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Anatomical and topographic classification of the mandibular canal with bone atrophy caused by the loss of the masticatory teeth

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ABSTRACT

The loss of teeth leads to disorders of the maxillofacial system, primarily causing bone atrophy, which by its destructive and morphological changes, affects the topographic features of the mandibular canal(s), causing a vector of restrictions in planning the rehabilitation of such patients.
To clarify these features, we conducted a study with the analysis of 2,457 3D digital images and a detailed morphometric study of 136 CT scans with the creation of 3D reconstruction models of the mandibular canal(s).
The identified anatomical variants and their systematization led to the aim to develop an informative anatomical and topographic classification of the mandibular canal with bone atrophy caused by the loss of the masticatory teeth for implementation in daily clinical practice.
In the body of the lower jaw, with a preserved dentition, the most common manifestations of the variant anatomy are bifid branches of the mandibular canal and, less often – trifid modifications that have a clear X-ray visualization. Also, additional independent canals with separate exit foramina on the outer surface of the chin area are diagnosed. However, their visualization is lost in the jaw with bone atrophy, leaving a reference point for the main trunk of the canal.
The results obtained confirm the expediency of creating an anatomical and topographic classification as an effective diagnostic tool to solve the problems of reconstructive, minimally invasive surgery presented in this paper.

Keywords: mandibular canal, bifid canal, trifid canal, mandibular nerve, bone atrophy, implantation

INTRODUCTION

Innovative development of medical progress provides an opportunity to choose effective, clinically proven methods for solving complex problems [1,2]. However, bone atrophy causes its vector of relevance and effectiveness in the applications of such innovations [3]. The proposed minimally invasive rehabilitation of patients with severe bone atrophy due to defects in the dentition or complete adentia, based on two implants [4,5], is often limited by its indications, due to the justification of the method of their use.

In turn, the results of clinical trials prove the effectiveness of achieving bone remodeling processes and partial compensation of lost volume by suppressing RANKL and IL-17A [6,7] under the conditions of existing pathology.

PRF (Platelet Rich Fibrin) and PRGF (Plasma Rich in Growth Factors) techniques are widely used, which differ in their effectiveness in directed bone regeneration in combination with osteotropic (bone-replacing) materials or their monocomponent use [8,9].

The issues of rehabilitation of patients with acquired bone atrophy due to the loss of the masticatory teeth remain uncoordinated, which has now become topical for in-depth research, thanks to available diagnostic methods, with all the morpho-

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logical structures that lie in it and with their topographic features [10–14].

Updated results of anatomical variation of the mandibular canal(s) have forced researchers to reconsider existing traditional claims [15–17] taught in educational institutions and justify their implementation in clinical practice.

Detailing the topography of the mandibular canal with its possible individual morphological characteristics is undoubtedly essential, both for preventing iatrogenic effects and for adequate rehabilitation of patients to restore the function of the maxillofacial system of patients or performing deep surgical interventions in these areas.

AIM

Based on the identified anatomical variants and our attempt to systematize them, this study aimed to develop an informative anatomical and topographic classification of the mandibular canal with bone atrophy caused by the loss of the masticatory teeth for implementation in daily clinical practice.

MATERIALS AND METHODS

The paper pre-analyzed 2,457 3D digital images, including 136 studies with a precise laying of the mandibular canal obtained using an extra-oral computed tomography system Vatech PaX-i 3D Green with 0.5 mm focal spot display (EC60336) on a 14-bit grayscale scale with a size of 0.2/0.3 voxels. Morphometric and 3D reconstruction analysis was performed using HEWLETT-SNCPUM1 computer technology with 16.0 GB of RAMB, 10 Pro for Workstations, 2019:00391-70000-00000-AA425, in the standardized computed tomography software "Vatech original 2020" after that, the material was divided according to the age of patients 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, people with preserved dentition (control group).

Morphometric studies (Figure 1), in the expression of absolute values, the location of the mandibular canal was carried out in the projection of the missing 3.7, 3.6, 4.6, 4.7 teeth relative to A) – the ridge of the mandibular base (RMB); B) – the buccal surface of the mandibular body (BR); C) – the lingual surface of the mandibular body (LR).

We used nonparametric statistical methods to compare the experimental groups 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.

This study was 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. The planned direction of these studies was reviewed by the Commission on biomedical ethics of Bukovinian State Medical University (Chernivtsi, Ukraine) and approved by Protocol No. 2 of 21.10.2021.

