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STUDY OF THE MANDIBULAR INCISIVE CANAL ANATOMY USING CONE BEAM COMPUTED TOMOGRAPHY

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Abstract:	Purpose: The aim of the present study was to identify the range of individual variability in dimensions and topography of the mandibular incisive canal (MIC) in vivo. Methods: One hundred Cone-Beam Computed Tomography (CBCT) scans of patients from dental outpatient hospitals of Minsk, Belarus were performed on Galileos GAX5 using standard exposure and patient positioning protocol. Reformatted panoramic and sagittal CBCT images were analyzed. Results: The MIC was visualized in 92% of CBCT images. It was detected in the first premolar root region in 93% of cases, and only in 21% of cases it reached the central incisors root area. The MIC started prior to the mental foramen opening with formation of the anterior mental loop in 48% of cases. The MIC started at the level of the mental foramen or close to it in 52% of cases. The degree of MIC visibility and its internal vertical diameter decreases when it comes closer to the midline of the mandible. The distance from the roots of teeth to the upper wall of MIC increases in the mesial direction, while the position of MIC in relation to the base of the mandible remains virtually unchanged. Conclusions: The MIC can appear in a different length and can reach the level of the root of the central mandibular incisor. Individual topography of MIC should be determined during the preoperative radiological examination and surgical procedures in the anterior region of the mandible.

STUDY OF THE MANDIBULAR INCISIVE CANAL ANATOMY USING CONE BEAM COMPUTED TOMOGRAPHY

Original article

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Classical anatomy textbooks state that all mandibular teeth and gingiva are innervated by the inferior dental plexus, which is formed by the branches of the inferior alveolar nerve located in the mandibular canal [8]. The canal starts with the foramen on the inner (lingual) surface of the mandibular ramus and passes through the body of the mandible to the mental foramen. The mental foramen is located on the outer (buccal) surface of the body of the mandible and contains the neurovascular bundle including the mental nerve, which is the branch of the inferior alveolar nerve. The mental nerve separates out in the molars region and innervates the skin of the lower lip and chin [32]. Before emerging from the mandibular canal it often forms the so-called anterior loop of the mental nerve, i.e. it is located in front of the projection of mental foramen first, and then changes the direction following upwards, back (posteriorly) and outwards [10].

The results of detailed anatomical studies and radiographic data obtained with the implication of modern diagnostic equipment show that the mandibular canal divides in the region of the first lower premolar's root into two branches: mental canal and incisive canal [7, 10, 16, 21, 22, 27, 30, 35]. The mandibular incisive canal often begins mesially to the projection of the mental foramen and goes forward parallel to the roots of the anterior teeth [36]. It has a variable length, and according to Mraiwa et al. reaches the midline in 18% of cases [18]. The mandibular incisive canal may also terminate with a foramen close to the genial tubercle on the lingual surface of the body of the mandible [27]. Blood vessels and nerves follow the canal and reach the root apices of first premolars, canines and incisors through inter-trabecular spaces.

Knowledge of the exact location and quantitative parameters of the mandibular incisive canal has high practical value. In vivo detection of the above mentioned structure reduces the risk of anatomical and functional complications of surgical procedures in the mental area, including dental implantation, bone harvesting and screw-retained plating of mandibular fractures [22].

The aim of the present study was to identify the range of individual variability in the diameter, length and topography of the mandibular incisive canal in vivo.

Material and Methods

During the retrospective study 100 cone-beam computed tomography (CBCT) scans of patients from dental outpatient hospitals of Minsk, Belarus were analyzed. Fifty three scans were taken from male patients and 47 scans were taken from female patients (range: 15-72, mean age: 38.3, SD: 14). All participants had no clinical and/or radiographic signs of mandibular pathology or previous surgery as well as any history of head and neck trauma in the past. All CBCT scans were performed on Galileos GAX5 (Sirona Dental Systems, Bensheim, Germany) using standard settings (85 kV; tube current: 5–7 mA; acquisition period: 14 s; effective radiation time: 2-6 s; voxel size: 0.3 × 0.3 × 0.3 mm). Reformatted panoramic and sagittal CBCT images were analyzed using GALILEOS Viewer (Sirona, Bensheim, Germany).

The following data were obtained from CT scan sections:

- the distance from the top border of MIC to the tooth at the level of which could the canal could not be visualized anymore;
- the distance from the lower border of MIC to the inferior border of the mandible at the level of the root apices of teeth where the canal was visualized;
- the distance from the border of MIC to the buccal cortical plate of the mandible;
- the distance from the border of MIC to the lingual cortical plate of the mandible;
- internal vertical diameter of MIC.

The appearance of the mandibular incisive canal was assessed using the four-point scale (Table 1).

Table 1 Rank scale for sagittal sections

rank	the degree of visualization	radiographic features
0	the canal is not visualized	network structure of cancellous bone only
1	the canal is poorly visualized	a continuous rounded radiolucent area without radiopaque walls
2	the canal is moderately visualized	a continuous rounded radiolucent area, defined by intensive thin radiopaque line (cortical plate) on one side
3	the canal is well visualized	a continuous rounded radiolucent area, defined by intensive thin line (cortical plate) on two sides

The length of MIC was defined as the distance from mental foramen to the roots of teeth (the first premolar, canine or central/lateral incisor) at the level of which the canal could not be visualized any more.

The degree of visualization of MIC was evaluated by two independent observers who were trained and calibrated in visual CT-scan analysis by the certified specialist in radiology. The overall score of 0.61 for the interobserver agreement for the degree of visualization of the MIC was obtained using kappa statistics[13] which showed substantial agreement between observers.

In addition to CBCT analysis, a macroscopic study of MIC walls was performed in four dry human hemi-mandibles. The MIC was opened in the longitudinal direction by removing the buccal cortical plate after decalcification in nitric acid in two cases (Fig. 1). In other two cases, anterior regions of mandibles were sectioned perpendicular to the axis of the body of mandible in 5 mm intervals. Figures 2 and 3 illustrate different degrees of visibility (corticalization) of the wall of MIC, revealed by CBCT and on anatomical specimens.

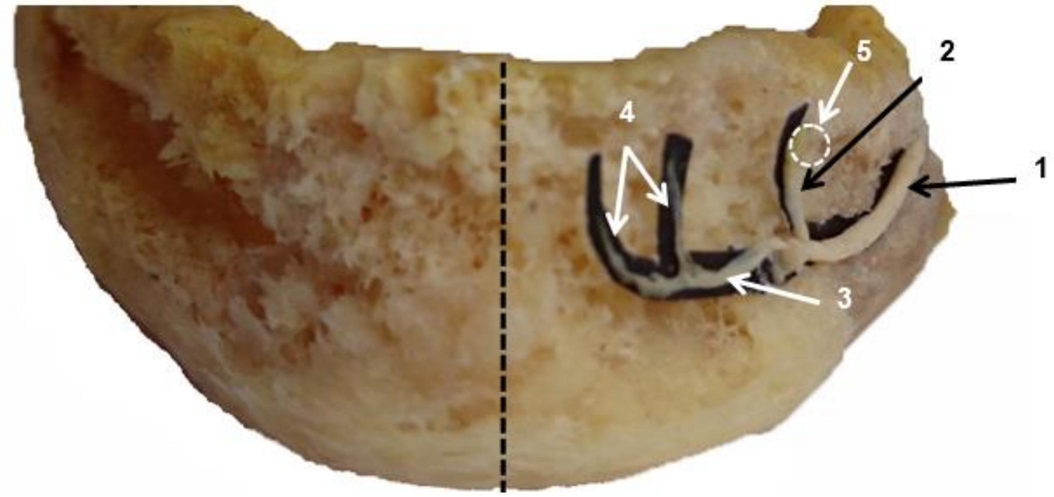

Fig. 1 Intraosseus branches of the inferior alveolar nerve
1 – inferior alveolar nerve; 2 – mental nerve; 3 – mandibular incisive nerve; 4 – inferior dental branches; 5 – level of mental foramen. Anterior view of edentulous mandible (buccal cortical plate removed)

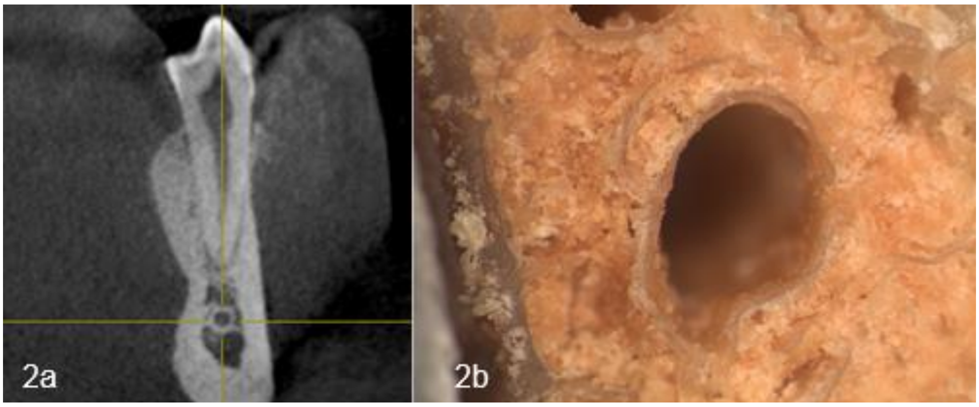

Fig. 2 Complete corticalization of mandibular incisive canal walls (rank 3) in the sagittal CBCT section at the level of the right first lower premolar (2a) and in the cross-section of dry mandible 5 mm anteriorly from the right mental foramen (2b)

