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Article

Cross-sectional anatomic study of direct positional relationships between mandibular canal and roots of posterior teeth using cone beam computed tomography.

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Abstract: Objectives: To establish the frequency of the various types of direct contacts of the root apices with the wall of the mandibular canal and to determine gender differences in number of such contacts in a selected Belarusian population using cone beam computed tomography. Methodology: One hundred and two cone beam computed tomography scans were analyzed to classify the types of contact and three-dimensional relationship between the mandibular teeth and the mandibular canal. Results: The direct contact between the teeth and the mandibular canal was observed in 63.7% of patients. Overall 300 roots of 189 teeth were in direct contact with the mandibular canal: 9.3% were second premolars, 14.7% were first molars, 33.8% were second molars and 50.0% were third molars. There were no statistically significant differences in the number of teeth with direct contact with the mandibular canal between males and females. Conclusion: The direct contact of the root apices with the mandibular canal was most often found in the second and third molars. The root apices of the third molars had the greatest variability of location relatively to the mandibular canal.

Keywords: Cone-beam computed tomography; inferior alveolar nerve; mandibular canal; mandibular molars; mandibular premolars.

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INTRODUCTION.

The mandibular canal (MC) starts with a foramen on the inner surface of the ramus of the mandible. Such terms as "inferior alveolar nerve canal" and "inferior dental canal" are often used in scientific publications.[1]

First it runs downward obliquely, then forward almost horizontally and ends with the mental foramen near the roots of the premolars.[2] The canal contains the inferior alveolar nerve (IAN), which accompanies the artery and vein of the same name, as well as lymphatic vessels. There are two canals in the mandible. In some cases, there is direct positional relationship or direct communication between root apices of posterior teeth and the MC, where the closest distance is 0mm.[3,4]

The proximity of the IAN to the roots of the lower molars and premolars is of great clinical relevance, particularly when performing invasive surgical procedures and during conventional root canal therapy.[5]

Inferior alveolar nerve damage may result from the endodontic treatment of mandibular molars and premolars and is a consequence of

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the chemical, mechanical or thermal irritation.[6]

A neurotoxic effect could be potentially caused by sodium hypochlorite, used for chemical disinfection of root canals, or paraformaldehyde-containing obturation materials.[7] An endodontic instrument advancing beyond the apical foramen or an inflammatory infiltrate forming around the apex of the root are possible mechanical irritants that can damage the inferior alveolar nerve.[8] The nerve can also be affected by high temperatures when the thermoplasticized gutta-percha obturation techniques are violated.[9]

The inferior alveolar nerve damage is accompanied by neurological symptoms such as labiomandibular paresthesia or complete anesthesia of the lower lip.[7] The symptoms may appear at any stage of endodontic treatment (during instrumentation/irrigation or obturation of the canal).

In most cases, the location of the mandibular canal is assessed in vivo on conventional periapical or panoramic radiographs. However, 2D radiographs have a number of disadvantages, such as the lack of buccal-lingual information, interference by the buccal plate, and the inherent magnification and distortion. The real relationship between the mandibular canal and the surrounding anatomical structures can be obtained using cone beam computed tomography (CBCT).[10]

The aim of the present cross-sectional study is to establish the frequency of the various types of direct contacts of the root apices with the wall of the mandibular canal, and to determine gender differences in the number of such contacts in a selected Belarusian population using cone beam computed tomography.

MATERIALS AND METHODS.

The present study was approved by the Ethics Committee of the Belarusian State Medical University (record of meeting 03.10.2017 No.2). Signed informed consents were obtained for the patients both for the treatment and for using their data for research purposes.

One hundred and two cone beam computed tomography (CBCT) scans were analyzed from 2014 to 2017 at the Minsk hospitals dental outpatient clinics. Images were performed for different clinical reasons such as dental implant planning, diagnosis of radiolucent lesions and temporomandibular joint disorders.

The CBCT scans were selected according to the following inclusion criteria: the complete visualization of the mandibular canal, and presence of the second premolars, and first and second molars on both sides. The exclusion criteria were defined as any history of orthognathic surgery and/or mandibular orthodontic treatments, previous mandibular fractures, dental disorders, severe mandibular growth retardation or any other pathology. According to our inclusion and exclusion criteria, the final sample group included data from 102 patients (56 males and 46 females). The mean age of the patients was 30.3 years old (SD±10.7) (ranged from 16 to 66 years).

