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Changes in the architectonics of the lower jaw in children depending on age

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SUMMARY

Objective. To study the peculiarities of the anatomical structure and architecture of the mandibular in children at different age to CT data.

Methods. 161 CT scans of the bones of the facial skull of children aged 1 to 18 years were selected. Orientation of the tomographic slices was based on the standardized protocol of CT studies. Differences were considered significant when p values were lower than 0.05.

Results. The width of the lower jaw was greatest in the area of the angle and chin symphysis. The general dynamics of the thickening of the cortical layer of the lower jaw from the vestibular side differed from the dynamics of the formation of the lingual cortex. The density of the cortical layer increased with age: the difference between its average value in the age groups of 1-3 years and 14-17 years was 16-46%.

Conclusions. The width of the lower jaw in the process of its growth and development increases in different areas by an average of 6-58%. The thickening of the cortical layer with age is more intensive than the general increase in its thickness and amounts to 41-51% for various areas of the jaw, except for the head of the condylar process. The radiological density of the cortical layer increases with age by 6-67%, and reaches 2064.2±180.54 in the older age group.

Keywords: mandibular, lower jaw, children, computer tomography, bone.

INTRODUCTION

The lower jaw (LJ) has a complex anatomical shape and architectonics, optimally adapted to the perception and redistribution of functional loads arising in the process of chewing, swallowing and speech. Geometrical parameters, mineral saturation and density of the cortical and spongy layer of the bone determine the nature of the distribution of stresses and deformations in the mandible under functional loads and the action of traumatic factors. The architectonics of the mandible in its various parts determines the peculiarities of surgical interventions: installation of implants, fixators for fractures, distraction and compression devices, osteotomies, bone augmentation, TMJ arthroplasty, etc.

Studies of the morphology and architectonics of the LJ in adults, based both on the study of cadaveric material and on computer tomography (CT) data, are numerous and well known. Works devoted to this problem in children are few, and their results are ambiguous and require additional confirmation.

MATERIAL AND METHOD

The material of this study was the MSCT data of the bones of the facial skull, selected from the database of patients of the Department of Surgical Dentistry and Maxillofacial Surgery of Pediatric Age by Bogomolets National Medical University, in the period from January 2020 to October 2022. Conducting the study, compliance with the principles of bioethics and patient rights was ensured in accordance with the Declaration of Helsinki and the Fundamentals of Ukrainian legislation on health care (1992). The study was approved by the University's Expert Committee on Bioethics, protocol No. 158 dated 05/23/2022.

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A total of 161 MSCTs of the lower jaw in children under 18 years of age were studied. Among them there were 98 (61%) boys and 63 (39%) girls. All patients, depending on their age, were divided into 5 groups corresponding to the periods of occlusion:

I period – 1-3 years formation of temporary bite n=23(14.2%);

II period – 4-6 years. temporary bite n=29 (18%);

III period – 7-9 years. early variable bite n=30(18.6%);

IV period – 10-13 years. late variable bite n=40(25%);

V period – 14-17 years. permanent bite n=39 (24.2%).