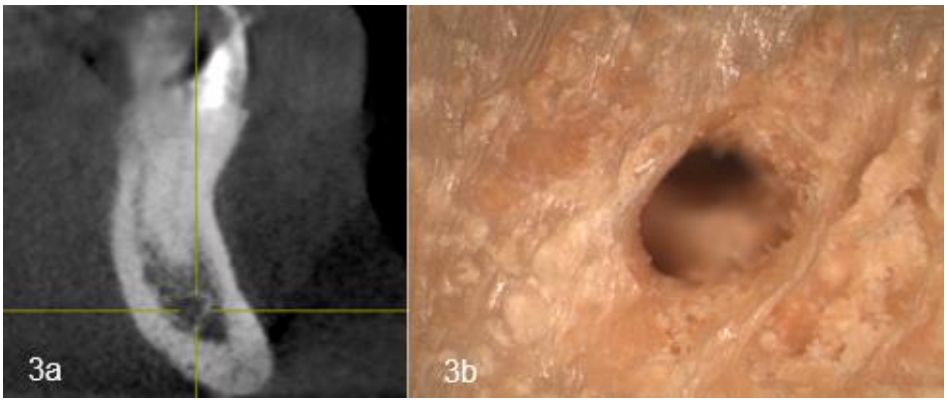

Fig. 3 Partial corticalization of mandibular incisive canal walls (rank 2) in the sagittal CBCT section at the level of the left lower canine (3a) and in the cross-section of dry mandible 10 mm anteriorly from right mental foramen (3b)

Results obtained in this study were processed in STATISTICA (version 10.0) software package (StatSoft, Inc., USA). Statistical significance of intergroup differences of studied parameters was assessed using non-parametric statistical tests, because obtained data did not follow the Gaussian distribution model according to Kholmogorov-Smirnov and Lillieforce criteria. The comparative analysis of independent groups was performed using Mann–Whitney U test. The differences between groups were considered statistically significant at $p < 0.05$. Results are presented as Me (median) and interquartile range (Q25; Q75). The study protocol was approved by Belarusian State Medical University Ethical Committee (Minsk, Belarus). Being a retrospective study, informed consent was not required.

Results

Mandibular incisive canal is the real anatomical structure containing neurovascular elements. It was found in 92% of assessed CBCT scans. The length of MIC varied in a wide range. It was detected at the first premolar root level in 93% of cases, at the canine root level in 70.5% of cases, at the of the lateral incisor root level in 32.5% and only in 21% of cases it reached the central incisors root area (Fig. 4).

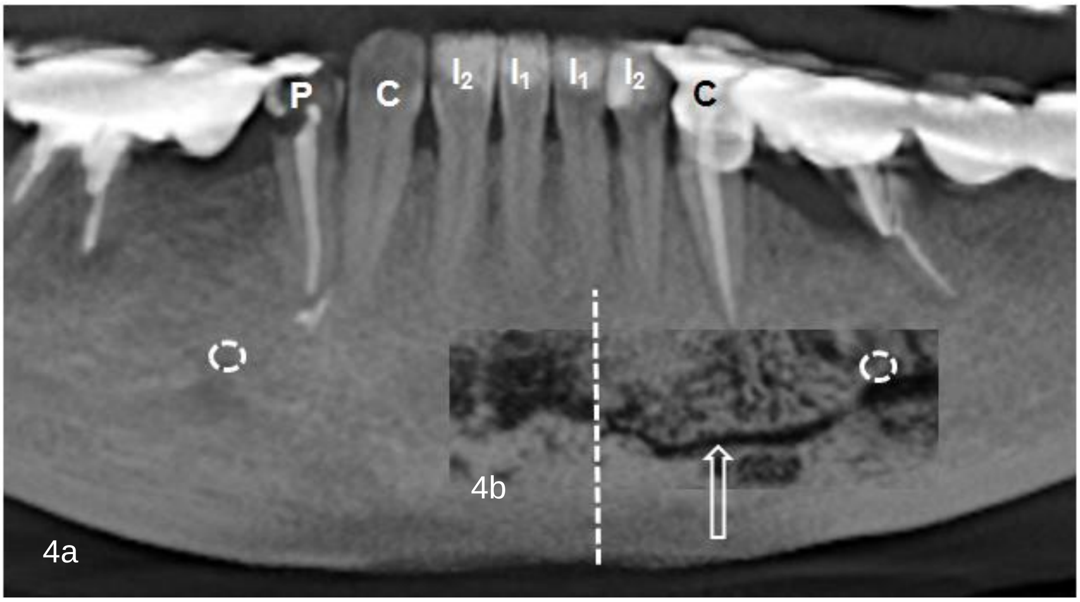

Fig. 4 Mandibular incisive canal (arrow) running from mental foramen (circle) to the level of central incisor's (I_1) root:
4a – panoramic CBCT image section; 4b - thin-slice panoramic CBCT image section
P – lower premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

The MIC started prior to the mental foramen opening with formation of the anterior mental loop in 48% of assessed cases. The MIC started at the level of the mental foramen or close to it in 52% of cases.

The data on the degree of MIC visibility at different levels are graphically summarized in Fig. 5.

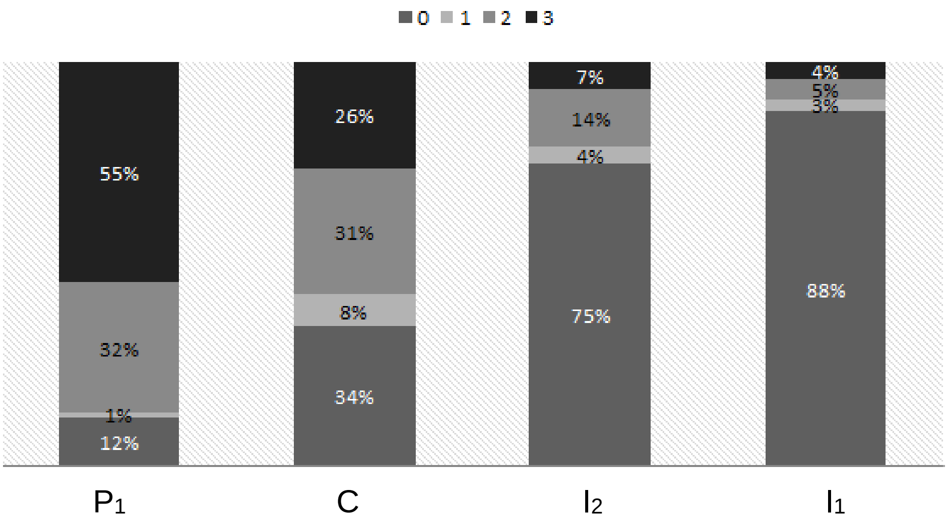

Fig. 5 Visibility ranking (%) of MIC at different teeth roots levels on CBCT scan images
0 - the canal is not visualized; 1- the canal is poorly visualized; 2 - the canal is moderately visualized; 3 - the canal is well visualized
P_1 – lower first premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

Our findings indicate that the cortical plate of MIC loses its visible integrity in the mesial direction and gradually ceases due to the decrease in the thickness of the bone substance in its wall. Eventually, blood vessels and nerves pass from MIC to root apices through the spaces between spongy bone trabeculae.

Internal vertical diameter of MIC decreases when it comes closer to the midline of the mandible (Table 2, Fig. 6). It is twice as less at the level of the central incisor's root (Me - 0.8 mm) as at the level of the first premolar's root (Me – 1.6 mm). However, the difference in the MIC diameter between the right and left sides or between male and female patients is not statistically significant.

