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Study of mandibular premolar anatomy by cone-beam computed tomography

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ABSTRACT

Introduction: The mandibular premolars represent a challenge in endodontic treatment due to their anatomical variations. Thus, cone-beam computed tomography (CBCT) is used for the detailed study of the dental anatomy. **Objective:** To evaluate dental anatomy of the mandibular premolars using CBCT. **Methods:** The sample included CBCT images in the coronal, sagittal and axial sections of 200 mandibular premolars. The number of roots, root canals and configuration according to Vertucci were analyzed. The variables were associated and compared at a significance level of 5%. **Results:** The type I configuration predominated in males and females and in the first and second premolars. However, Fisher's exact test evidenced that it is not possible to confirm an association between the sexes and the configuration of the root canals according to the Vertucci classification. The Mann-Whitney test indicated that the number of roots (p=0.04) and canals (p=0.01) are different between genders. The presence of a single root and a single canal was observed in 62% of the first premolars and 92% of the second premolars. The Friedman test indicated that the number of roots and canals also differs between teeth (p=0.02). C**onclusion:** CBCT enabled noninvasive and effective way to analyze the morphology of teeth and it was found that type I was the most frequent in both genders and in the first and second premolars. The number of roots and canals differs significantly between genders and between teeth.

Keywords: Cone-Beam Computed Tomography. Premolar. Root Canal Therapy.

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Introduction

One of the factors associated with the success of endodontic therapy is the knowledge of the morphology and three-dimensional anatomy of the root canal system.[1] Lack of knowledge of the internal anatomy or diagnostic failure can lead to errors in the stages of endodontic treatment, including access, location, cleaning and filling of the root canal.[2,3] Vertucci (1984)[4] and England et al. (1991)[5] reported that a considerable number of failures, such as the presence of canals not found, could be attributed to anatomical variations.

The mandibular premolars are an enigma for endodontists due to the high degree of morphological variability of their roots and canals.[5,6] Different factors can influence the diverse anatomy, such as ethnicity, age and sex.[7-11] Therefore, the investigation of these variables may aid in all endodontic therapy.

In view of these morphological differences, correct diagnosis and endodontic treatment depend on radiographic examinations, specifically complementary radiographs with variations in horizontal angle, as well as cone-beam computed tomography (CBCT).[9] However, there are limitations in conventional radiographs, such as compression of 3D structures, geometric distortion and artifact.[12]

Thus, CBCT is an important auxiliary tool in endodontic practice, especially in complex cases, such as canal localization, dental anomalies, resorptions and pathological periapical lesions. It is a non-invasive technique that has been widely used by clinicians for better visualization of the work field, indicated in the detection of the internal dental anatomy. The advantages of this examination include the absence of overlapping of structures, precision in the images, visualization of the root morphology in three dimensions, as well as the number of canals and their convergences and divergences.[12,13]

The aim of the present study was to evaluate by cone-beam computed tomography the internal anatomy of mandibular premolars of individuals living in Maringá, State of Paraná, using the image bank of the Laboratory of Images in Clinical Research of the State University of Maringá.

Methods

All tomographic images analyses were performed prior to approval by the Standing Committee on Ethics in Research (COPEP), with certificate of presentation for ethical evaluation (CAAE) 603116.6.0000.0104.

For this documentary study, we used cone-beam computed tomography images of the mandibular premolars that were taken for various odontological reasons in the i-CAT Next Generation tomograph (Imaging Sciences International, Hatfield, PA, USA).

Patients with teeth with incomplete apex, previous endodontic treatment, presence of intraradicular posts extensive metallic crowns, or any artifact that would make it impossible to visualize the internal anatomy of the studied tooth were excluded from the sample.

The images were obtained through the tomography belonging to the Laboratory of Images in Clinical Research, by the same professional specialist in Dental Radiology and Imaginology.

In the acquisition protocol, a 14-bit gray scale and a focal point of 0.5 mm were used. The volumes were reconstructed with 0.125 mm^3 to 0.250 mm^3 isometric voxel, with FOV (Field of View) of 8 × 8 cm, tube voltage of 120 kV and with tube current of 3-8 mA. The amount of radiation was evaluated using the Dose Area Product (DAP) function in the last generation of the device, which was displayed on the monitor screen and stored next to the patient data on the computer.