RESULTS

Anatomical awareness plays an important role in planning reconstructive surgical interventions, in particular, transposition of the neurovascular bundle, as well as its laying in the mandibular canal(s) with the places of their furcations (two or more), and in carrying out directed regeneration of bone tissue.

In the previous study, we presented [18] the classification of the topography of the mandibular canal

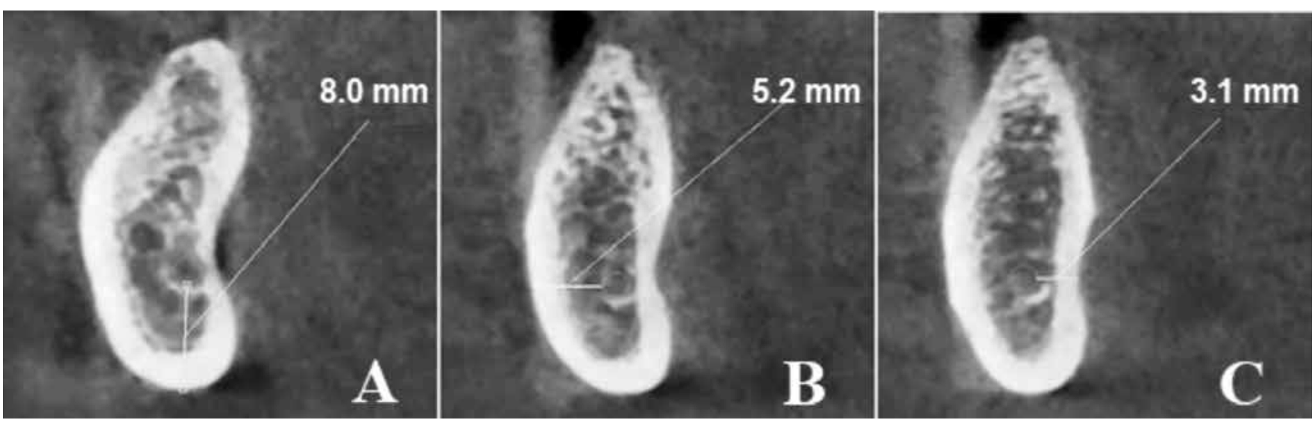


FIGURE 1. 3D reconstruction model for studying the topography of the main mandibular canal on the toothless segment, sections in the sagittal plane

(Table), which has become a clear and accessible diagnostic criterion, a significant theoretical achievement in topographic anatomy, and a tool of clinical thinking, but requires detail regarding the morphological structure of the canal: the diametric volume of the entrance and variants of the exit foramen(-ina), the length of the main trunk to its furcations, the density of the canal walls, etc.

TABLE 1. Classification of the topography of the human mandibular canal in case of bone atrophy caused by the loss of bone tissue of the masticatory teeth, 2022 (Oshurko AP, Oliinyk IYu & Kuzniak NB)

Class	Age, years	RMB, mm	BR, mm	LR, mm
First class (I-cl)	< 45	7.2 (ᵓ 7.0)	4.8 (ᵓ 5.0)	2.9 (ᵓ 3.0)
Second class (II-cl)	> 45	8.0	5.3	3.3

Note: RMB – distance from the ridge of the mandibular base to the mandibular canal (MC); BR – distance from the ridge of the buccal surface to the MC; LR – distance from the edge of the lingual surface to the MC. (ᵓ...) – a sign of approaching a specific number.

After conducting studies and carefully analyzing them, we found that additional canals are visualized in the control group (individuals with a preserved dentition, 25-75 years old) [19]. They branch off the main trunk or have independent laying with differentiation of entrance and exit foramina (Figure 2).

The most common manifestations of the variant anatomy are bifurcation branches with a slightly smaller tube diameter in the projection of the first sizeable angular tooth (first molar) with one type or two exit foramina and different localization and directions of their opening (Figure 3).

With a lower frequency, there are variants of the mandibular canal with a trifurcation branch (Figure 4) at different distances, with atypical locations of their exit foramina both posteriorly from the main trunk and near the middle.

Anatomical multifacetedness of the canal(s) variant with the same topographic laying's in the mandibular body preserves the priority X-ray visualization of the main trunk and the typical opening between small molars (Figure 5, 6). However, it indicates the autonomy of canals, the beginning of which is laid by a common entrance foramen. We assume that by different functional purposes. For the convenience of clinical interpretation, we have assigned them to the group of morphological variants – polycanal type of the lower jaw. Differential variant diagnosis is not difficult in well-mineralized

FIGURE 2. 3D reconstruction model of the variant anatomy of the mandibular canals and their entrance and exit foramina: A) single-canal morphology of the lower jaw on the right side with one (typical) exit foramen and polycanal – on the left side with three exit foramina; B) projections of (typical) entrance foramina on the right and left sides of the lower jaw.