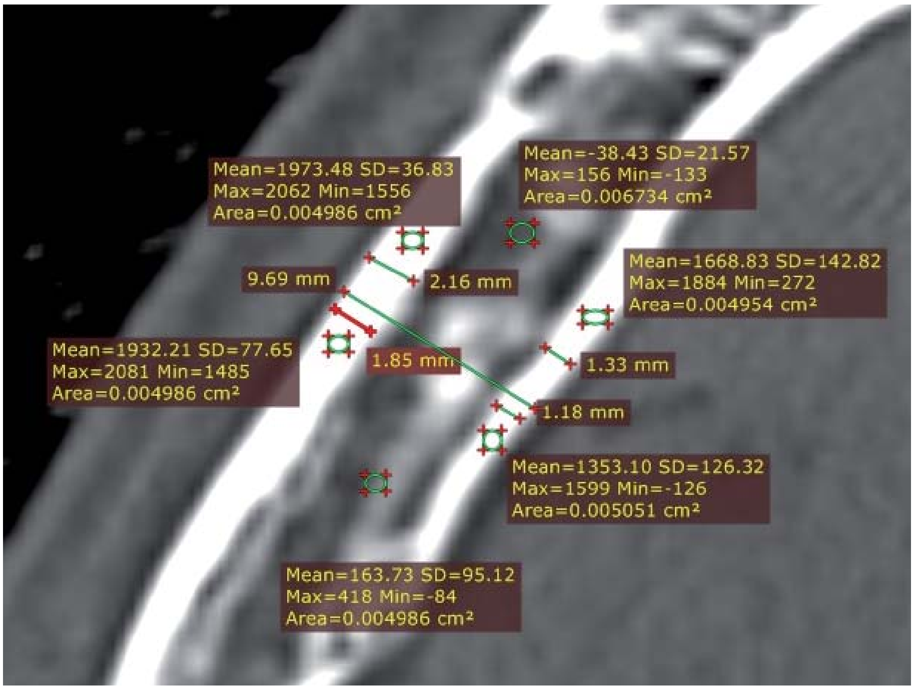

Fig. 1. Determination of the thickness and radiological density of different bone layers according to CT data in the axial section of the LJ in the projection of the first molar

MSCT scans were performed for various clinical reasons not directly related to the purpose of this study. The criteria for inclusion in the study were as follows – high-resolution images that included the entire lower jaw, pediatric patients, signed informed consent of the patient's parents or guardians for the use of CT data for scientific and educational purposes.

Exclusion criteria were: children older than 18 years, refusal of the patient's parents to participate in the study, low quality of the tomographic image, presence of artifacts that made it impossible to carry out appropriate measurements, lack of complete clinical documentation of the case, presence of orthodontic appliances and other devices and/or implants with high radiological density on the lower jaw, the presence of inflammatory processes, tumors and tumor-like diseases, the presence of congenital malformations, anomalies and deformations of the facial skull, the presence of traumatic fractures of the lower jaw in the area of measurement.

In all cases, CT was performed using a 4-slice multispiral ToshibaAsteion 4 computed tomograph, with a slice thickness of 0.5 mm. The orientation of the tomographic sections was based on the standardized CT protocol of facial skull studies. The obtained data in the form of a series of DICOM format files were imported into the software environment RadiAnt DICOM ViewerVersion: 2022.1.1 (32-bit) Builddate: 17.08.2022 (#23000) for the analysis of tomographic images. After image conversion, axial sections obtained on computed tomography and the reconstruction of these images in the sagittal and frontal planes were studied, as well as three-dimensional reconstructions of the LV created using direct volume rendering algorithms. To fulfill the tasks of the study, the bone contrast mode was used. Using the standard tools of the RadiAnt software environment.

The measurement was carried out in the following anatomical parts of the lower jaw: symphysis and parasymphysis, in the projection of the metal hole, the first permanent molar, the angle of the lower jaw, the base of the condylar process and its head, which corresponds to the typical locations of the fracture according to the AO CMF trauma classification system. In each of these zones, the thickness and X-ray density of the cortical and spongy layers, as well as the total width of the LJ were measured.

The width of the LJ at the corresponding anatomical sites was determined as the distance between the outer edges of the cortical plate from the vestibular and oral sides. The thickness of the cortical layer was determined as the distance from the periosteum to the cortical-spongy border from the vestibular, oral side, and in the area of the lower edge of the LJ.

Bone's mineral saturation in the cortical and cancellous layer was determined by the average value of absorption of the radiological image in the "zones of interest" (ROI), elliptical shape d=0.5 mm, expressed in Hounsfield HU units (Figure 1).

Peculiarities of carrying out measurements on different anatomical areas of the LJ. Symphysis / parasymphysis. Determination of the relevant pa-