The files of CT scans were exported in DICOM (Digital Imaging and Communication in Medicine) format to an independent workstation. XoranCat Software Version 3.1.62 (Xoran Technologies, Ann Arbor, Michigan, USA) and a WXGA TFT LCD monitor, 4.1" in size, were used to visualize the images.

We evaluated 100 first and 100 second mandibular premolars (MPs) in axial sections to analyze the number of roots and canals (0.3 mm thickness), and sagittal and coronal sections to verify the configuration of the canals (2 mm thickness) (Fig 1).

The MPs canals had their configurations classified according Vertucci (1984)[4], into eight types (I to VIII). In addition, the following anatomical questions were also evaluated: number of root canals and roots, which were associated with the gender of the respective patients. Such analyses were performed by a calibrated radiologist.

The analyses were done using the statistical environment R (R Development Core Team, 2017). Firstly,

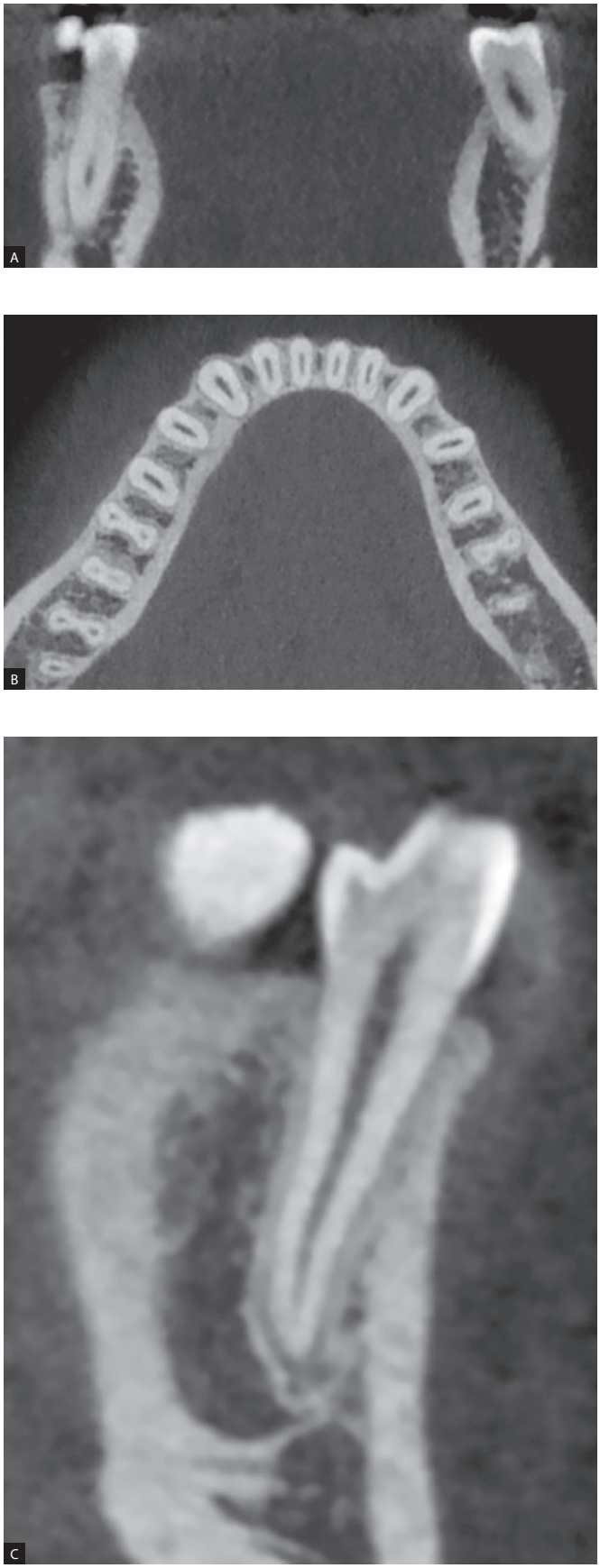

Figure 1. Cone-beam computed tomography image: **A**) Crown section; **B**) Axial section; **C**) Sagittal section.

a descriptive analysis of the data corresponding to the investigated variables was carried out: gender, age, number and type of roots and canals. In order to check for the difference in the number of roots relative to the gender, it was observed that the assumptions of the two-proportions comparison test were not met and the alternative was the application of a non-parametric test, the Mann-Whitney test.