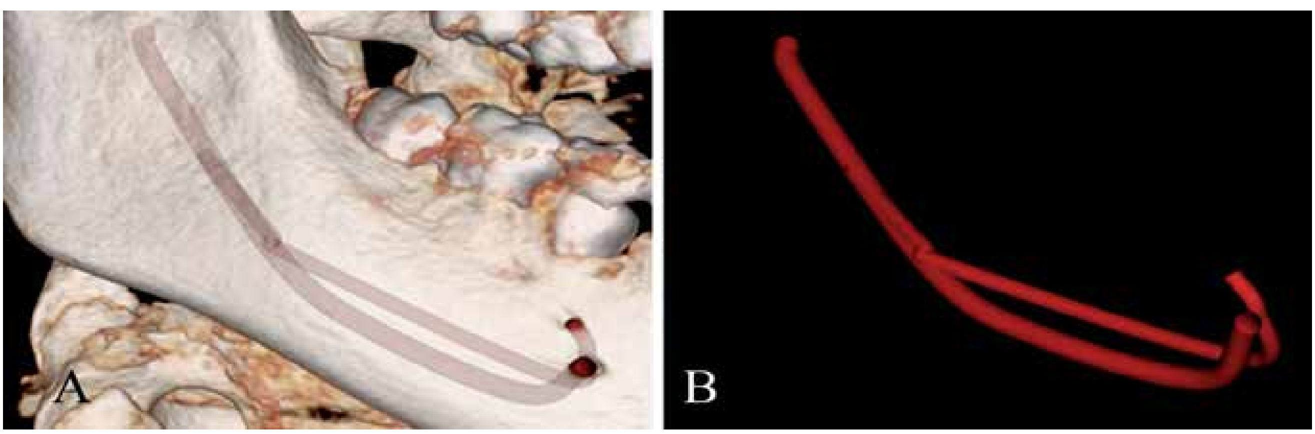


FIGURE 3. 3D reconstruction model of the variant anatomy of the bifurcation type of the mandibular canal and its exit foramina: A) single-canal bifurcation type with two separate exit foramina on the right side; B) a 3D reconstruction model of the bifurcation type of the morphological structure of the canal.

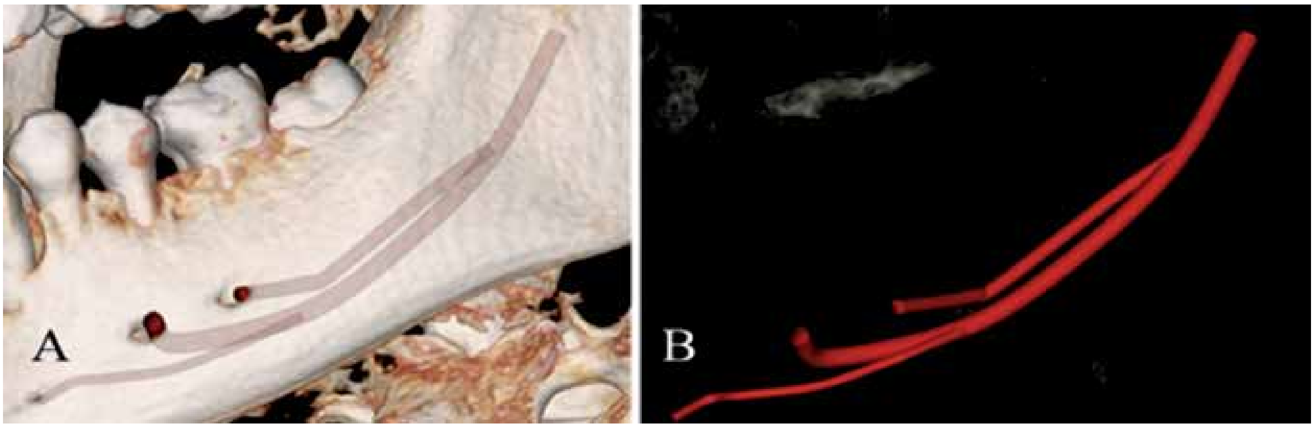


FIGURE 4. 3D reconstruction model of the variant anatomy of the trifurcation type of the mandibular canal and its exit foramina: A) single-canal trifurcation type with three separate exit foramina on the left side; B) a 3D reconstruction model of the trifurcation type of the morphological structure of the canal.