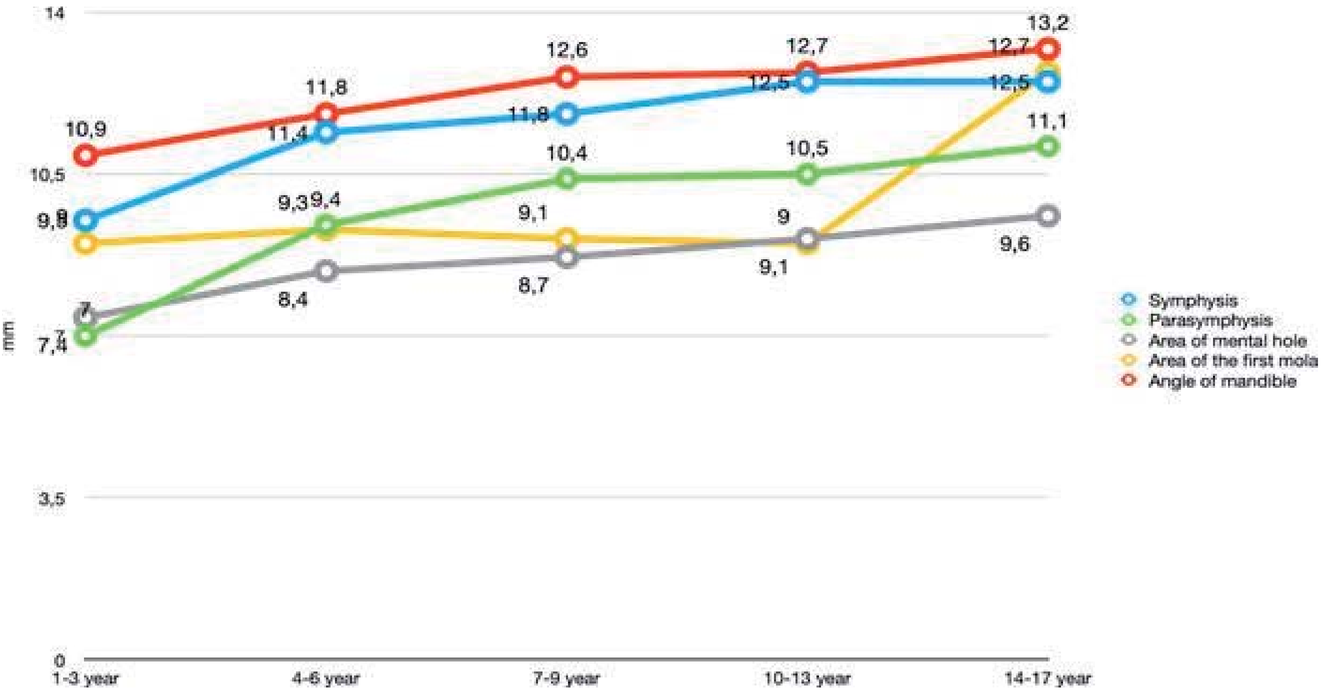

Fig. 2. The width of LJ (mm) varies with the age of the child and the anatomical area

rameters was carried out in a sagittal section along the middle line of the LV - symphysis. In the area of the parasymphysis it was done between the roots lower canines and lateral incisors. In these areas, the width of the cortical layer on the vestibular and oral side, as well as the total width of the jaw, was measured at the midpoint of the distance from the tops of the roots of temporary/permanent teeth (including unformed ones), or their rudiments, and the border of the cortical and cancellous layer along the lower edge of the jaw.

In the projection of the mental hole. The width of the cortical layer on the vestibular and oral sides, as well as the total width of the jaw, were measured in an axial section at the midpoint of the distance from the tops of the roots of temporary and permanent teeth, or their rudiments, to the cortical-spongy border along the lower edge of the jaw in front and behind the mental foramen. The width of the cortical layer of the lower edge of the jaw was determined in the frontal section that passed through the mental foramen. X-ray bone density was determined in the areas of linear measurements.

In the projection of the first permanent molar. The width of the cortical layer on the vestibular and oral sides, as well as the total width of the jaw, was measured in an axial section at the midpoint of the distance from the apex of the roots of the first permanent molar or its rudiment to the cortical-cancellous border along the lower edge of the lower jaw. The thickness of the cortical layer of the lower edge of the jaw was determined in the frontal section that passed between the roots of the first constant molar of the lower jaw.

In the projection of the angle of the lower jaw. Measurements were taken in the projection of the retromolar area (in younger aged groups of children) and the follicle of the lower third molar (in older children). The principles of measuring the thickness and density of the cortical layer from the vestibular and oral side were identical to those given above.

The base of the condylar process and the head of the lower jaw. Determination of the thickness and density of the cortical and spongy layer was carried out in axial sections at the level of the notch of the LJ (the base of the condylar process) and the lateral pole of the head of the LJ.

Statistical analysis. Sample size was verified using an online sample size calculator (https://clincalc.com). ANOVA (in the case of a normal distribution law) or the Kruskal-Wallis test (in the case of a non-normal distribution law) was used for comparison.