CBCT images were obtained by the Galileos GAX5 scanner using standard settings (85 kV; tube current 5-7mA; acquisition period 14s; effective radiation time 2-6s; voxel size 0.3*0.3*0.3mm). Axial, sagittal, panoramic and formatted transverse tomograms were assessed using GALILEOS Viewer (Sirona, Bensheim, Germany).

The location of the mandibular canal in relation to the roots of the mandibular second premolars and molars was defined as following:[11]

Class I: the mandibular canal is located apically from the tooth root/roots (apical position) (Figure 1. A, B, C);

Class II: the mandibular canal is located on the buccal side of the tooth root/roots (buccal position) (Figure 1. D, E);

Class III: the mandibular canal is located on the lingual side of the tooth root/roots (lingual position) (Figure 1. F, G, H);

Class IV: the mandibular canal is located between the roots of teeth (interradicular position) (Figure 1. I).

Contacts of the roots and the mandibular canal in each class (the distance between root and MC=0mm) were divided into three types:[11]

Type 1 - the roots are in contact with the mandibular canal wall with a complete radiopaque (white) line (Figure 1. B)

Type 2 - the roots are in contact with the mandibular canal wall with a defective white line (Figure 1. F G)

Type 3 - the roots of the mandibular second premolar and molars penetrate the mandibular canal (Figure 1. E, H)

The images were analyzed by two researchers to classify the type of the contact and three-dimensional relationship between the mandibular teeth and the mandibular canal.

In case of disagreement, a senior professor took part in the discussion and a consensus decision was recorded.

The software package «Statistica 10.0» was used for the statistical analysis of the obtained data. The chi square test with Yates's correction and Fisher's exact test were used to compare observed groups. Results were considered statistically significant when the probability of faultless prognosis was calculated at 95.5% (p<0.05).

Table 1. Number of patients with multiple direct contacts of teeth with the mandibular.

Number of teeth in direct contact with MC simultaneously	Patients	Male	Female
2	13	9	4
3	8	2	6
4	20	11	9
5	2	2	-
6	4	1	3
8	1	1	-
Total	48	26	22

Table 2. Direct contact of the teeth with the mandibular canal.

Gender	Tooth	Number of patients	Number of teeth	Direct contact with MC			p-value
				Number of patients	Number of teeth	Frequency (%)	
Male	2nd premolar	56	112	7	10	8.9	0.97ns
Female		46	92	7	9	9.8	
Male	1st molar	56	112	10	18	16.1	0.45ns
Female		46	92	8	12	13	
Male	2nd molar	56	112	23	37	33	0.6ns
Female		46	92	20	32	34.8	
Male	3rd molar	42	78	23	35	44.9	0.17ns
Female		35	64	24	36	56.3	
Total	2nd premolar	102	204	14	19	9.3	
	1st molar	102	204	18	30	14.7	
	2nd molar	102	204	43	69	33.8	
	3rd molar	77	142	47	71	50	

Comparison between male and female was assessed using chi-test – Pearson's chi-squared test with Yates's correction or Fisher's exact test. **ns**= Not significant.

Table 3. Bilateral direct contact of the teeth with the mandibular canal.

Tooth	Tooth in direct contact with MC on the left and right side			Tooth in direct contact with MC only on one side		
	Total†	Mesial roots‡	Distal roots§	Total	Right	Left
2nd premolar	5			9	4	5
1st molar	12	6	7	6	2	4
2nd molar	26	19	20	17	13	4
3rd molar	24	20	22	23	13	10
Total	67	45	49	55	32	23

†: Number of teeth having mesial and/or distal roots in direct contact with MC.
‡: Mesial roots were in direct contact with MC on the left and right side simultaneously.
§: Distal roots were in direct contact with MC on the left and right side simultaneously.

