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Cone-beam computed tomographic evaluation of the root canal anatomy of the lower premolars and molars in a Brazilian sub-population

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ABSTRACT

Purpose: This study evaluated anatomical variations in the root canals of the lower premolars and molars in a Brazilian sub-population using cone-beam computed tomography (CBCT).

Materials and Methods: In total, 121 CBCT images of patients were selected from a database. All images contained lower first and second premolars and molars on both sides of the arch, fully developed roots, and no treatment, resorption, or calcifications. In each image, the root canals of the lower premolars and molars were evaluated according to the Vertucci classification in On-Demand 3D software in the multiplanar reconstruction with dynamic navigation. Twenty-five percent of the images were re-assessed to analyze intraobserver confidence with the kappa test. Data were statistically evaluated with linear regression to evaluate the correlations of anatomic variations with age and sex, and the Wilcoxon test to analyze the laterality of variations, with a significance level of 5%.

Results: The intraobserver agreement (0.94) was excellent. In general, the root canals of lower premolars and molars showed a higher prevalence of type I than other Vertucci classification types, followed by type V in premolars and type II in molars. When the molar roots were evaluated separately, type II was more frequent in mesial roots and type I in distal roots. Although age showed no correlations with the results, sex and laterality showed correlations with tooth 45 and the lower second premolars, respectively.

Conclusion: The lower premolars and molars of a Brazilian sub-population showed a wide range of root canal anatomic variations. ***(Imaging Sci Dent 2023; 53: 77-82)***

KEY WORDS: Anatomy; Bicuspid; Cone-Beam Computed Tomography; Dental Pulp Cavity; Molar

Introduction

The success of endodontic treatment is influenced by the clinician's knowledge of morphology and possible variations of the root canal system, as well as its cleaning, instrumentation, and adequate filling.[1] If these steps are not carried out adequately, microorganisms that were not eliminated may proliferate and cause a secondary infection, resulting in treatment failure. The obstacles to achieving such goals are closely linked to the complexity of root canal anatomy such as roots and supernumerary canals, root dilaceration, isthmus, ramifications, apical deltas, C-shaped canals, and flattening, which are more common in the posterior teeth.[2]

The lower premolar anatomy is considered challenging for a successful endodontic treatment, due to considerable variation in the number of canals and roots,[3,4] with findings such as the presence of 4-root canals.[5] Variations in root canal morphology in the lower first and second molars, such as distolingual roots,[6] the presence of supernumerary roots,[7] and C-shaped root canals[6] have been shown to be influenced by racial and genetic factors.[8]

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The scientific literature presents a wide variety of methods that can be used to study the anatomical variations of root canals, such as cutting, grinding, cleaning, dye infiltration, scanning electron microscopy, 3-dimensional reconstruction methods, and radiographic examinations.[9,10] Vertucci[11] developed a classification system based on the evaluation of 2,400 maxillary and mandibular permanent teeth and identified 8 different root canal configurations. This classification has been frequently used in previous studies among different populations of the world because it is a reliable morphological evaluation of the root canals of different teeth.[4,6-8,12-14]

Although the most common method of root canal morphology evaluation is through periapical radiography images, studies have recently used cone-beam computed tomography (CBCT), which is accurate and capable of providing a detailed 3-dimensional image of the anatomical structures examined. CBCT images eliminate the overlapping of nearby structures,[15] making CBCT suitable for the visualization, evaluation, and diagnosis of pathological processes, impacted teeth, paranasal sinuses, trauma, and variations in the anatomy of teeth and the root canal system.[16]

Considering the anatomical complexity of the permanent lower premolars and molars and the lack of studies carried out in the Brazilian population, it is important to evaluate the anatomy of these teeth associated with aspects such as sex, laterality, and age. The results of this study may validate the accuracy of the diagnostic method and show the incidence of anatomical variations in the Brazilian population. Thus, the objective of the present study was to evaluate, by means of CBCT and the Vertucci classification,[11] the anatomical variations of lower premolars and molars according to sex, age, and laterality.

Materials and Methods

This study was approved by the Ethics and Research Committee of the Faculty of Dentistry of Ribeirão Preto of the University of São Paulo (CAAE: 13121119.3.0000.5419).