Table 2 Internal vertical diameter of the mandible incisive canal, Me(Q25;Q75), lim

Teeth	Overall	Right side	Left side	Male	Female
Central incisors	0.8 (0.7;1.0)	0.9 (0.7;1.2)	0.8 (0.7;0.9)	1.1 (0.7;1.5)	0.8 (0.7;0,9)
	0.6-1.5	0.6-1.5	0.6-1.5	0.7-1.5	0.6-1.5
n	18	9	9	6	12
Lateral incisors	1.0 (0.8;1.3),	1.1(0.7;1.3)	1.0 (0.8;1.4)	1.0 (0.8;1.4)	1.1(0.8-1.3)
	0.6-2.8	0.5-2.8	0.7-1.9	0.6-2.8	0.6-1.9
n	43	19	24	22	21
Canines	1.2 (1.1;1.6),	1.2 (1.1;1.5)	1.3 (1.0;1.6)	1.3 (1.0;1.6)	1.2 (1.0-1.6)
	0.6-2.7	0.6-2.2	0.6-2.7	0.6-2.7	0.8-2.2
n	133	64	69	55	78
First premolars	1.6 (1.3;1.9),	1.6 (1.4;2.0)	1.6 (1.4;1.9)	1.6 (1.3;1.9)	1.6 (1.4;1.9)
	0.6-3.9	0.6-3.0	0.9-3.9	1.0-3.0	0.6-2.6
n	182	90	92	81	101

n – number of teeth

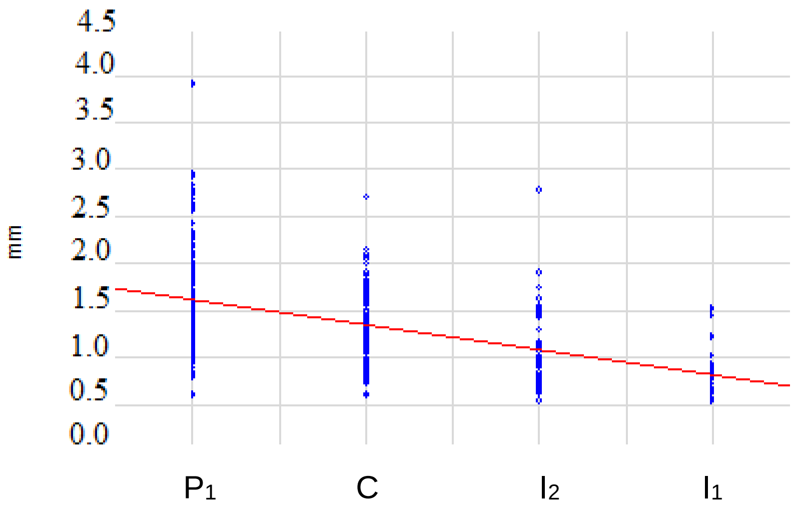

Fig. 6 Internal vertical diameter of mandibular incisive canal at different teeth roots levels
P_1 – lower first premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

Distances from MIC to inferior border of the mandible, to buccal and lingual cortical plates of the mandible, as well as to root apices of teeth are shown in Table 3.

Table 3 Values of the distance from the mandibular incisive canal (MIC) to various mandibular landmarks, Me(Q25;Q75), lim

Teeth	Overall	Right side	Left side	Male	Female
Distance of the mandible incisive canal to inferior border, of mandible					
Central incisors	9.8 (8.4;10.7)	9.4 (9.2;11.77)	10.2 (8.4;10.6)	10.7(10.6;11.9)	9.3 (8.2;10.3)

	6.6-15.3	6.7-15.3	6.6-11.9	7.8-13.0	6.6-15.3
n	18	9	9	6	12
Lateral incisors	9.2 (8.4;11.2)	9.6 (9.0;12.0)	9.1 (8.3;10.6)	9.2 (8.4;11.2)	9.2 (8.6; 11.7)
	5.6-13.4	7.5-12.9	5.6-13.4	5.6-13.4	8.2-12.9
n	41	18	23	22	19
Canines	8.5 (7.2;9.8)	8.1 (7.1;9.6)	8.6 (7.4;9.8)	8.0 (6.9; 9.1)*	8.8 (7.4;10.0)*
	5.3-14.9	5.3-13.5	5.5-14.9	5.3-14.9	5.8-14.1
n	124	60	64	53	71
First premolars	9.5 (8.2;10.5)	9.4(8.1;10.2)	9.7 (8.4;10.8)	9.5 (8.4;10.2)	9.6 (8.2;10.9)
	3.2-15.5	3.2-15.5	6.5-13.2	5.8-15.5	3.2-13.3
n	171	84	87	79	92
Distance of the mandible incisive canal to lingual cortical plate of the mandible					
Teeth	Overall	Right side	Left side	Male	Female
Central incisors	5.7 (3.9;6.6),	5.9 (3.9;6.6)	5.6 (4.5;6.9)	6.8 (4.8-7.2)	5.6 (3.9-6.3)
	3.4-9.4	3.7-7.2	3.4-9.4	4.0-9.4	3.4-7.3
n	18	9	9	6	12
Lateral incisors	5.5 (4.2;7.3),	6.1 (4.2;7.5),	5.3 (3.9;6.3),	5.4 (4.3-6.6)	6.0 (4.2-7.5)
	2.2-10.6	2.9-10.0	2.2-10.6	2.7-10.6	2.2-9.4
n	43	19	24	22	21
Canines	4.4 (3.3;5.6),	4.4 (3.4;5.3)	4.3 (3.2;5.9)	4.0 (3.3-5.0)	4.4 (3.3;5.9)
	1.3-10.0	1.5-10.0	1.3-8.8	1.3-10.0	1.5-8.9
n	133	64	69	55	78
First premolars	4.8 (3.7;6.0),	4.8 (3.8;5.9)	5.0 (3.6;6.0)	4.8 (3.7-5.8)	4.9 (3.9-6.1)
	0.6-9.0	1.2-8.9	0.6-9.0	1.2-9.0	0.6-9.0
n	182	90	92	81	101
Distance of the mandible incisive canal to buccal cortical plate of the mandible					
Teeth	Overall	Right side	Left side	Male	Female
Central incisors	5.7 (4.8;6.6)	5.1 (3.3;6.6)	5.7 (5.1;6.2)	5.1 (4.8;7.8)	5.8 (4.7-6.4)
	2.5-8.1	2.5-7.8	4.8-8.1	2.5-8.1	3.0-7.4
n	18	9	9	6	12
Lateral incisors	4.3 (3.2;5.2)	3.5 (2.6;4.7) *	4.8 (3.7;5.9)	4.2 (3.5;5.1)	4.4 (3.2;5.2)
	1.4-7.3	1.4-6.5	1.8-7.3	1.4-7.3	2.5-7.0
n	43	19	24	22	21
Canines	3.9 (2.9;5.4)	3.8 (2.9;5.2)	4.0 (2.9;5.6)	3.7 (3.0;5.4)	4,0 (2.6;5.4)
	1.4-8.0	1.3-7.8	1.1-8.0	1.3-7.8	1.1-8.0
n	133	64	69	55	78
First premolars	2.9 (2.2;3.8)	2.8 (2.1;3.7)	3.0 (2.2;3.9)	3.0 (2.0;3.5)	2.9 (2.3;4.0)
	1.0-7.5	1.0-7.5	1.1-7.0	1.1-7.0	1.0-7.5
n	182	90	92	81	101
Distance of the mandibular incisive canal to root apex					

Teeth	Overall	Right side	Left side	Male	Female
Central incisors	8.1 (6.8;8.7)	8.3 (6.8;8.5)	8.0 (7.0;10.8)	7.7 (6.8;7.9)	8.4 (7.0; 10.8)
	4.0-13.1	4.1-13.1	4.0-12.6	4.0-8.4	4.1-13.1
n	17	9	8	5	12
Lateral incisors	6.7 (5.5;8.5)	5.9 (4.7;7.0)	7.6 (5.6;8.6)	7.8 (6.1;8.5)	5.7 (5.5;7.4)
	1.3-11.4	1.3-10.1	2.7-11.4	3.6-11.4	1.3-11.0
n	42	18	24	21	21
Canines	5.2 (3.1;7.3)	5.5 (3.3;7.6)	5.2 (3.1;6.6)	5.3 (3.9;7.0)	5.0 (2.7;7.3)
	0.1-15.6	0.0-15.6	0.8-12.6	1,9-11,6	0.0-15.6
n	132	63	69	55	77
First premolars	5.2 (3.4;7.1)	5.4 (3.9;7.2)	5.1 (3.2;7.0)	5.2 (3.4;6.7)	5.1 (3.4;7.4)
	0,1-14.4	0.00-3.9	0.6-14.3	0.6-10.9	0.0-14.4
n	175	88	87	76	99

n – number of teeth
* – significant difference (p>0.05)

Discussion

Mandibular incisive nerve was first defined as an independent branch of the inferior alveolar nerve with an intrabony path mesially to the mental foramen by Oliver in 1928 [20]. During embryogenesis mandible bud formation starts from the point of branching of the inferior alveolar nerve into its terminal branches (mandible incisive and mental nerve). With time ossification zone extends distally and mesially [6, 25, 26]. Therefore, the presence of the incisive nerve determines the formation of the bone canal around it.

Current anatomical studies illustrate that MIC containing the same-name nerve is not a sign of individual morphological variability, but the permanent anatomical structure, which is revealed in more than 90 % of people with dentate mandible (Table 3). The presence of MIC in dissections of edentulous mandibles was revealed in 31% of cases [19].

Detection frequency of MIC on CBCT scans in adults ranges from 71.6% to 100% [22]. In children and adolescents, MIC was found to appear on CBCT scans in 49.5% of cases [3]. In our study, the presence of MIC was noticed in 92% of cases that could be defined as high prevalence. The end point of the well visualized MIC varied from being noted at the level of the first premolar in 55% of cases to the level of the central incisor in 4% of cases. In comparison, MIC with good visibility was identified in 22% of the cases utilizing spiral CT scans [9]. In children, Cantekin et al. reported good visibility of MIC on CBCT scans only in 7.5% of all observations [3].