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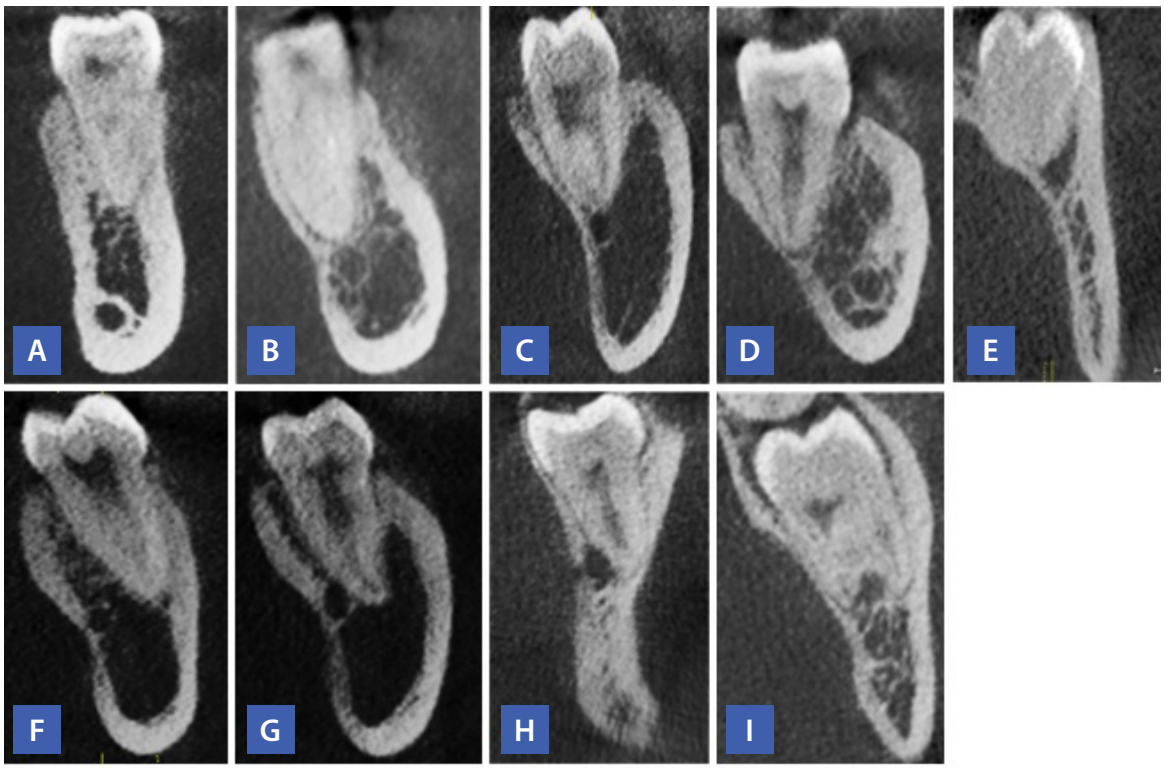
Table 4. Position of the mandibular canal in relation to the roots and type of the contact.

Roots	No Direct contact					Direct contact																										N
						Premolar				First molar (M1)							Second molar (M2)							Third molar (M3)								
	P	M1	M2	M3	N	Type I	Type II	Type III	N	Type I		Type II		Type III		N	Type I		Type II		Type III		N	Type I		Type II		Type III		N	
										m	d	m	d	m	d		m	d	m	d	m	d		m	d	m	d	m	d		
Class I†	170	286	150	40	646	19	-	-	19	16	20	3	1			40	36	41			1		77	17	18	6	5	9	9	64	200
Class II‡	8	19	133	109	269					-	1					1	11	16				1	28	15	16	4	4		1	40	69
Class III§	7	61	14	2	84						1			1		1			11	17	3	2	5	3	5	4	4	1	3	20	69
Class IV¶																					1		1			1	1	2		4	5
Total	185	366	297	151	999	19			19	16	22	3	1			42	36	41	11	17	3	2	111	35	39	15	14	12	13	128	300

† : The mandibular canal is located apically. **‡ :** The mandibular canal is located on the buccal side. **§ :** The mandibular canal is located on the lingual side. **¶:** The mandibular canal is located between the roots. **Type I :** Contact with a complete white line. **Type II :** Contact with a defective white line. **Type III :** Penetration of the mandibular canal.