In total, 121 CBCT images of patients (48 men, 73 women) between 18 and 75 years (mean ± standard deviation, 28.2 ± 11.7 years) were selected from the Faculty of Dentistry of Ribeirão Preto, University of São Paulo. These images were obtained between August 2017 and December 2019 for the diagnosis and development of a treatment plan for 121 patients at the clinic of the Faculty of Dentistry of Ribeirão Preto, University of São Paulo in Brazil. All CBCT images were obtained by an Eagle 3D unit (Dabi Atlante; Ribeirão Preto, Brazil) adjusted with a field of view of 8 cm × 12 cm, 0.2-mm voxel size, 90 kVp, 6.3 mA, and an acquisition time of 25 seconds.

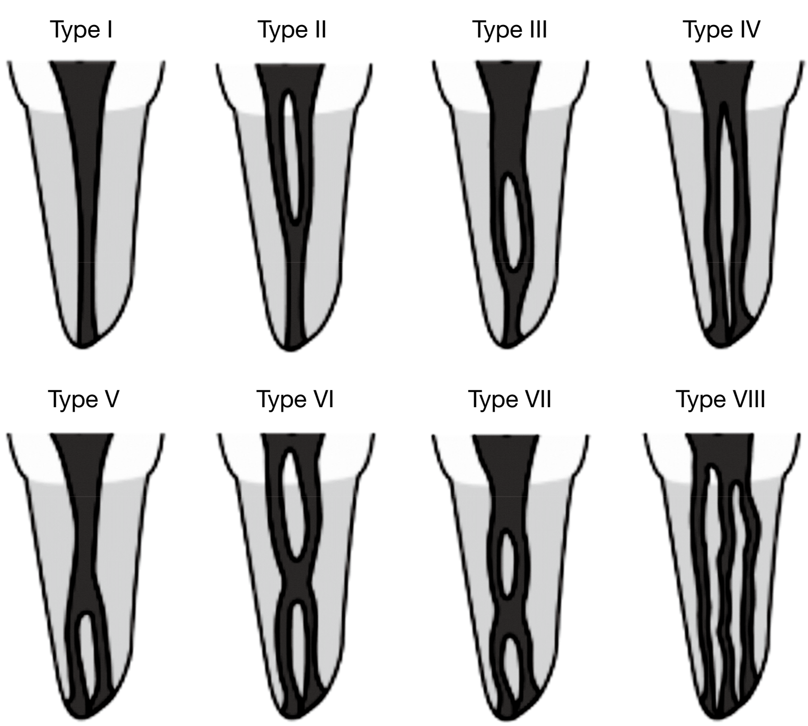

Fig. 1. Schematic representation of the anatomical variations of the root canal according to the Vertucci classification.

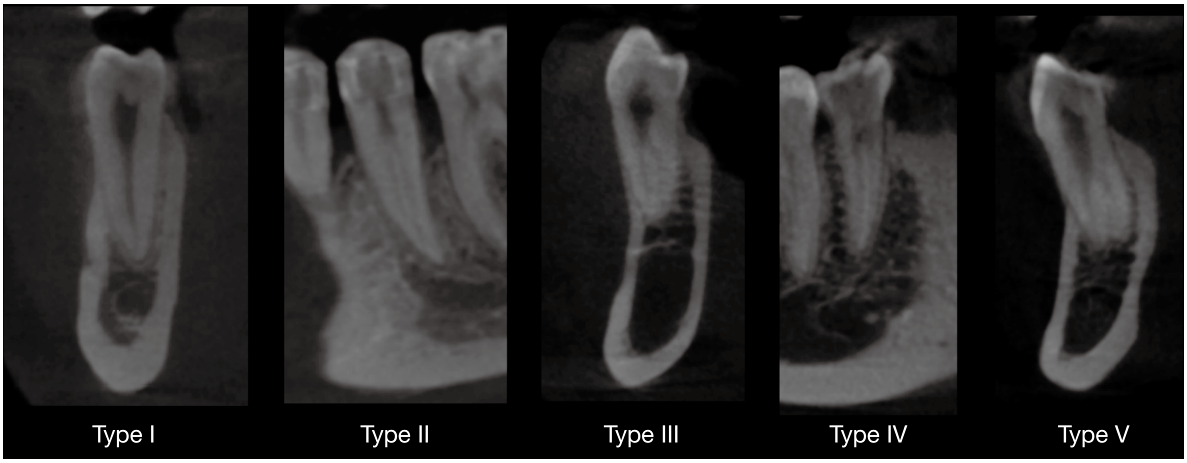

Fig. 2. Sagittal (types II and IV) and coronal (types I, III, and V) cone-beam computed tomography reconstructions of the most frequent types of root canal anatomic variations evaluated in the lower premolars according to the Vertucci classification.