RESULTS

The parameters of the lower jaw architectonics that were determined in this study had probable age and topographical differences. The width of the LJ was the largest in the area of the angle and the chin symphysis in all age periods. In these areas, its average width grew from 10.9 mm to 13.2 mm (angle) and from 9.5 to 12.5 mm (symphysis), respectively. The most intensive growth of the jaw in width occurred in early childhood: differences

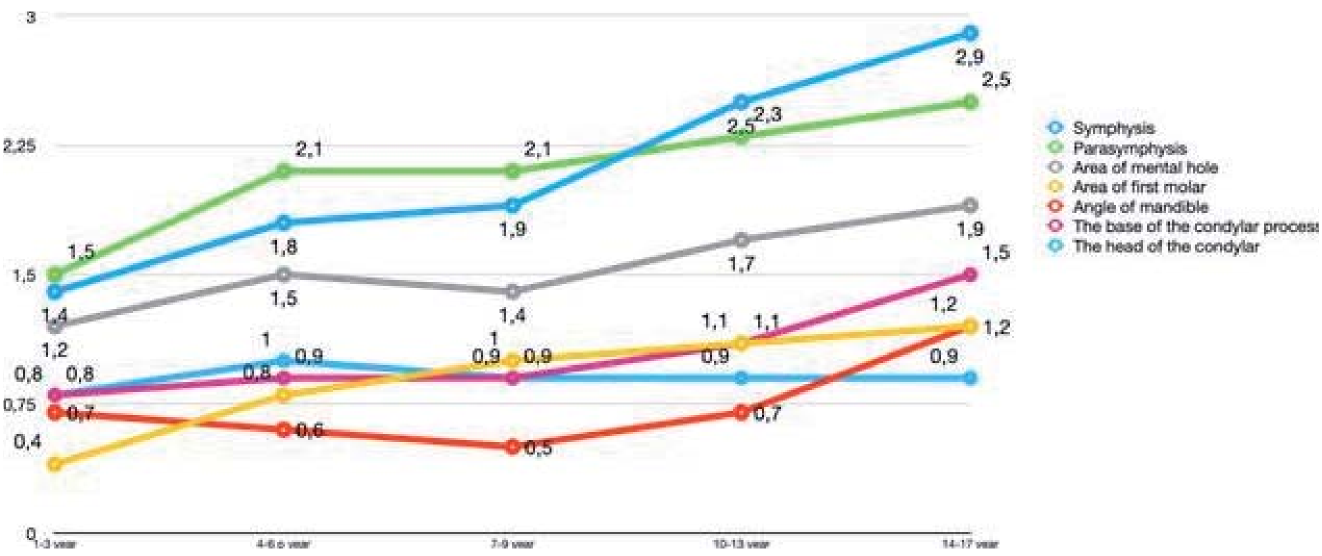

Fig. 3. An image showing an x-ray for WL determination in a buccolingual direction

between the average values for the age groups of 1-3 and 4-6 years, it was 3% in the area of the first molar and 34% in the area of the parasymphysis, in the future the growth rates slowed down somewhat. The growth of the LJ in width in the area of the symphysis at the age of 14-17 practically stopped, on the other hand, in the area of the angle and parasymphysis in this age group, growth acceleration was noted by 4% and 6%, respectively. On average, in the studied age groups, the width of the LJ increased by 6-58%. The smallest increase in width during the postnatal growth period was characteristic of the area of the first constant molar, the largest was for the parasymphysis (Figure 2).

Increase in cortical thickness was significantly greater than the increase in jaw width at the corresponding sites. The formation of the cortical layer of the tongue from the lingual side was determined by the development of the muscular apparatus, in particular the muscles that lower the tongue, the formation of the speech apparatus and the general patterns of jaw formation during teething (Figure. 3).

The growth process proceeds differently in different parts of the lower jaw. In the age group of 1-3 years, the average thickness of the cortical layer on the oral side in all areas was less than 1.5 mm, and then with age it increased by 58-200%, with the exception of the head of the lower jaw, where the thickness of the cortical layer remained almost constant in all age groups, and even in the 14-17-year-old group, its average value remained less than 1 mm. In all other areas before the completion of jaw growth, this indicator was greater than 1 mm, and in the area of the symphysis it was the largest, reaching 2.9±0.64 mm.

The general dynamics of the thickening of the cortical layer of the LJ on the lingual side was nonlinear and was characterized by rapid thickening under the age of 6 years with subsequent stabilization of the parameter at the age of 7-9 and further intensification of growth in older age groups. In the group of 14-17 years, the cortical layer on the lingual side thickened most clearly in the areas of the symphysis (by 16% compared to the age group of 9-13 years), the angle (by 71%) and the base of the condylar process (formation of the torus mandibular) – by 36%.

In the age group of 1-3 years, its average thickness did not exceed 1.1 mm, and then with age it increased by 72-110%, with the exception of the head condylar process, where the thickness of the cortical layer remained constant in all age groups and did not exceed 1 mm on average.