In 48 % of cases MIC started anteriorly to the mental foramen (Type I), and in 52 % of cases – at the level of the mental foramen (Type II). Obtained data do not coincide with the results of Yovchev et al. [36], which found much higher prevalence of Type I MIC over Type II. Our results are also in disagreement with findings of Couto-Filho et al. [5] regarding the prevalence of the anterior loop identified through CBCT. It was detected only in 29.8% of the samples using CBCT. In case of Type I MIC the mental nerve forms the anterior loop before leaving the mental foramen [10]. Damage to this loop or MIC perforation can generate neurological symptoms associated with implant placement in the anterior mandible [11, 12]. Those symptoms include pain and discomfort in the lower lip and/or incisors and, according to Walton, are found in 24 % of cases being mainly transient up to 2 weeks after surgery [33]. Permanent sensory disturbances in the anterior region of the lower lip were detected by Wismeijer et al in 7% of the cases where 2 - 4 implants were placed [34]. All of them were installed in the so-called mandibular "safe zone", i.e. at least 3 mm anterior to the mental foramen. Most likely, the incisive nerve damaged rather than the mental nerve.

Another complication of surgical procedures in the anterior mandible is postoperative bleeding, which in turn can cause compression of the incisive nerve and appearance of neurological symptoms [13, 21].

The length of MIC can vary in a wide range from 7 to 24 mm (Table 3). The practical importance though is not so much the length of MIC but the level at which MIC is detected in relation to the roots of the teeth. In 93 % of analyzed cases it was detected at the level of the first premolar, in 70.5 % of cases at the level of the canine, in 32.5 % of cases at the level of the lateral incisor and only in 21 % of the scans the canal reached the root of the central incisor. Topçu et al. [29] in Turkish patient population found MIC at the level of the first premolar in 95% of cases, in 90% – at the level of the canine, in 78% – at the level of the lateral incisor, and in 55% of cases at the level of the medial incisor. In comparison, Xu et al. [35] found that in 70% of the samples MIC terminated at the level of the lateral incisor in Chinese population.

The diameter of MIC decreases in the direction to the midline of the mandible. Our findings coincide with the range reported previously by other researchers (Table 4). It shows the absence of significant regional, gender and racial differences in the MIC diameter, as well as the similarity of the technical specifications of CBCT units used

Table 4 The incidence and dimensions of the mandibular incisive canal according to different authors

Investigators	Total number of cases in study	Type of study	%	MIC length (mm) M±SD	MIC width (mm) M±SD	Nation
Xu et al. [35]	80 hemi-mandibles	In vitro (cadaver)	100	24,87 ± 2.23	1.76 ± 0.27	China
Yu et al. [37]	26 hemi-mandibles	In vitro (cadaver)		-	2.22±0.59	Korea
Mardinger et al. [17]	46 hemi-mandibles	In vitro (cadaver)	100	-	Range, 0.48 to 2.19	Israel
Mraiwa et al. [18]	50	In vitro (cadaver)	96	-	1.8 ± 0.50	Belgium
Obradovic et al. [19]	105 (70- dentulous; 35 – edentulous)	In vitro (cadaver)	92 – dentulous 31 - edentulous			Serbia
Pereira-Maciel et al. [22]	100	In vivo (CBCT)	100	9,8 ± 3.8	-	Brasil
Ramesh et al. [27]	120	In vivo (CBCT)	71,66	10,173	2.578	India
Apostolakis & Brown [2]	102	In vivo (CBCT)	93	8,9 (range, 0 to 24.6)	-	Greece
Yovchev et al. [36]	140	In vivo (CBCT)	92.9		1.44 ± 0.39 (0,7 – 2,5)	Bulgaria
Al-Ani et al. [1]	60	In vivo (CBCT)	100			Malaysia
Pires et al. [23]	89	In vivo (CBCT)	83	7 ± 3,8	0.4 × 0.4 - 4.6 × 3.2	USA
Sokhn et al. [28]	40	In vivo (CBCT)	97,5%			Lebanon
Parnia et al. [21]	96	In vivo (CBCT)			1.47 ± 0.50	Iran
Makris et al. [16]	100	In vivo (CBCT)	83,5%	15 (from mental foramen)		Greece

The difference in MIC detection using radiographic methods and individual variations in length may be associated with its diameter. Approaching the midline, it becomes so small that the resolution of the CBCT is not enough for MIC visualization [23]. In some cases mandibular anterior teeth are innervated by the incisive nervous plexus that contains small- diameter bundles of nerve fibres which are located not the canal directly but in the spaces between the spongy substance of the mandible [15, 18].

The frequency of incisive canal detection depends on the quality of images obtained by cone beam computed tomography [3]. Some unexpected conditions such as subtle movements of a patient can worsen the image. Image quality also gets influence from the intensity of the MIC wall mineralization. According to Mardinger et al. [17] complete MIC wall corticalization with compact bone substance was found in 10 of 46 halves of the mandible, and in 9 cases the cortical bone was completely absent. Authors also mentioned that in 24 % of the specimens (11 halves of mandibles) MIC was visualized well with routine radiographic methods, in 32 % (15 halves of mandibles) MIC was visualized less clearly and in the rest of the cases MIC was not detected at all on conventional radiographs (e.g. panoramic radiograph). Different levels of intensity of the bone plate forming a boundary of MIC were observed in the present study on anatomical preparations. It is simultaneously loosing integrity with a decrease in thickness in mesial direction.

The distance from the roots of teeth to the upper wall of incisive canal increases in the mesial direction from the mental foramen to the mental symphysis (Fig. 7), while the position of MIC in relation to the base of the mandible remains virtually unchanged.

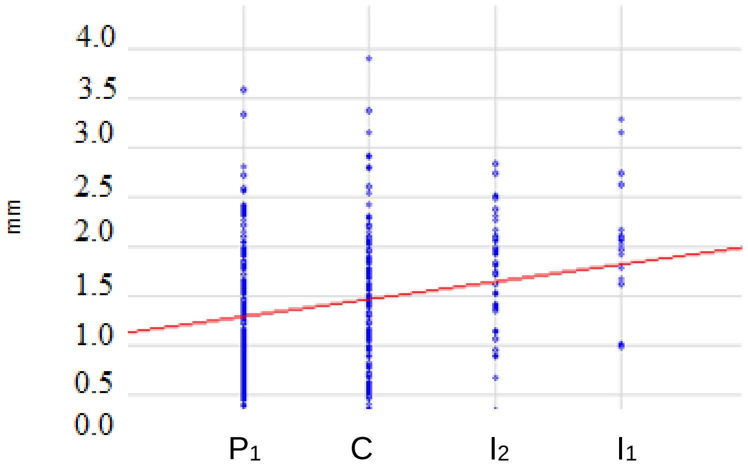

Fig. 7 Distance from mandibular incisive canal to the teeth root apices
P_1 – lower first premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

Bone graft transplantation in the area of the planned implant installation is a modern standard of care in dental practice [4]. Often times an autograft is taken from the body of the mandible at the level of incisors (mandibular symphysis or chin bone harvesting). That procedure can possibly lead to the MIC damage. Hemodynamic impairment and pulp sensitivity of teeth located on the mesial side of the area of surgery may occur [24]. On the other hand, the presence of anastomoses with the sublingual artery promotes the preservation of blood supply to the pulp which prevents the development of pulp necrosis, requiring endodontic treatment. It may take from 3 to 12 months for pulp sensitivity to recover [31]. It is recommended to harvest the bone in the 5 to 8 mm range from the roots of lower incisors to avoid complications. Following that recommendation it is possible to prevent complications in 75% of cases [24]. Our data confirmed the lower boundary of the safe zone with respect the roots of the teeth. Q75 (Table 2) is 8.7 mm for the central incisor and 8.5 mm for the lateral.

The comparative analysis did not reveal any statistically significant difference between the left and right side as well as between males and females in the distance from MIC to buccal and lingual cortical plates, root apices and length of MIC according to teeth levels.

The absence of similar discrepancy was also noted by Pereira-Maciel et al. [22]. However, they reported the distance from MIC to the base of mandible to be shorter in women than in men ($p<0.0001$). Authors explained that with the smaller size of the mandible in women, than in men.