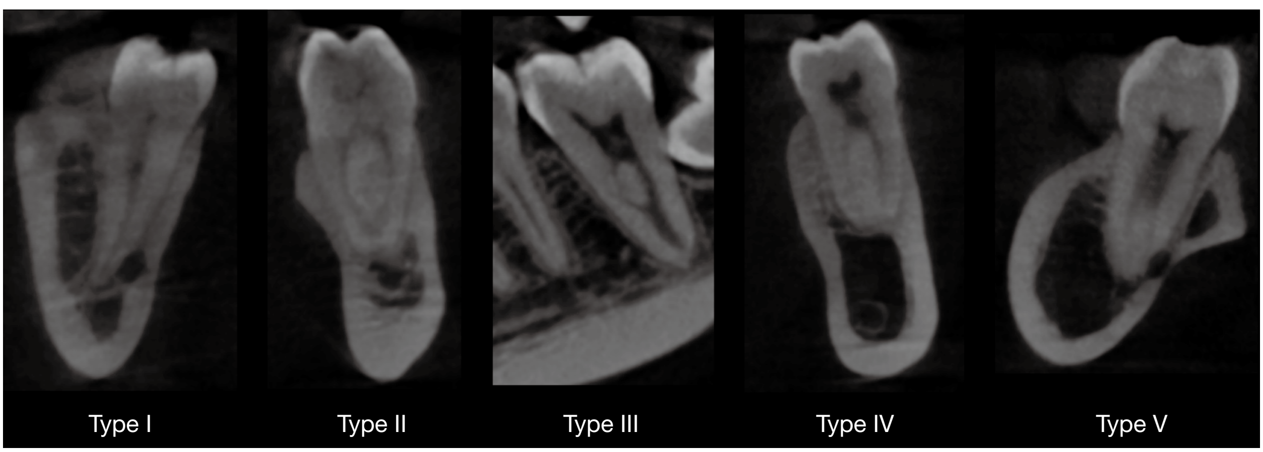

Fig. 3. Coronal (types I, II, IV, and V) and sagittal (type III) cone-beam computed tomography reconstructions of the most frequent types of root canal anatomic variations evaluated in the lower molars according to the Vertucci classification.

As inclusion and exclusion criteria, the CBCT images selected contained lower first and second premolars and molars on both sides of the arch, with fully developed roots, without any apparent treatment, without resorptions or calcifications, and whose exams had good image quality in the area of interest.

The CBCT images were analyzed by a previously calibrated observer using On Demand 3D App™ Software (Daejeon, Korea) with a thickness of 0.2 mm, on a 14-inch monitor (Inspiron 14R 5420, Dell, Austin, USA), with a resolution of 1,366 × 768 pixels, in a dark and calm environment. In each image, the root canals of the lower first and second premolars and molars were analyzed in a multiplanar reconstruction with dynamic navigation according to the Vertucci classification,[11] as described below (Figs. 1-3): type I: a single root canal from the pulp chamber to the root apex; type II: 2 separate root canals leave the pulp chamber and unify near the root apex, forming a single canal; type III: 1 canal leaves the pulp chamber, divides into 2 in the middle of the root and unify near the root apex, forming a single canal; type IV: 2 separate root canals from the pulp chamber to root apex; type V: 1 canal leaves the pulp chamber and divides into 2 root canals, type VI: 2 separate root canals leave the pulp chamber, unify in the middle of the root, and divide into 2 root canals near the root apex, forming 2 separate root canals; type VII: 1 canal leaves the pulp chamber and divides into 2 root canals, unifies into 1 canal and divides again into 2 root canals; and type VIII: all other morphologies.

In the evaluation of the root canals of lower molars, mesial and distal roots were analyzed separately. After 30 days, 25% of the CBCT images were reassessed to analyze intraobserver confidence.