Figure 1. Relation of root apices to the mandibular canal.



A : Class I: Apical position, no contact. **B : Class I:** Apical position with complete white line. **C-Class I:** Apical position with defective white line. **D-Class II:** Buccal position, no contact. **E-Class II:** Buccal position with penetration of the mandibular canal. **F-Class III:** Lingual position, no contact. **G-Class III:** Lingual position with defective white line. **H-Class III:** Lingual position with penetration of the mandibular canal. **I-Class IV:** Interradicular position with penetration of the mandibular canal.

RESULTS.

On the 102 CBCT scans examined 754 second premolars, second and third molars were observed, for a total of 1299 roots.

In this sample, the direct contact of 300 roots of 189 teeth with the mandibular canal wall was detected on 65 CBCT scans (63.7% of the scans examined), including 31 in women and 34 in men. In 17% of samples, only one tooth was observed, having at least one root in direct contact with the mandibular canal. Data on the number of patients with multiple direct contacts of teeth with the mandibular canal(s) is presented in Table 1.

Analyzing the number of teeth with roots in direct contact with the mandibular canal on one side only, we found that in 46 cases there was one tooth; in 49 cases there were two teeth with roots in contact with the same canal; in 11 cases there were three teeth, and in three cases there were four teeth in that type of the relationship.

In 30.9% of cases two to four teeth had roots in direct contact with the same mandibular canal simultaneously.

Nineteen second premolars (9.3% of the total number of premolars), 30 first molars (14.7% of the total number of the first molars), 69 second molars (33.8% of the second molars) and 71 third molars (50% of the third molars) were in direct contact with the mandibular canal. There were no statistically significant differences between the number of teeth in direct contact with MC in males and females. (Table 2)

The frequency of the symmetrical direct contact with the mandibular canal was assessed in the contralateral teeth in which at least one had a direct contact with the canal. In 67 cases (54.9%) the direct contact of one or both of the roots of the teeth with the wall of the mandibular canal was detected simultaneously on the right and left sides of the mandible, in 32 cases (26.2%) – only on the right side, and in 23 cases (18.9%) – on the left side only. (Table 3)

Most often the roots of the second and third molars were in direct contact with the wall of the mandibular canal. There were 112 mesial and 126 distal roots observed in total. (Table 4) In more than half of cases, the apices of the roots of M3 and M2 were in direct contact with the mandibular canal wall. In those cases, the integrity of the cortical plate was usually maintained in the area of the contact. (Type 1) However, some cases of the mandibular canal wall penetration by roots (Type 3) were detected. That type of the interaction was found in the mesial root of one second molar, 12 mesial and 13 distal roots of the third molars.

It was found that 29.7% of the roots of the second molars and 46.9% of the roots of the third molars interacted with the wall of the mandibular canal on the lateral surface of the root .(Class II & III) Of the 41 roots of the second and third molars located on the lingual side of the mandibular canal (Class III), 25 roots (61%) were in direct contact with the mandibular canal. Of the 310 roots of M2 and M3 located on the buccal side of the mandibular canal (Class II), 68 roots (22%) were in direct contact with it. Isolated cases of canal location between the roots of the teeth and the presence of the contact between them were noted. (Class IV) Those cases were observed in three roots in second and third mandibular molars. The mandibular canal was located between the mesio-buccal and mesio-lingual roots.

DISCUSSION.

The direct contact of the roots with the mandibular canal is an unfavorable variation of the anatomical structure because of the possible iatrogenic injury of the inferior alveolar nerve during endodontic treatment due to the direct interventions related to the treatment or the application of an instrument beyond the apical foramen. The inferior alveolar nerve may be injured during extraction of the mandibular third molar, which often results in severe complications for patients. In the Lee *et al.,*[12] study the mean incidence of nerve damage during extraction of the mandibular third molar was 0.65%. In the group of patient who exhibited an overlap between the mandibular third molar and MC on panoramic radiograph the incidence of nerve damage was 1.1%.

According to published data, the roots of the third molars have the closest location to the mandibular canal. Shneider *et al.,*[13] found the direct contact with the MC in 46.7% of third molars. In samples analyzed by Bürklein *et al.,*[3] and Aksoy *et al.,*[5] such contacts were detected in 31.3% and 32.2% of cases respectively. We found a direct contact of the roots with the mandibular canal in 50% of the third molars.