Conclusion

The present study demonstrated the high value of CBCT as a method of identification of the mandibular incisive canal in vivo. It can appear in a different length and reach the level of the root of the central mandibular incisor. The diameter of MIC decreases in mesial direction. Individual topography of the mandibular incisive canal should be determined during the preoperative radiological examination and surgical procedures in the anterior region of the mandible.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Fig. 1 Intraosseus branches of the inferior alveolar nerve
1 – inferior alveolar nerve; 2 – mental nerve; 3 – mandibular incisive nerve; 4 – inferior dental branches; 5 – level of mental foramen. Anterior view of edentulous mandible (buccal cortical plate removed)

Fig. 2 Complete corticalization of mandibular incisive canal walls (rank 3) in the sagittal CBCT section at the level of the right first lower premolar (2a) and in the cross-section of dry mandible 5 mm anteriorly from the right mental foramen (2b)

Fig. 3 Partial corticalization of mandibular incisive canal walls (rank 2) in the sagittal CBCT section at the level of the left lower canine (3a) and in the cross-section of dry mandible 10 mm anteriorly from right mental foramen (3b)

Fig. 4 Mandibular incisive canal (arrow) running from mental foramen (circle) to the level of central incisor's (I_1) root: 4a – panoramic CBCT image section; 4b - thin-slice panoramic CBCT image section.
P – lower premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

Fig. 5 Visibility ranking (%) of MIC at different teeth roots levels on CBCT scan images
0 - the canal is not visualized; 1- the canal is poorly visualized; 2 - the canal is moderately visualized; 3 - the canal is well visualized
P_1 – lower first premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

Fig. 6 Internal vertical diameter of mandibular incisive canal at different teeth roots levels
P_1 – lower first premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

Fig. 7 Distance from mandibular incisive canal to the teeth root apices
P_1 – lower first premolar, C – lower canine, I_2 – lower lateral incisor, I_1 – lower central incisor

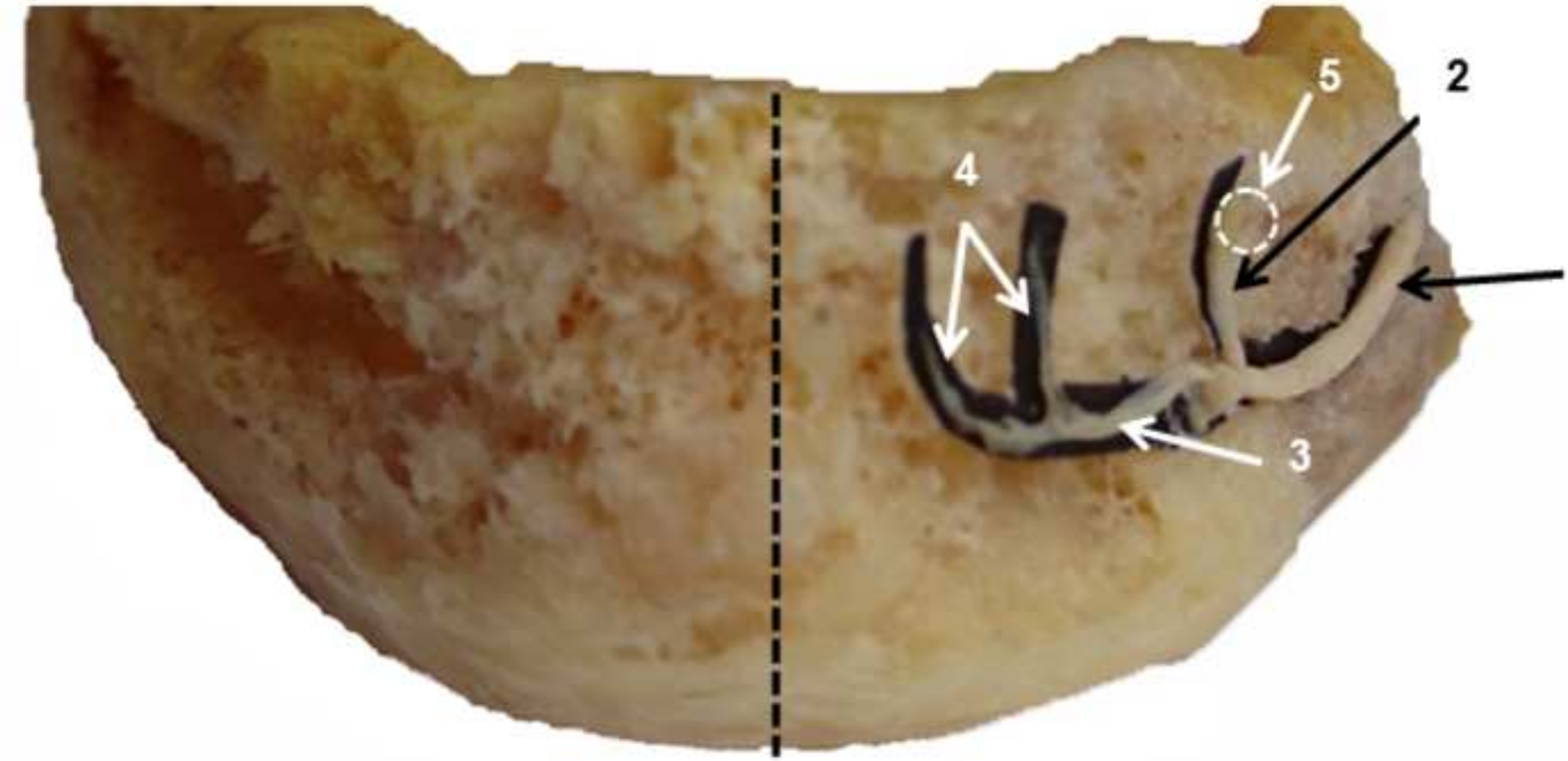
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Figure

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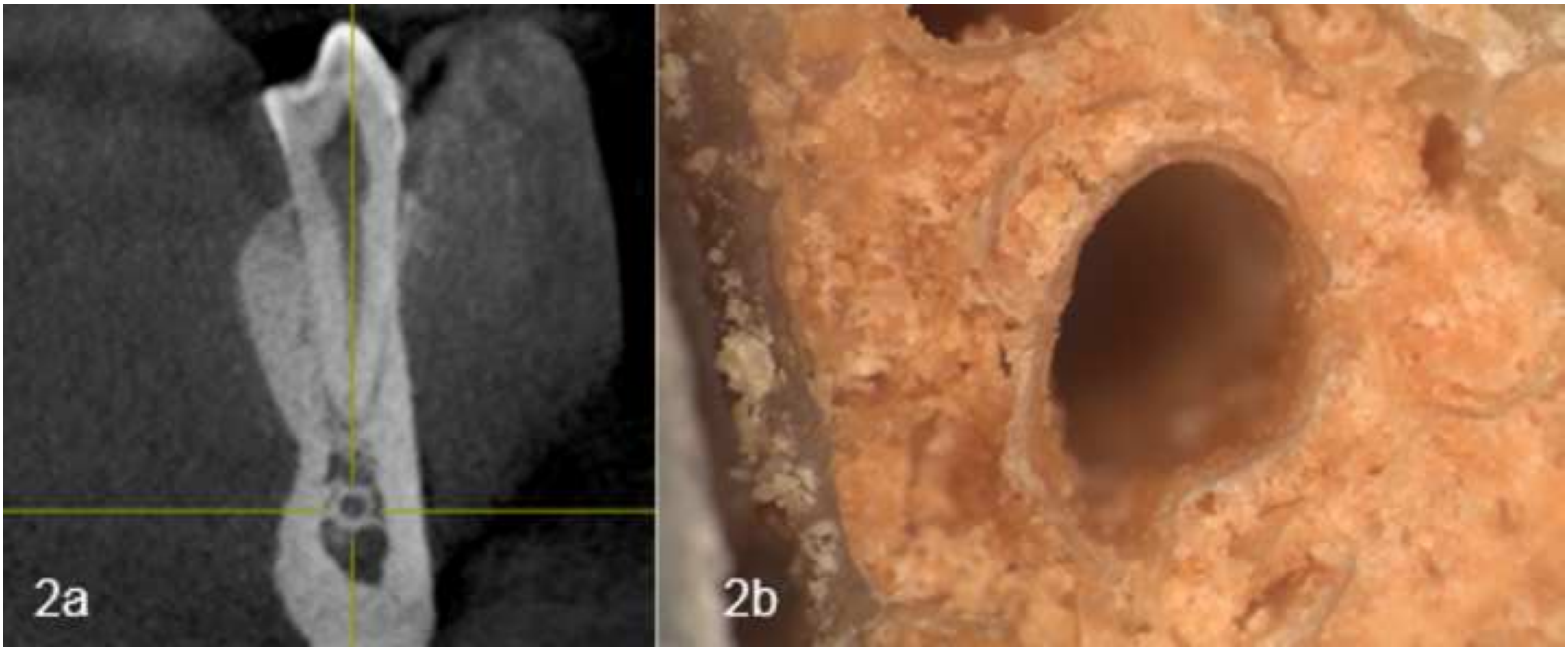