Then, the two-proportions comparison test was applied to compare the proportion of number of canals with respect to gender. The Friedman's test was used to test whether the number of roots and, subsequently, the number of canals differed in relation to the types of teeth.

Finally, a possible association between gender and canal configuration was tested by means of Fisher's exact test. The level of significance was 5%.

Results

General data and associations

From the images analyzed, 140 teeth were from female patients and 60 teeth from male patients. The majority of the patients were women, totaling 35 (70%), while the total number of men was 15 (30%). The mean age of the patients was 26.5 years.

The female gender had 79 roots and 84 canals more than the male gender. Through the Mann-Whitney's test, there is sample evidence that the number of roots ($p = 0.04$) and canals ($p = 0.01$) differed between genders. Most, 62%, of the first MPs presented a root and a canal, while 25% had a root and two canals and 13% had two roots and two canals. The percentage of second MPs that presented a root and a canal was even more expressive, 92%, while 6% presented a root and two canals and 2%, two roots and two canals.

The Friedman's test indicated that the number of roots and canals also differed between types of teeth ($p = 0.02$). At the 5% level, it can be stated that, regarding the number of canals, the first right and left MPs are equal; the same is observed when we analyze the second MPs.

Canal configuration according to the genre

When examining the root canal types of MPs, type I was found to be the most frequent in both genders (Table 1). At the significance level of 5%, Fisher's ex-

Table 1. Types of root canals found in different genders, first and second MPs, according to Vertucci classification. F: feminine. M: masculine.

	Gender		Tooth	
	F	M	1º PMI	2º PMI
Type I	91,4%	86,7%	84%	96,0%
Type II	1,4%	5,0%	2,0%	3,0%
Type III	2,9%	6,7%	7,0%	1,0%
Type IV	1,4%	0,0%	2,0%	0,0%
Type V	2,9%	1,7%	5,0%	0,0%

act test showed evidence of no association between genders and canal configuration according to the Vertucci classification (p = 0.10).

Canal configuration in relation to the first and second mandibular premolars

In relation to the tooth, it is observed that type I again prevails. In addition, it was possible to verify the absence of types VI, VII and VIII (Table 1).

Discussion

The success of endodontic therapy depends on the knowledge of the morphology of root canal systems. After all, errors such as, for example, not locating existing canals can be avoided or minimized with such understanding. Also, the largest number of studies investigating the internal anatomy of MPs through CBCT was drawn abroad, predominantly in China and India (Box 1). In Brazil, we did not find, in our review, studies with these same methodologies.

Vertucci described 8 types of root canals in the classification.[4] This classification, used herein, was also employed in other studies that investigated the dental anatomy of MPs.[10,11,14-19] In MPs, the main canal that divides into the medium or apical third into 3 others, is denominated type IX,[8] a little detailed condition that was also reported by Ordinola-Zapata et al. (2013).[20] However, this classification was not used in the present study.

The mandibular premolars present greater vestibulolingual length and mesiodistal flattening. Like Yu et al. (2012)[10] and Yang et al. (2013)[11], in this study, we observed that the first and second MPs presented mainly a single root, but up to three roots can be found in these teeth.[21] Most of the root canals of the first MPs found in similar investigations were type I, followed by type V.[10,11,17-19] However, in the present study, type III was the second most common. In the second MP, type I was even more expressive, similar to the studies of Yu et al. (2012)[10] and Shetty et al. (2014)[17] (Table 2).

One of the anatomical variations found in MPs is the bifurcation of the main canal into two independent canals up to the apical third.[22] This is an important clinical consideration, since in the vestibular canal, the access is usually direct, while the lingual canal does not obey the direction of the main canal, it is necessary to overcome an acute angle to the location of the same. In addition, the crown of this tooth has a slope to the lingual, making it even more difficult to detect this canal. Some studies also found, in a reduced percentage, mandibular premolars with C-channel,[10,11,17] which was not found in the present study.