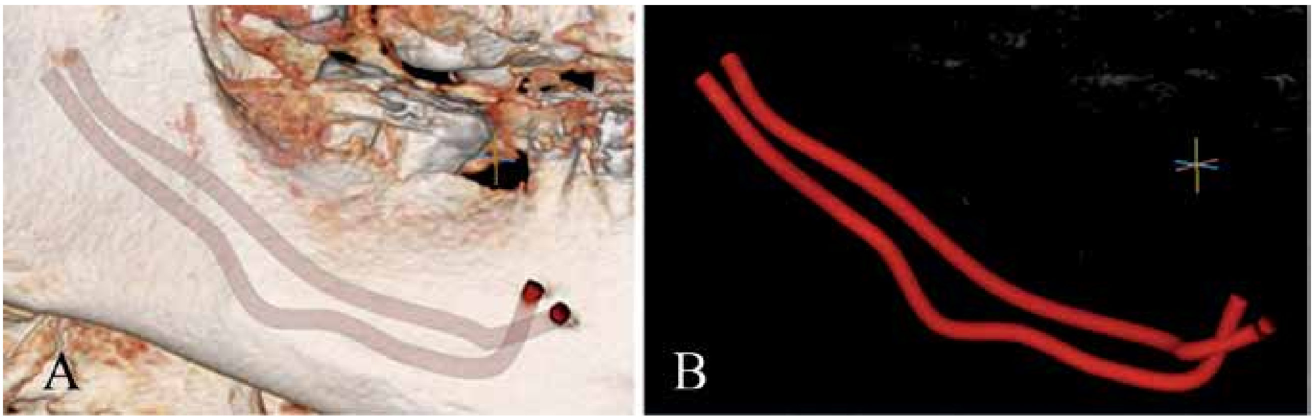


FIGURE 5. 3D reconstruction model of the variant anatomy of the polyfurcation type of the mandibular canal and its exit foramina: A) two-canal bifurcation type with two separate exit foramina on the right side; B) 3D reconstruction model of a two-canal variant of the morphological structure of canals on the right side.

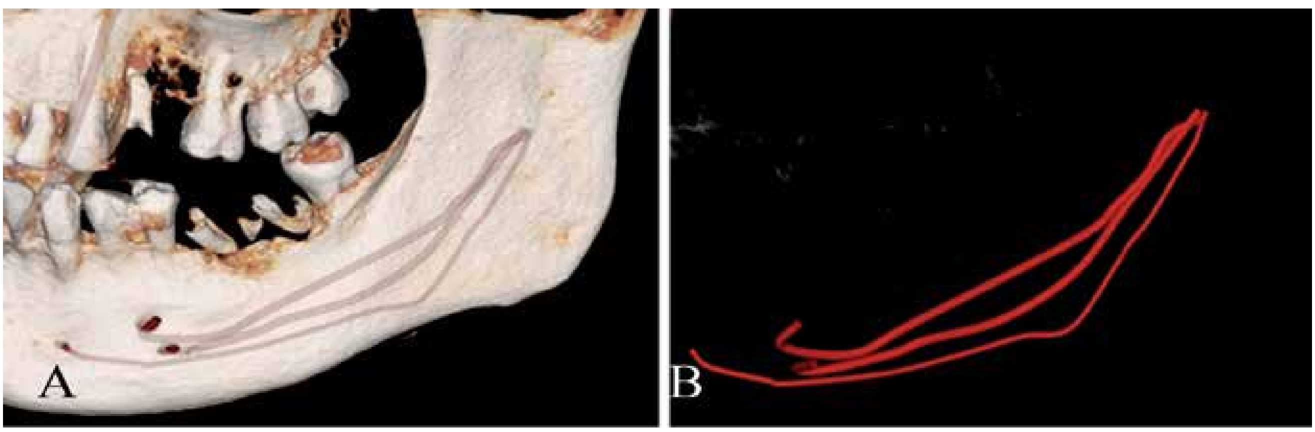


FIGURE 6. 3D reconstruction model of the variant anatomy of the polyfurcation type of the mandibular canal and its exit foramina: A) three-canal type with three separate exit foramina on the left side; B) 3D reconstruction model of a three-canal variant of the morphological structure of canals on the left side.

trabecular layers of jaw bone tissue. The frequency of manifestations of polycanal types of the lower jaw is not high, and they are challenging to diagnose and cannot be traced in toothless jaws with low bone density.