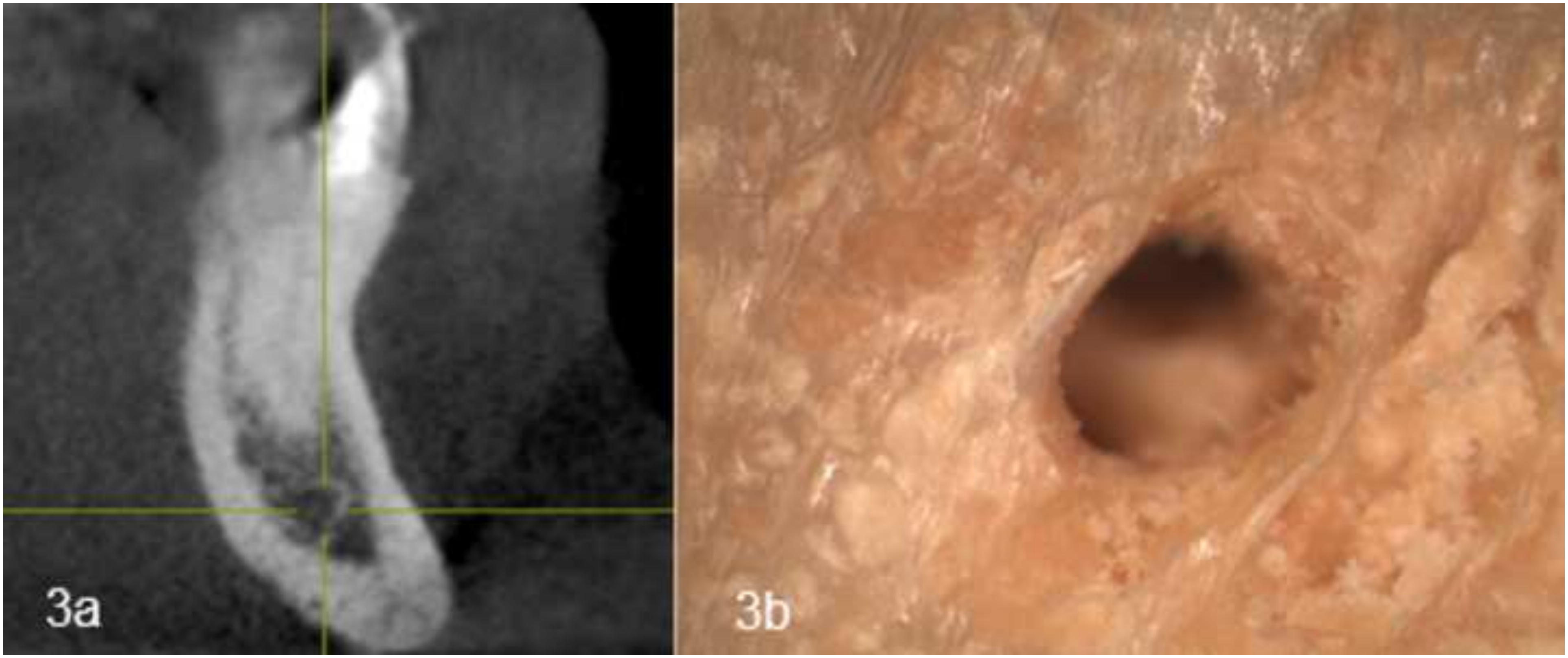
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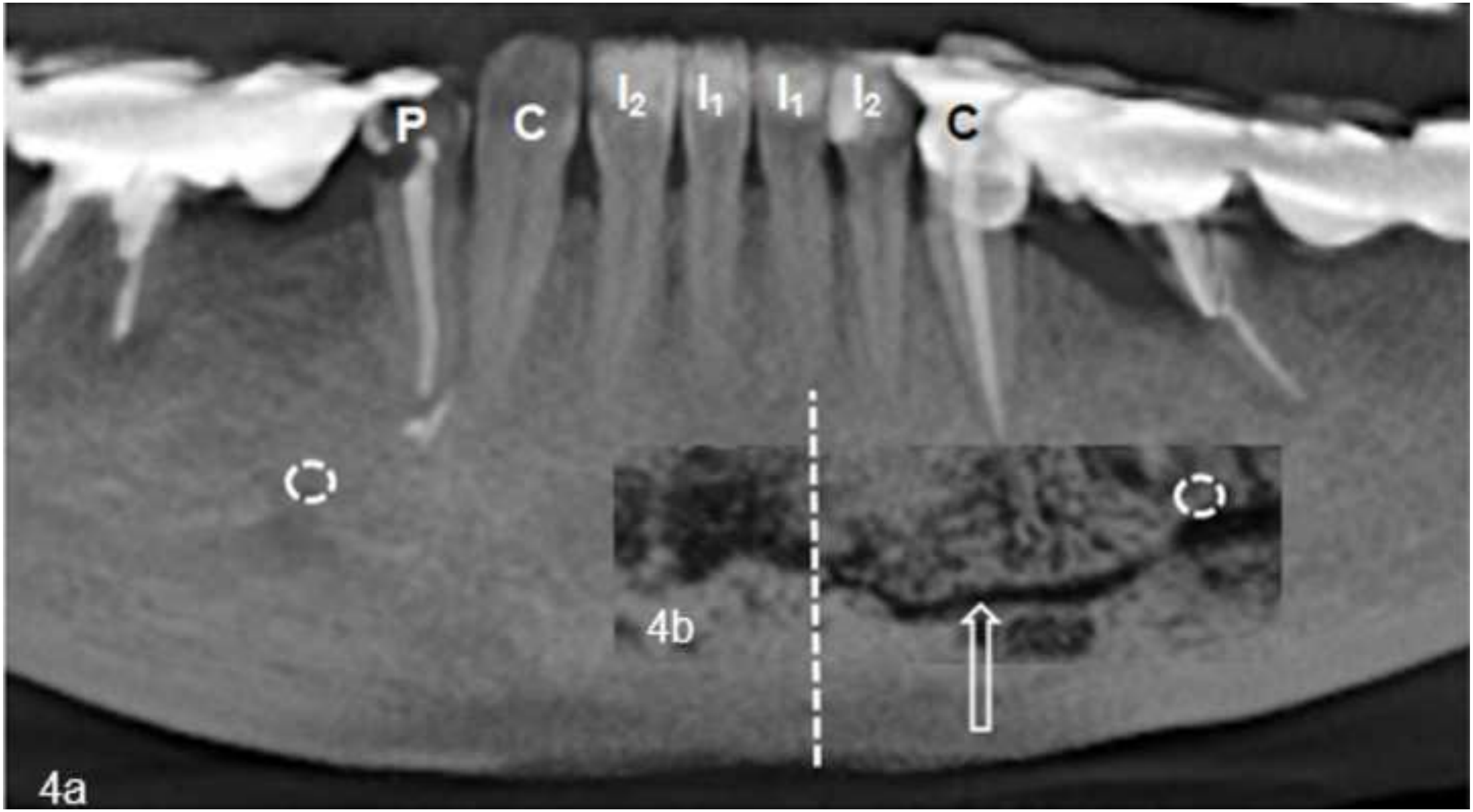
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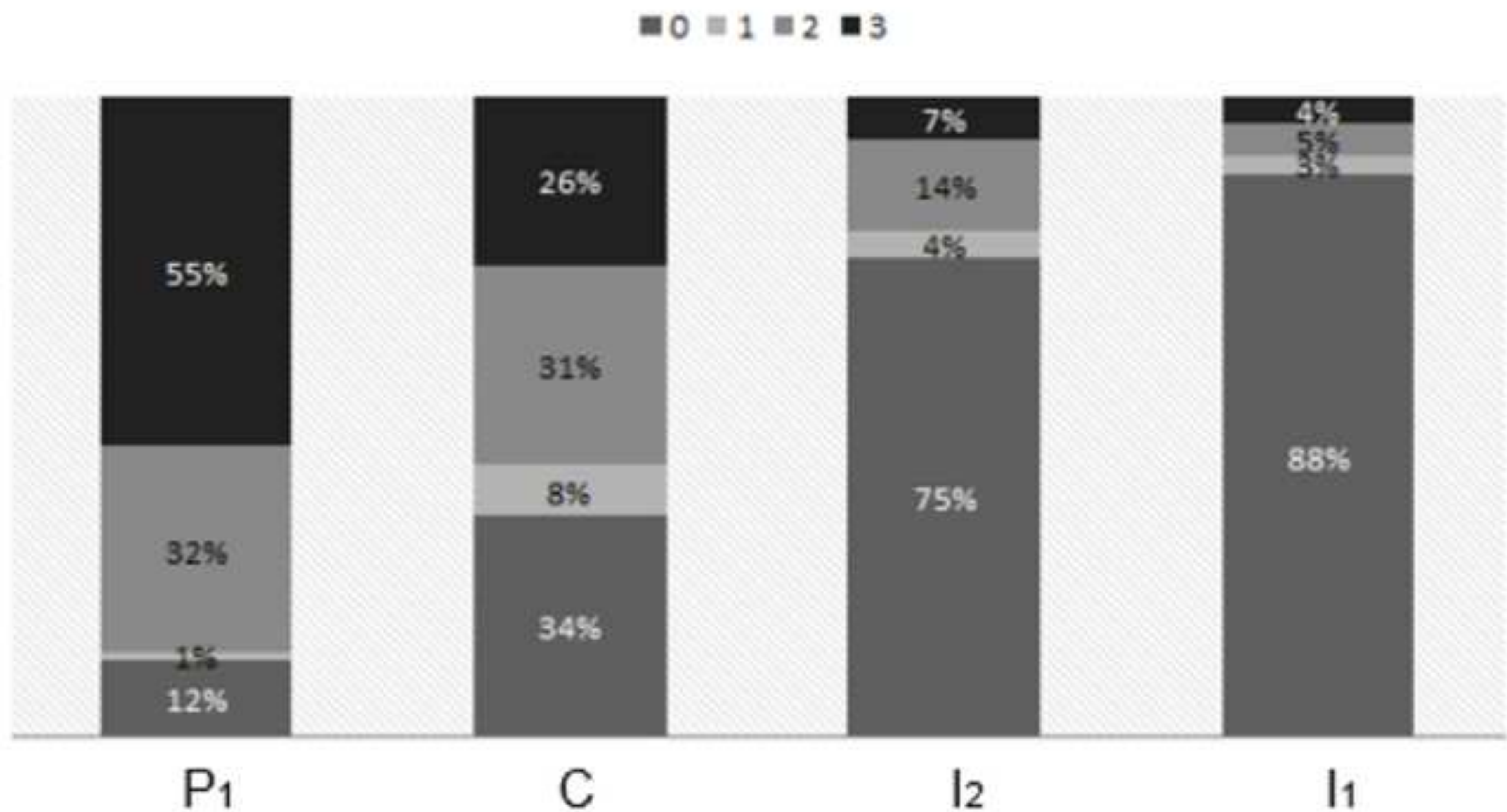
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Figure