According to Kovisto *et al.,*[14] who did not include the third molars, the roots of the second molars were the closest to the mandibular canal. Nair *et al.,*[15] found that the roots of the second molars were in direct contact with the inferior alveolar canal in 20.4% of the cases on the right side and 13.6% of the cases on the left side in sample of 44 patients. According to our data, the roots of 69 second molars (33.8% of the total number of the second molars) in 43 cases (20 women and 23 men) were radiographically in direct contact with the MC. The incidence was twice as high as the data given by Bürklein *et al.,*[3] and Aksoy *et al.,*[5] which showed the direct contact of roots with the canal in 15.2% and 16% of the second molars respectively. They considered that their investigation was the first study reporting the relatively high incidence of the direct contact between the root apices with the mandibular canal.

The most frequently endodontically treated tooth is the first mandibular molar[16] and the proximity of the inferior

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alveolar nerve to root structures is a critical anatomic issue for this surgery, even with the advanced technology available.[17]

We found the roots of 30 first molars to be in direct contact with the wall of the mandibular canal (14.7% of total number of molars) in 18 cases, including 8 women and 10 men. Nineteen mesial and 23 distal roots were in direct contact with the canal. Bürklein *et al.,*[3] found a similar relationhip in 2.9% of teeth. In the cohort surveyed by Simonton *et al.,*[17] IAN immediate contact with one or two roots of the first mandibular molars was present in 3% of patients. Three persons had only the distal root in contact with the nerve, and one person only the mesial root. In two cases, both roots of the first molar interacted with the nerve.

According to our data, the roots of 9.3% of the second premolars were in direct contact with the upper wall of the mandibular canal. Direct communication between second premolar and the MC was found in 3.2% of teeth by Bürklein *et al.,*[3] and in 3.3% of teeth by Aksoy *et al.*[5]

Individual variations in the position of the mandibular canal relatively to the roots were assessed in the present study. The canal can be located below the roots, on the buccal or lingual side. The roots of the third molars have the greatest variability regarding their location relatively to the MC. According to our data, the frequency of direct contact between the teeth and the mandibular canal wall increases insignificantly when it is located lingually.

The previous study[18] demonstrated that there is an increasing potential for an IAN injury when the mandibular canal is situated lingually. Gu *et al.,*[11] hypothesize that the lingually positioned MC is more likely to be in contact with the mandibular third molar due to insufficient space, as well as a interradicular position of the mandibular canal. In contrast, as stated by Xu *et al.,*[19] the highest rates of IAN injury occur when the roots of impacted third molars are located buccally in relation to the MC.

It is known that the distance between the root apices of the posterior teeth (except the third molars) and the wall of the mandibular canal depends on the age and gender of the patients[10,14] and It increases with age. In women of all age groups, the distance between the root apices of the second molars and mandibular canal is significantly less than in men of the same age group.[9] That difference can explain why chronic pain after endodontic treatment occurs four times more often in women than in men.[20] No statistically significant gender difference in the number of molars having direct contact with MC was observed in the present study.

The high frequency of the direct contact of roots with the mandibular canal, as well as the high incidence of bilateral symmetry of such relations, are most likely related to the fact that the individual anatomical features of the mandible are more determined by genetic than by environmental factors. The ethnic differences between the assessed populations can explain the significant discrepancies in the incidence of the direct contact relationship between the posterior teeth and the mandibular canal obtained in the present study compared to the published data.

CONCLUSION.

Cone beam computed tomography indicated a relatively high population frequency of the direct contact between the apex or lateral surface of the roots of the posterior teeth and the mandibular canal. The direct contact of the root apices with the mandibular canal was most often found in the symmetrically located second and third molars. The root apices of the third molars had the greatest variability of location relatively to the mandibular canal. An accurate knowledge of the topographic-anatomical relationships between the roots of the teeth and the mandibular canal in a particular patient reduces the probability of iatrogenic inferior alveolar nerve lesions upon removal, endodontic treatment, or apical resection of the apex of the root of the posterior teeth of the mandible.

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