In all other areas, before the growth of the jaw was completed, this indicator was greater than 1.5 mm, and was the largest in the area of the corner, reaching 2.1 mm. The general dynamics of the thickening of the cortical layer of the lingual cortex on the vestibular side differed from the dynamics of the formation of the lingual cortex. Under the age of 13, its thickening occurred slowly, but it accelerated sharply in the age group of 14-17 years. In the younger age groups (II, III, IV), its thickness exceeded 1.5 mm only in the area of the first constant molar, which is the first of the constant teeth and the mental foramen. On the other hand, in the group of 14-17 years, the cortical layer on the vestibular side was thicker in comparison with the age group of 9-13 years in the area of the symphysis by 28%, parasymphysis by 33%, angle -50%, the base of the

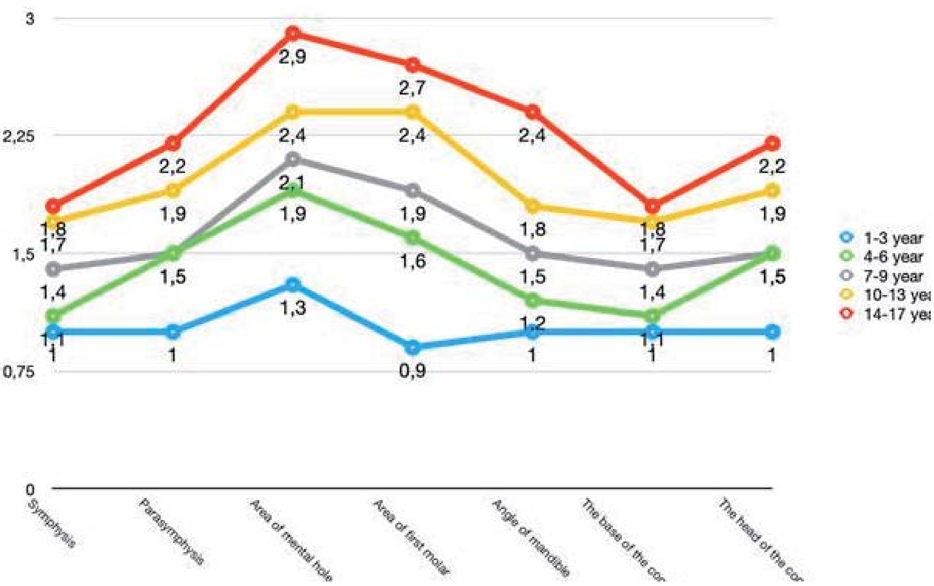

Fig. 4. An image showing the root canal curvature measurement on an x-ray using EndoPrep App. The curvature of showed canal is 49

in early childhood, and then slightly increased, reaching an average of 1747.3±456.4 – 1885.1±164 HU in the older age group.

In the area of the first constant molar, the corner and the base of the condylar process, which are subjected to the greatest loads during chewing, the density of the cortex on the oral side in early childhood was less than 1500 HU and then probably increased by 30-85%, reaching maximum values in older age the group. The lowest value of radiological density of the cortical layer

condylar process by 45%, in the area of the molars and premolars 11-17%. The width of the cortical layer along the lower edge of the jaw in children aged 1 to 3 years was 0.9-1 mm in all studied areas, except for the area of the mental foramen, where it averaged 1.3±0.32 mm. At the age of 14-17, it reached an average of 2.9 mm (Figure 4).

The thickness of the cortical layer along the lower edge of the lower jaw was the smallest and largest in the projection of the first molar and increased from 0.9±0.27 to 2.9±0.66 mm depending on the age of the children. In other areas, the thickness of the cortex along the lower edge of the LV increased by 80-140% compared to the 1st group. The dynamics of these changes were different. The density of the cortical layer on the oral side in children was lower than on the vestibular side by 9-25%. The maximum density of the cortical layer on the oral side was in the area of the symphysis, parasymphysis, and projection of the mental foramen. At the same time, high bone density was achieved

was observed in the area of the head of the condylar process. This parameter gradually increased with age, while in all age groups it was within 500-800 HU. The difference between the density of the cortical layer of the head at the age of 1-3 years and 14-17 years from the vestibular and oral sides was 30 and 45%, respectively. With the age, the density of the cortical layer in this area increased by 14-46%, and reached the level of 1600-1800 HU. The density of the spongy layer depended more on the anatomical site than on the age period in which the research was conducted. The spongy layer had the highest density (500-700 HU) in the area of the symphysis. The average level of X-ray density in the range of 200-400 HU was inherent in the condylar process, parasymphysis and area of the mental foramen. Low mineral saturation of the spongy layer (less than 200 HU) was characteristic of the first molar area. The average ratio of the thickness of the cortical and spongy layers in different age (Table).