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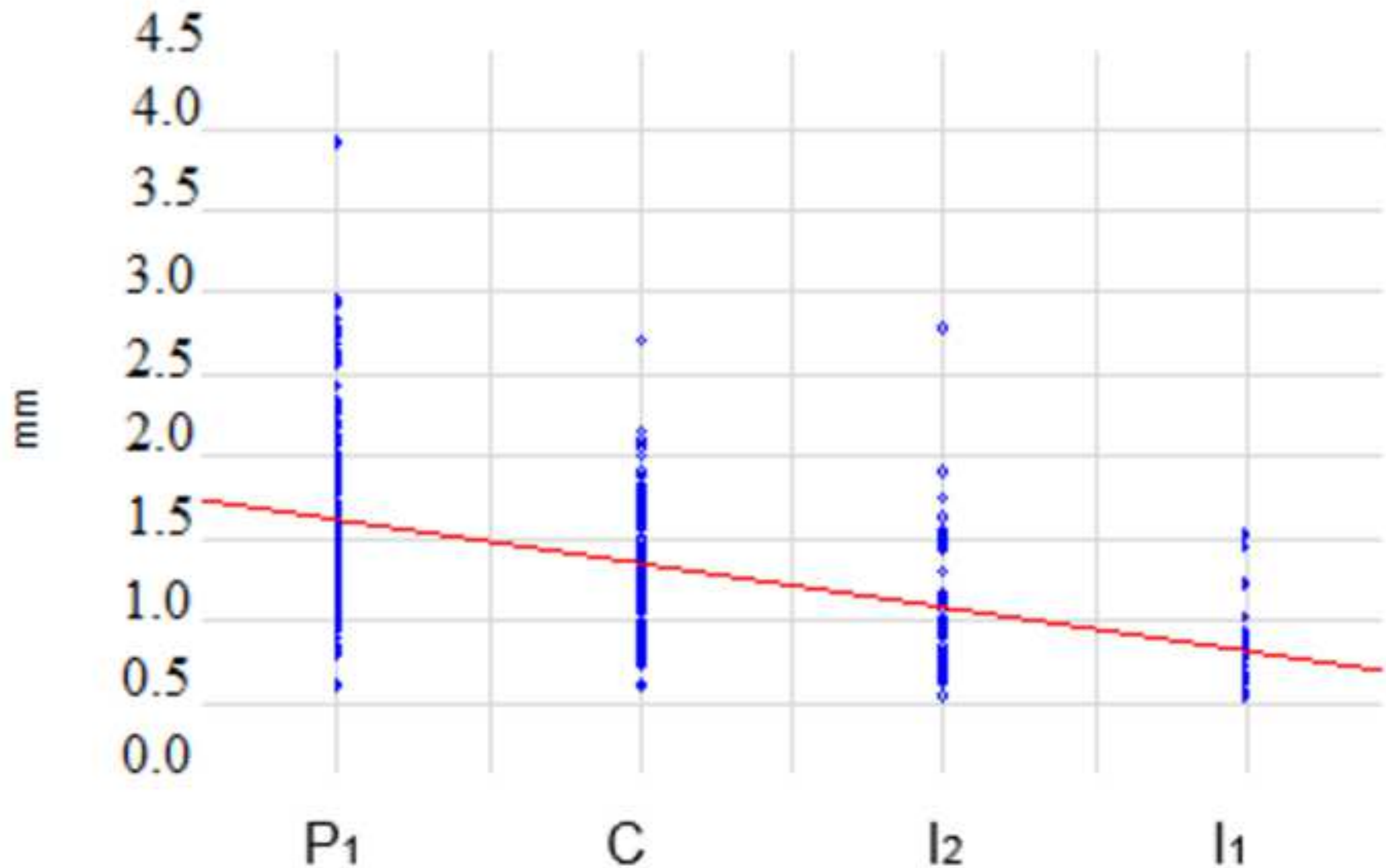

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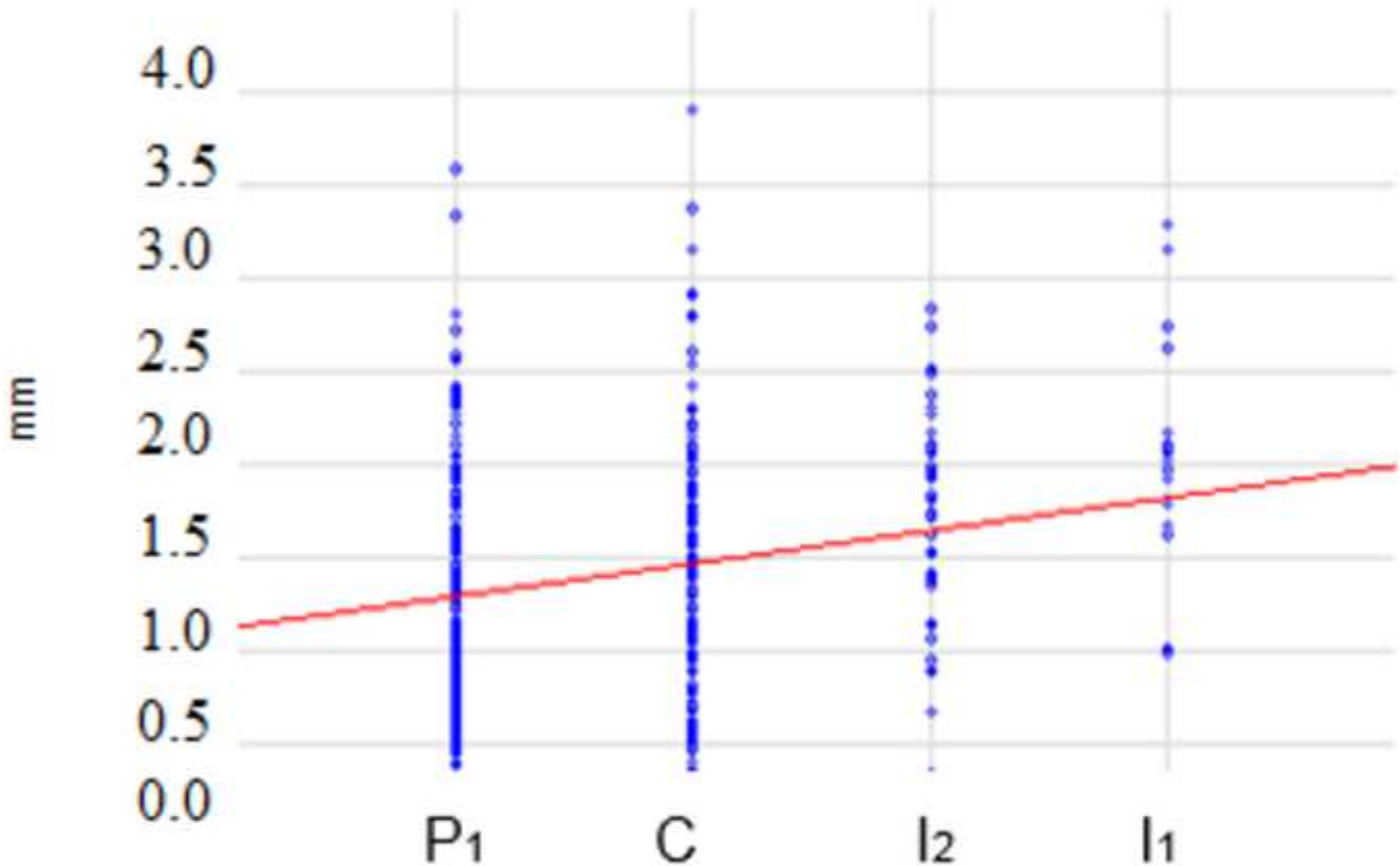

Table

Table 1 Rank scale for sagittal sections

rank	the degree of visualization	radiographic features
0	the canal is not visualized	network structure of cancellous bone only
1	the canal is poorly visualized	a continuous rounded radiolucent area without radiopaque walls
2	the canal is moderately visualized	a continuous rounded radiolucent area, defined by intensive thin radiopaque line (cortical plate) on one side
3	the canal is well visualized	a continuous rounded radiolucent area, defined by intensive thin line (cortical plate) on two sides