This justification is caused by the complexity in the study of their differentiation due to the ratio and topographic variability even at short intervals of the mandibular body. Also, their displacement is noted relative to the most stable and steady atrophic

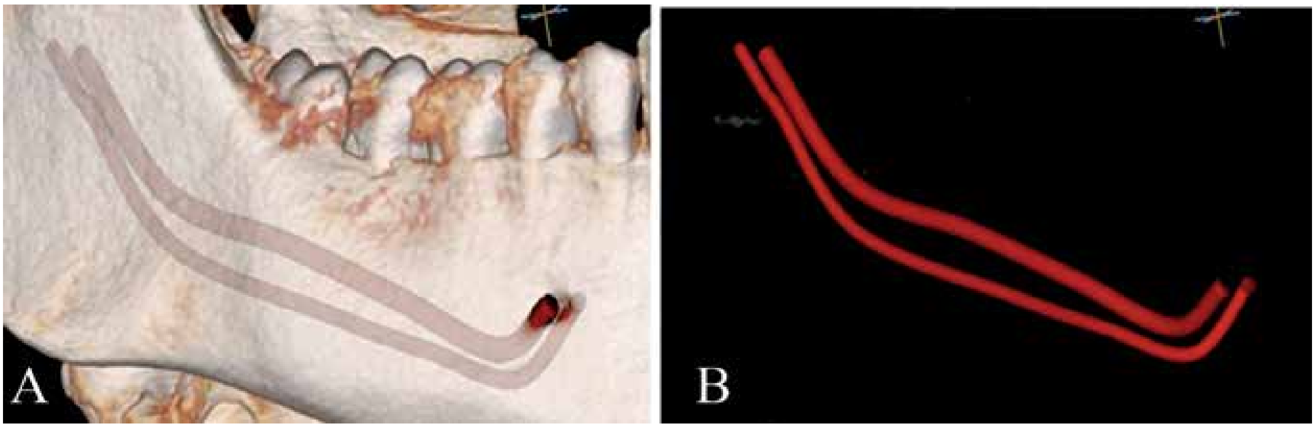


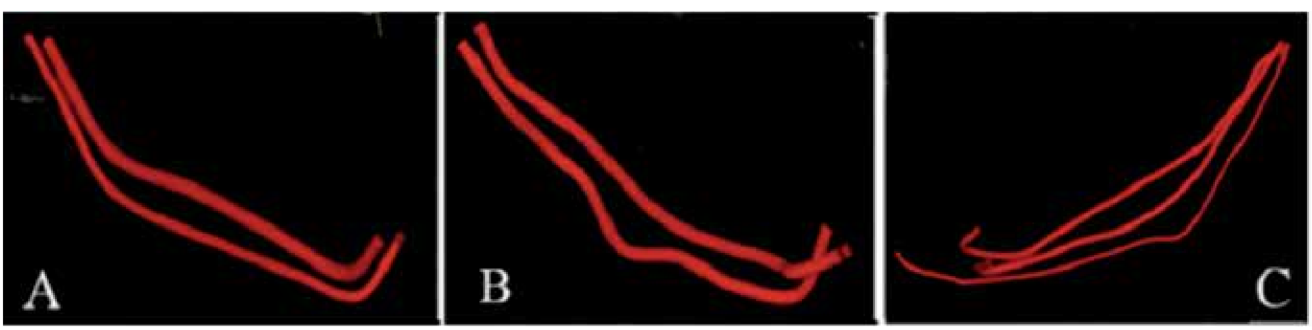
FIGURE 7. 3D-reconstruction model of the variant anatomy of the polycanal type of the lower jaw with a unifying exit foramen: A) two-canal type with one exit foramen on the right side; B) 3D reconstruction model of a two-canal variant of the morphological structure of canals on the right side.

changes in the sides of the lower jaw – the lingual and lower ridge of the base of its body. 3D reconstruction reproduction is excluded by superimposing an imprint of the transferred destructive and inflammatory processes or their presence for the duration of the study.

I. By anatomical variation:

1.1. Single-canal type (single-tube – A, bifurcation – B, trifurcation – C)

1.2. Polycanal type (two-canal – A and B, multi-canal – C)



II. By topographic ratio:

First class (I-cl, < 45 years old):

– **RMB**, distance from the ridge of the mandibular base to the mandibular canal – 7.2 (=7.0) mm;

– **BR,** distance from the ridge of the buccal surface to the mandibular canal – 4.8 (=5.0) mm;

– **LR**, distance from the ridge of the lingual surface to the mandibular canal – 2.9 (=3.0) mm.