Table. The average ratio of radiological density of the cortical and spongy layers in different age periods

Anatomic area of the LJ	1-3 years	4-6 years	7-9 years	9-13 years	14-17 years	p
Symphysis	0.33±0.31	0.36±0.13	0.36±0.12	0.48±0.18	0.53±0.39	<0.001
Parasymphysis	0.48±0.36	0.53±0.25	0.42±0.21	0.5±0.37	0.56±0.25	<0.001
Area of the mental hole	0.46±0.14	0.51±0.14	0.44±0.19	0.62±0.18	0.7±0.25	<0.001
Area of the first molar	-	0.36±0.15	0.38±0.13	0.44±0.41	0.51±0.18	<0.001
The base of the condylar process	0.54±0.23	0.56±0.71	0.65±0.54	0.82±0.42	0.77±0.88	<0.001
The head of the condylar process	0.1±0.04	0.11±4.5	0.09±0.04	0.09±5.3	0.07±0.03	<0.001

DISCUSSION

The issues of growth and development of the oral cavity have been the subject of numerous studies in the field of orthodontics, anatomy and maxillofacial surgery (1, 2). In an embryo, the LJ consists of two parts, which fuse together by the end of the first year of life. During infancy, a well-defined structure of the body and branches of the jaw is determined radiologically, but the main bone beams cannot be distinguished. With normal development of teeth and jaws, the process of eruption of temporary teeth begins at the 6th-8th month, which lasts up to 2-2.5 years. By the age of two, the jaw noticeably increases, its structure becomes denser, groups of main bone beams are clearly visible, which run along the body of the jaw and vertically from it to the alveolar process. Which is actively developing, the basal part of the lower jaw thickens, the branches of the lower jaw increase, the contours of the mandibular canal are changed, the size of the mandibular angle decreases, the topography (differentiation) and architecture of the lower jaw become more complicated (3, 4). From 4.5 to 6 years there is preparation for the period of variable bite. At the age of 3-9 years, there is an active restructuring of the spongy substance. In the frontal part, the bone acquires a medium-looped structure, and in the lateral part – large-looped (5, 6). From the age of 9, the growth of the jaws slows down, but a noticeable growth of the cellular process is noted. The ramus of the jaw increases intensively at the age of 3-4 and 9-11 years. She rises from the rear edge of the body of the lower jaw upwards and obliquely back, forms the angle of the lower jaw with the lower edge of the body. The growth of the jaw ends mainly by 15-17 years, when the formation of a constant bite is completed and the bone structure reaches the highest degree of differentiation (7, 8). The compact plate and the system of correspondingly oriented trabeculae of the cancellous substance of the bone are closely related to each other and form the base that perceives and transmits the load. This ensures the stability of the bone structure and determines the features of the distribution of stresses and deformations in it (9, 10, 12).

Previous works focus on age-related changes in tooth loss and reduced functional load. Studies of adults have shown significant differences in cortical bone properties (thickness, elasticity, degree of anisotropy) depending on tooth loss (11, 13, 14). The conducted research is based on the results of the analysis of intravital MSCT of children of different age groups. A distinctive feature of this work is the study of the radiomorphometric parameters of the thickness and density of the cortical and spongy layer in different anatomical areas of the LJ corresponding to the zones of typical localization of its fractures. Therefore, the specified parameters directly affect the efficiency and the possibility of installing plates during osteosynthesis (15-17).

The growth process of the lower jaw does not occur linearly, its takes with periods of acceleration and stabilization. In conclusion, we can say that obtaining and understanding data on the structure and its changes in the age aspect are necessary to increase the efficiency and ensure the "safety" of surgical interventions.

CONCLUSIONS

The width of the lower jaw in the process of its growth probably increases in different areas by an average of 6-58%, and this process occurs nonlinearly. Thickening of the cortical layer with age occurs more intensively than the general increase in its thickness and amounts to 41-51% for various areas of the jaw, except for the head of the condylar process. The radiological density of the cortical layer increases with age by 6-67%, and reaches 2064.2±180.54 in the older age group, while changes in the radiological density of the spongy layer remain unstable. The architectonic of the lower jaw must be taken into account when planning surgical interventions on the LJ in children's patients.

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STATEMENT OF CONFLICTS OF INTEREST

The authors state no conflict of interest.

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