Table

Table 2 Internal vertical diameter of the mandible incisive canal, Me(Q25;Q75), lim

Teeth	Overall	Right side	Left side	Male	Female
Central incisors	0.8 (0.7;1.0)	0.9 (0.7;1.2)	0.8 (0.7;0.9)	1.1 (0.7;1.5)	0.8 (0.7;0,9)
	0.6-1.5	0.6-1.5	0.6-1.5	0.7-1.5	0.6-1.5
n	18	9	9	6	12
Lateral incisors	1.0 (0.8;1.3),	1.1(0.7;1.3)	1.0 (0.8;1.4)	1.0 (0.8;1.4)	1.1(0.8-1.3)
	0.6-2.8	0.5-2.8	0.7-1.9	0.6-2.8	0.6-1.9
n	43	19	24	22	21
Canines	1.2 (1.1;1.6),	1.2 (1.1;1.5)	1.3 (1.0;1.6)	1.3 (1.0;1.6)	1.2 (1.0-1.6)
	0.6-2.7	0.6-2.2	0.6-2.7	0.6-2.7	0.8-2.2
n	133	64	69	55	78
First premolars	1.6 (1.3;1.9),	1.6 (1.4;2.0)	1.6 (1.4;1.9)	1.6 (1.3;1.9)	1.6 (1.4;1.9)
	0.6-3.9	0.6-3.0	0.9-3.9	1.0-3.0	0.6-2.6
n	182	90	92	81	101

n – number of teeth

Table

Table 3 Values of the distance from the mandibular incisive canal (MIC) to various mandibular landmarks, Me(Q25;Q75), lim

Teeth	Overall	Right side	Left side	Male	Female
Distance of the mandible incisive canal to inferior border, of mandible					
Central incisors	9.8 (8.4;10.7)	9.4 (9.2;11.77)	10.2 (8.4;10.6)	10.7(10.6;11.9)	9.3 (8.2;10.3)
	6.6-15.3	6.7-15.3	6.6-11.9	7.8-13.0	6.6-15.3
n	18	9	9	6	12
Lateral incisors	9.2 (8.4;11.2)	9.6 (9.0;12.0)	9.1 (8.3;10.6)	9.2 (8.4;11.2)	9.2 (8.6; 11.7)
	5.6-13.4	7.5-12.9	5.6-13.4	5.6-13.4	8.2-12.9
n	41	18	23	22	19
Canines	8.5 (7.2;9.8)	8.1 (7.1;9.6)	8.6 (7.4;9.8)	8.0 (6.9; 9.1)*	8.8 (7.4;10.0)*
	5.3-14.9	5.3-13.5	5.5-14.9	5.3-14.9	5.8-14.1
n	124	60	64	53	71
First premolars	9.5 (8.2;10.5)	9.4(8.1;10.2)	9.7 (8.4;10.8)	9.5 (8.4;10.2)	9.6 (8.2;10.9)
	3.2-15.5	3.2-15.5	6.5-13.2	5.8-15.5	3.2-13.3
n	171	84	87	79	92
Distance of the mandible incisive canal to lingual cortical plate of the mandible					
Teeth	Overall	Right side	Left side	Male	Female
Central incisors	5.7 (3.9;6.6),	5.9 (3.9;6.6)	5.6 (4.5;6.9)	6.8 (4.8-7.2)	5.6 (3.9-6.3)
	3.4-9.4	3.7-7.2	3.4-9.4	4.0-9.4	3.4-7.3
n	18	9	9	6	12
Lateral incisors	5.5 (4.2;7.3),	6.1 (4.2;7.5),	5.3 (3.9;6.3),	5.4 (4.3-6.6)	6.0 (4.2-7.5)
	2.2-10.6	2.9-10.0	2.2-10.6	2.7-10.6	2.2-9.4
n	43	19	24	22	21
Canines	4.4 (3.3;5.6),	4.4 (3.4;5.3)	4.3 (3.2;5.9)	4.0 (3.3-5.0)	4.4 (3.3;5.9)
	1.3-10.0	1.5-10.0	1.3-8.8	1.3-10.0	1.5-8.9
n	133	64	69	55	78
First premolars	4.8 (3.7;6.0),	4.8 (3.8;5.9)	5.0 (3.6;6.0)	4.8 (3.7-5.8)	4.9 (3.9-6.1)
	0.6-9.0	1.2-8.9	0.6-9.0	1.2-9.0	0.6-9.0
n	182	90	92	81	101
Distance of the mandible incisive canal to buccal cortical plate of the mandible					
Teeth	Overall	Right side	Left side	Male	Female
Central incisors	5.7 (4.8;6.6)	5.1 (3.3;6.6)	5.7 (5.1;6.2)	5.1 (4.8;7.8)	5.8 (4.7-6.4)
	2.5-8.1	2.5-7.8	4.8-8.1	2.5-8.1	3.0-7.4
n	18	9	9	6	12
Lateral incisors	4.3 (3.2;5.2)	3.5 (2.6;4.7) *	4.8 (3.7;5.9)	4.2 (3.5;5.1)	4.4 (3.2;5.2)
	1.4-7.3	1.4-6.5	1.8-7.3	1.4-7.3	2.5-7.0
n	43	19	24	22	21
Canines	3.9 (2.9;5.4)	3.8 (2.9;5.2)	4.0 (2.9;5.6)	3.7 (3.0;5.4)	4,0 (2.6;5.4)

	1.4-8.0	1.3-7.8	1.1-8.0	1.3-7.8	1.1-8.0
n	133	64	69	55	78
First premolars	2.9 (2.2;3.8)	2.8 (2.1;3.7)	3.0 (2.2;3.9)	3.0 (2.0;3.5)	2.9 (2.3;4.0)
	1.0-7.5	1.0-7.5	1.1-7.0	1.1-7.0	1.0-7.5
n	182	90	92	81	101

Distance of the mandibular incisive canal to root apex					
Teeth	Overall	Right side	Left side	Male	Female
Central incisors	8.1 (6.8;8.7)	8.3 (6.8;8.5)	8.0 (7.0;10.8)	7.7 (6.8;7.9)	8.4 (7.0; 10.8)
	4.0-13.1	4.1-13.1	4.0-12.6	4.0-8.4	4.1-13.1
n	17	9	8	5	12
Lateral incisors	6.7 (5.5;8.5)	5.9 (4.7;7.0)	7.6 (5.6;8.6)	7.8 (6.1;8.5)	5.7 (5.5;7.4)
	1.3-11.4	1.3-10.1	2.7-11.4	3.6-11.4	1.3-11.0
n	42	18	24	21	21
Canines	5.2 (3.1;7.3)	5.5 (3.3;7.6)	5.2 (3.1;6.6)	5.3 (3.9;7.0)	5.0 (2.7;7.3)
	0.1-15.6	0.0-15.6	0.8-12.6	1,9-11,6	0.0-15.6
n	132	63	69	55	77
First premolars	5.2 (3.4;7.1)	5.4 (3.9;7.2)	5.1 (3.2;7.0)	5.2 (3.4;6.7)	5.1 (3.4;7.4)
	0,1-14.4	0.00-3.9	0.6-14.3	0.6-10.9	0.0-14.4
n	175	88	87	76	99

n – number of teeth

* – significant difference (p>0.05)

Table

Table 4 The incidence and dimensions of the mandibular incisive canal according to different authors

Investigators	Total number of cases in study	Type of study	%	MIC length (mm) M±SD	MIC width (mm) M±SD	Nation
Xu et al[10]	80 hemi-mandibles	In vitro (cadaver)	100	24,87 ± 2.23	1.76 ± 0.27	China
Yu et al[28]	26 hemi-mandibles	In vitro (cadaver)		-	2.22±0.59	Korea
Mardinger et al[29]	46 hemi-mandibles	In vitro (cadaver)	100	-	Range, 0.48 to 2.19	Israel
Mraiwa et al[12]	50	In vitro (cadaver)	96	-	1.8 ± 0.50	Belgium
Obradovic et al[18]	105 (70- dentulous; 35 – edentulous)	In vitro (cadaver)	92 – dentulous 31 - edentulous			Serbia
Pereira-Maciel et al[9]	100	In vivo (CBCT)	100	9,8 ± 3.8	-	Brasil
Ramesh et al[8]	120	In vivo (CBCT)	71,66	10,173	2.578	India
Apostolakis & Brown[30]	102	In vivo (CBCT)	93	8,9 (range, 0 to 24.6)	-	Greece
Yovchev et al[11]	140	In vivo (CBCT)	92.9		1.44 ± 0.39 (0,7 – 2,5)	Bulgaria
Al-Ani et al[31]	60	In vivo (CBCT)	100			Malaysia
Pires et al[32]	89	In vivo (CBCT)	83	7 ± 3,8	0.4 × 0.4 - 4.6 × 3.2	USA
Sokhn et al[33]	40	In vivo (CBCT)	97,5%			Lebanon
Parnia et al[7]	96	In vivo (CBCT)			1.47 ± 0.50	Iran
Makris et al[6]	100	In vivo (CBCT)	83,5%	15 (from mental foramen)		Greece