Second class (II-cl, > 45 years old);

– **RMB**, distance from the ridge of the mandibular base to the mandibular canal – 8.0 mm;

– **BR,** distance from the ridge of the buccal surface to the mandibular canal – 5.3 mm;

– **LR,** distance from the ridge of the lingual surface to the mandibular canal – 3.3 mm.

Note: (=...) – a sign approaching a specific number.

FIGURE 8. Anatomical and topographic classification

There are variants of a two-canal lower jaw with a unifying exit foramen (Figure 7), which remain difficult to diagnose and pose risks during reconstructive surgical interventions or even treatment of fractural displacements during jaw fractures. After all, their close location, a slight difference in diametric ratios, can make up a false diagnostic imagination, especially with low bone density reflected in its tunnel structure.

A description is presented with a 3D reconstruction of the mandibular canal(s), taking into account our previous studies' results (see below). Classification of the topography of the human mandibular canal in case of bone atrophy caused by the loss of bone tissue of the masticatory teeth, 2022 (Oshurko AP, Oliinyk IYu & Kuzniak NB) [18] prompted the creation of a new anatomical and topographic classification of the mandibular canal, which combines into a universal diagnostic criterion that covers the topographic features of the canal(s) in the toothless segments of the body of atrophied bone tissue of the lower jaw, which is presented below (Figure 8).

DISCUSSIONS

The intensity of the study of the morphological variation of the mandibular canal increases every time. It is updated with a load of information that requires both theoretical (research) and practical testing.

Work (Langlais RP, Broadus R, Glass BJ) with a high level of citation more than 290 times, conducted using a simple 2D X-ray image back in 1985, was published on the pages of the Journal of the American Dental Association, already indicated the detection of a bifid manifestation of the mandibular canal [20].

Nowadays, most authors direct their research to the application of classification by Naitoh [21], which characterizes the anatomical variation of the mandibular canal in individuals with a preserved dentition.

With bone atrophy caused by the loss of the masticatory teeth, there is a morphological restructuring of the mandibular body and morphofunctional structures, such as the mandibular canal(s). Therefore, to build a classification, it becomes necessary to take the laying of the canal as the primary, well-visualized tubular tunnel, its topography relative to the lingual and buccal surfaces, and the lower edge of the mandibular body. Such systematization requires taking into account individual variant-anatomical manifestations of the «canal system», their degenerative changes depending on the time of tooth loss or the duration and course of destructive processes of bone tissue, which are reflected in the topographic features of the mandibular canal(s), during computed tomographic studies.

We did not consider postmolar branches with a high frequency of manifestations and variability since their topography did not have a particular significance in our work. We only conducted a conditional analysis of them during the study and clinical experiment. We agree that understanding their topography in this jaw area is essential during atypical operations to extract retinized wisdom teeth or collect a bone autograft [22,23].

Authors [24], in the summary of their work, note that «Bifid and trifid mandibular canals result from abnormal fusions of nerve canals». However, there is a high frequency of manifestations of bifid mandibular canals of bifid and trifid modifications [25,26]; although they differ in the presented values of manifestation in the given percentages from the number of the objects under study, it gives the right to challenge such «assumptions» and assert their **normal** anatomical variation.

We present the term «main canal», which is always well visualized at different types of density and even with pronounced processes of bone atrophy. The same opinion is accompanied in the research work [27] with the confirmation that the identified canals are additional, are laid separately from the main trunk, or merged with it, at different intervals and with different variations of branches.

This research topic will remain debatable for the next few years; the newer the capabilities of optional software tools, the more filled with updated results of normal anatomy [28], which become guides in clinical application.

CONCLUSIONS

Bifurcation of the mandibular canal with bifid and trifid modifications are normal anatomical variants.

The mandibular canal has a clear X-ray visualization and functional-architectonic structure and is its central canal. Canals that branch off from the main trunk, or are laid separately at different intervals of the mandibular body, are additional.

Anatomical and topographic classification of the mandibular canal, 2022 (Oshurko AP, Oliinyk IYu & Kuzniak NB), which covers its morphological and topographic features and combines them into a single universal diagnostic criterion, has been tested and implemented in clinical use and has a scientific basis.

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