All data were expressed as a percentage distribution of the number of cases. As the variables did not present a normal distribution, the linear regression test was used for sex and age as demographic predictors. The Wilcoxon paired test was used to compare pairs of teeth to assess the existence of laterality. The weighted kappa test was used to measure intraobserver agreement, and the results were interpreted according to Landis and Koch[17] (0.00-0.20: poor; 0.21-0.40: fair; 0.41-0.60: moderate; 0.61-0.80: good; 0.81-1.00: excellent). All analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA), with a significance level of 5%.

Results

The intraobserver agreement was excellent (0.9). The frequency of distribution of the different root canal configurations evaluated in the 121 CBCT images (48 men and 73 women) showed a higher prevalence of type I for the lower premolars (range, 62.8%-96.7%), followed by type V (range, 0.8%-24.8%). Similarly, the lower molars showed a higher frequency of type I (range, 0.0%-90.9%) and type II (range, 0.0%-72.7%). When the mesial and distal roots were evaluated separately, type II was the most frequent in the mesial roots (range, 62.8%-72.7%), followed by type IV (range, 12.4%-33.8%). In the distal roots, the most common configuration was type I (range, 72.7%-92.6%), followed by type III (range, 2.5%-13.2%) (Table 1).

Linear regression tests revealed that sex was correlated with the prevalence of anatomical types analyzed according to the Vertucci classification in tooth 45 ($P=0.034$). Furthermore, age showed no correlation with the prevalence of the analyzed anatomical types ($P>0.05$).

The Wilcoxon paired test revealed that laterality influenced the observed distribution of types, with a statistically significant difference in the 2 hemi-arches studied for the lower second premolars ($P<0.05$).

Discussion

Failures of endodontic treatment are mostly due to anatomical variations of the root canal. Thus, errors of iatrogenic origin, such as a lack of root canal treatment, perforations, extrusion of debris, and trephination, among others, may arise due to an inadequate knowledge of root canal morphology.[18] CBCT enables 3-dimensional visualization of the teeth of interest and an accurate assessment of root canal anatomy.[19] The present study evaluated the root canal configurations of lower premolars and molars on CBCT images and showed a higher prevalence of Vertucci type I, in agreement with previous studies.[7,18,20,21]

The most common imaging modality used by professionals to assess the configuration of root canals is periapical radiography. However, due to its 2-dimensional nature, periapical radiography may provide insufficient information for the planning and diagnosis of endodontic treatment. In contrast, CBCT is a reliable and accurate imaging modality that allows a 3-dimensional evaluation of root canal morphology of *in vivo* teeth with similar diagnostic accuracy as micro-

Table 1. Distribution of different configurations of root canals of lower premolars and molars in men and women according to Vertucci's classification (%)

Tooth number	Type I			Type II			Type III			Type IV			Type V			Type VI			Type VII			Type VIII		
	G	M	F	G	M	F	G	M	F	G	M	F	G	M	F	G	M	F	G	M	F	G	M	F
45	92.6	97.2	85.4	0.0	0.0	0.0	3.3	0.0	8.3	0.8	1.4	0.0	2.5	1.4	4.10	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	2.1
44	63.6	67.2	54.1	0.0	0.0	0.0	6.6	5.5	8.3	2.5	2.7	2.1	24.8	20.5	35.40	1.7	2.7	0.0	0.0	0.0	0.0	0.8	1.4	0.0
34	62.8	68.5	54.2	0.0	0.0	0.0	9.1	9.6	8.3	1.7	1.4	2.1	24.0	11.6	31.30	0.0	0.0	0.0	1.7	1.4	2.1	0.8	0.0	2.1
35	96.7	98.6	93.8	0.8	0.0	2.1	1.7	1.4	2.1	0.0	0.0	0.0	0.8	0.0	2.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47m	13.2	20.5	6.3	70.2	67.1	72.9	0.8	1.4	0.0	12.4	8.2	18.8	0.0	0.0	0.00	1.7	1.4	2.1	0.0	0.0	0.0	1.7	2.7	0.0
47d	90.9	90.4	91.6	0.0	0.0	0.0	2.5	1.4	4.2	0.0	0.0	0.0	1.7	1.4	2.10	0.8	1.4	0.0	0.0	0.0	0.0	4.1	5.5	2.1
46m	0.0	0.0	0.0	62.8	61.6	66.7	0.8	1.4	0.0	33.8	34.2	31.3	1.7	1.4	2.10	0.8	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46d	72.7	72.6	70.8	4.1	2.7	6.3	13.2	13.7	12.5	3.3	4.1	2.1	5.0	4.1	6.25	0.0	1.4	0.0	1.7	1.4	2.1	0.0	0.0	0.0
36m	0.0	0.0	0.0	66.1	67.1	64.6	0.0	0.0	0.0	31.4	31.5	31.3	2.5	1.4	4.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36d	81.0	76.7	81.3	0.8	4.1	0.0	9.9	12.3	8.3	4.1	2.7	6.3	2.5	1.4	4.20	0.0	0.0	0.0	1.7	2.7	0.0	0.0	0.0	0.0
37m	9.1	16.4	4.2	72.7	65.8	77.1	3.3	2.7	4.2	14.1	13.7	14.6	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.4	0.0
37d	92.6	91.8	93.8	0.0	0.0	0.0	2.5	2.7	2.1	0.8	1.4	0.0	2.5	2.7	2.10	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.4	2.1