MPs can be considered one of the most difficult teeth to treat endodontically and tend to present anatomical variations,[23] which may hamper the cleaning, modeling and filling of the root canal. Because of this complex anatomy and lack of knowledge about the root canal system morphology,[24] microorganisms can survive in unaccessed areas, and these untreated canals will contribute to the failure of endodontic treatment.[5,25]

Table 2. Comparative analysis of the studies using cone-beam computed tomography to investigate the root and root canal types in the first and second mandibular premolars.

Works	Study method		Country	Sample size	1st mandibular premolar			2nd mandibular premolar		
					Root	Canal	Vertucci	Root	Canal	Vertucci
Yu et al.[10] 2012	TCFC Accuitomo 3D (MCT-1 [EX-2F], Morita Manufacturing Corp, Kyoto, Japão)	80 kV 5,0 mA 17 s 0,125 mm³ (voxel) Slice 1,0 mm.	West China	352 174 (1 PM) 178 (2 PM)	1 = 98% 2 = 2%	» 1 = 87,1% » 2 = 11,2% » 3 = 0,6% » in C = 1,1%	I = 86,8% III = 1,7% V = 9,8% VIII = 0,6% in C = 1,1%	1 = 100%	» 1 = 97,2% » 2 = 2,2% » in C = 0,6%	» I = 97,2% » II = 0,55% » V = 1,7% » in C = 0,55%
Yang et al.[11] 2013	TCFC scanner (Galileos, Sirona, Alemanha)	85 kV 35 mA 2-6 s 0,125 mm³ (voxel) Slice 1,0 mm	China	440 (1 PM)	1 = 99,32% 2 = 0,68%	» 1 = 77,14% » 2= 22,05% » in C = 1,14%	I = 76,14% II = 3,41% III = 2,73% IV = 6,59% V = 9,32% VIII = 0,68% in C = 1,14%	-	-	-
Shetty et al.[17] 2014	TCFC Kodak 9000 3D	60 kV 2 mA 10,8 s 0,076 mm³ (voxel) Slice 76 µm 5x3,7 (FOV)	South India	1186 (1 PM) 814 (2 PM)	Inclusion criteria 1 = 100%	-	I = 83,81% II = 0,3% III = 2,1% IV = 0,27% V = 11,97% VI = 0,1% VIII = 0,3% em C = 0,92%	Inclusion criteria 1 = 100%	-	I = 93,48% II = 1,4% III = 0,2% V = 3,9% VIII = 0,1% in C = 0,7%
Huang et al.[18] 2014	TCFC i-CAT, Imaging Sciences International, Hatfield, PA, EUA	120 kV 3-7 mA 20-40 s 0,25 mm³ (voxel)	Taiwan	300	» 1 root/1 canal = 65,7% » 1 root/2canals = 16,3% » 2 roots/2 canals = 17% » 3 roots/3 canals = 1%		I = 65,7% II e III = 16,3% IV e VII = 17% VIII = 1%	-	-	-
Zhang et al.[19] 2016	TCFC Scanner (Galileos, Sirona, Alemanha)	85 Kv 21 mA 2-5 s 125 µm (voxel)	Southwest China	143 extracted teeth	-	-	I = 72,73% III = 4,9% V = 17,48% IX (1-3, 1-3-2) = 4,9%	-	-	-

Several techniques have been used for the study of the internal dental anatomy among them are diaphanization,[14] sectioning,[15,16] microtomography and helical radiography.[16] Conventional radiography provides us with a two-dimensional image of a three-dimensional structure; thus, studies with the CBCT enabled a non-invasive, three-dimensional analysis and among its indications is the anatomical investigation of the root canals.[26] Therefore, in this study we decided for CBCT, which produces images in sections in the three planes of the space without overlapping adjacent anatomical structures.

It is important to emphasize that the CBCT allows the increase in precision and resolution, reduces the scanning time, the radiation dose and the costs to the patient when compared to helical tomography.[27] The quality of the image is related to voxel measurements. It is desired that the three-dimensionality of the voxel (height, width and thickness) presents isotropy, that is, equivalent values. The smaller the voxel size the better the image quality (smaller voxel: 0.075 mm³). On the other hand, there is a longer scanning time and, consequently, an increase in the radiation dose.[28] As can be seen in Box 1, only one study uses voxel of 0.076 mm³, with a voxel predominance of 0.125 mm³.

It is known that the incidence, location and morphology of root canals can be related to the different ethnicities and world populations.[9,11,14-17] Based on the