loss of the masticatory teeth as the influence of a pathoetiological factor on the morphological components of the TMJ, but, at the same time, do not detail the morphometric and densitometric definitions of the studied areas of the articular process of the lower jaw.

Therefore, we propose to take the results obtained as a basis of morphometric values and density – quantitative and qualitative characteristics of the bone tissue of the articular processes of the lower jaw since the sources available do not disclose similar studies, which makes it impossible to compare them.

CONCLUSIONS

1. Changes in bone density of the articular processes of the lower jaw depend not only on the loss of the masticatory teeth but also on the functionality of the muscular system, particularly the masticatory muscles, and adaptation processes aimed at preparing and forming the oral lump.
2. The loss of chewing teeth, causing the pathology bounded edentulous spaces in the dentition, leads to atrophy, first of all, of the trabecular layer of bone tissue of the articular processes in the I-st period

of adulthood of postnatal human ontogenesis and growth of its density in the II-nd period of adulthood postnatal ontogenesis in final dentition defects.

3. The bone density of the cortical layer of the lower jaw angle, which is considered to be conditionally "stable", undergoes densitometric variation depending on the time, the strength of action, and the spread of pathoetiological factors.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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