G: general, M: male, F: female, m: mesial, d: distal

CT imaging.[22] Considering that micro-CT imaging is only performed in a laboratory environment and involves a higher dose of radiation, CBCT is the widely most indicated modality for clinical use because it is non-invasive and non-destructive. Furthermore, despite the slightly higher radiation exposure compared to 2-dimensional imaging, the benefit of CBCT imaging in the assessment of root canal anatomy is greater than the associated risk due to X-rays.[23]

Differences in anatomical variations and the prevalence and behavior of pathologies according to sex have been widely addressed in the literature over the years.[1,4,6-9,11-14,16,18,20-23] Recent studies with different sub-populations have shown differences in root canal configuration by sex, with female sex being associated with a higher prevalence of type I in anterior and premolar teeth and type II and III in the distal roots of first and second lower molars.[12,24] However, although the present study demonstrated a higher prevalence of type I in lower premolars in men and type I for distal roots and type II for mesial roots of lower first and second molars in women, only tooth 45 showed a significant influence of sex on the configuration of the root canal according to Vertucci, in agreement with the study by Mashyakhy and Gambarini,[24] which showed no association between sex and the configuration of root canals in the lower first molars. The heterogeneity of results among studies can be explained by the different sub-populations, as these studies were from different regions of the world - Saudi Arabia, Portugal, and Brazil, respectively. Although a previous study showed an association between the configuration of root canals of lower first molars and laterality,[25] the present study demonstrated the influence of laterality only for the lower second premolars.

Over the years, changes within the root canal configuration may occur due to the physiological deposition of secondary dentin, which contributes to a decrease in the volume and shape of the root canal.[26,27] In contrast, several studies[28,29] have reported that age did not influence root canal morphology, which coincides with the findings of the present study. However, Martins and colleagues[13] showed that over the years, root canals may become narrower and change from single to multiple. It is noteworthy that in addition to studies in the literature being carried out among different sub-populations, they also have differences in methodological design, as well as different age groups of patients.

Differences in the configuration of root canals found among studies can be attributed to differences in sub-populations, methodology, and samples.[12,24-29] New studies, including genetic analyses, should be carried out to improve the understanding of the anatomical aspects of the teeth and the factors that can influence these characteristics.

To the authors' knowledge, this is the first study evaluating the anatomical variations of root canals in the lower premolars and molars in a Brazilian sub-population using CBCT and considering sex, age, and laterality. This study demonstrated that CBCT images allow the differentiation of the various configurations of the root canals in the lower premolars and molars. Thus, the results of this study highlight the importance of using CBCT for preoperative planning and diagnosis of complex cases in endodontics, considering that 2-dimensional images do not accurately identify the morphology of root canals. However, it must bear in mind that the decision to perform CBCT should depend on radiation protection principles and whether the benefits of the radiographic examination outweigh the risk of the radiation dose.[30,31] In conclusion, the lower premolars and molars in a Brazilian sub-population showed a wide range of root canal anatomic variations on CBCT images. These patterns demonstrated an association with sex in tooth 45 and with laterality in lower second premolars.

Conflicts of Interest: None

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