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# Root canal morphology of 1316 premolars from Brazilian individuals: an *in vivo* analysis using cone-beam computed tomography

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***ABSTRACT***

*The aim of this study was to investigate the internal root canal anatomy of maxillary and mandibular premolars in a Brazilian subpopulation, in order to establish the prevalence of the different configurations proposed by Vertucci. Three hundred and ninety-eight cone-beam computed tomography scans were collected from a private imaging clinic database in Rio de Janeiro, including 217 maxillary and 226 mandibular scans. A total 1316 premolars (594 maxillary and 722 mandibular) were evaluated using an image viewer, and classified according to Vertucci. Two calibrated examiners determined the frequency of each morphological Type. A third examiner reviewed discordant cases. The Kappa test was applied to verify inter-rater agreement, and Fisher's Exact Test to verify gender-related differences. The most frequent root canal configurations of maxillary first and second premolars were Type IV (73.86%) and Type I (47.18%), respectively. Type I was the most prevalent in mandibular first and second premolars (80.59% and 95.86%, respectively). Only Types I and VIII presented a statistically significant difference between sexes. Type I was more frequent in females and Type VIII in males. A highly significant frequency of Type I was found in both mandibular first and second premolars, whereas the most frequent maxillary premolar root canal configuration was Type IV for first premolars and Type I for second premolars.*

***Keywords:*** *anatomy - cone-beam computed tomography - premolars - root canal.*

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# Morfologia do canal radicular de 1.316 pré-molares de indivíduos brasileiros: análise *in vivo* usando tomografia computadorizada de feixe cônico

***RESUMO***

*O presente estudo teve como objetivo investigar a anatomia interna de pré-molares superiores e inferiores em uma subpopulação brasileira para estabelecer a prevalência das diferentes configurações propostas por Vertucci. Trezentos e noventa e oito exames de tomografia computadorizada de feixe cônico foram coletados de um banco de dados de uma clínica privada de imagem no Rio de Janeiro, incluindo 217 exames maxilares e 226 mandibulares. Um total de 1.316 pré-molares (594 superiores e 722 inferiores) foram avaliados usando um visualizador de imagens e categorizados de acordo com a classificação de Vertucci. Dois examinadores calibrados determinaram a frequência de cada tipo morfológico. Um terceiro examinador revisou os casos discordantes. O teste Kappa foi aplicado para verificar a concordância entre os avaliadores e o Teste Exato de Fisher para verificar diferenças relacionadas ao gênero. A configuração do canal radicular mais frequente dos primeiros e segundos pré-molares superiores foi Tipo IV (73,86%) e Tipo I (47,18%), respectivamente. O tipo I foi o mais prevalente nos primeiros e segundos pré-molares inferiores (80,59% e 95,86%, respectivamente). Os tipos I e VIII foram os únicos que apresentaram diferença estatisticamente significativa entre os sexos. O tipo I foi mais frequente nas mulheres e o tipo VIII nos homens. Uma frequência altamente significativa do Tipo I foi encontrada em ambos os primeiros e segundos pré-molares inferiores, enquanto a configuração do canal radicular dos pré-molares superiores mais frequente foi o Tipo IV para os primeiros pré-molares e o Tipo I para os segundos pré-molares.*

***Palavras-chave:*** *anatomia - tomografia computadorizada de feixe cônico - pré-molares - canal radicular.*

## INTRODUCTION

The root canal system (RCS) is complex and there is significant variability among dental groups, individuals, and different teeth in the same individual[1]. Lack of knowledge of root canal anatomy can lead to failure in endodontic treatment that may require maintenance or cause the onset of periradicular disease[2].

The literature is unanimous in stating that radiographic investigation is essential for root canal treatment. However, images obtained by digital or conventional radiography are restricted to two dimensions, so the anatomy of a three-dimensional region is analyzed in a two-dimensional image, with frequent overlapping of images. These limitations may lead to misinterpretation and consequently, misdiagnosis[3].

To compensate for this deficiency, computational methods were introduced in the field of medical and dental radiology, culminating in the advent of cone-beam computed tomography (CBCT) followed by micro-computed tomography (micro-CT). CBCT is a non-destructive method that enables three-dimensional and individual evaluation of a tooth, revealing peculiarities that are imperceptible in conventional radiographic images[1].

According to Martins et al.[4], premolars and molars have significant anatomical variability. The apparent simple external root canal configuration of single-rooted or two-rooted premolars may lead to the assumption of simple internal anatomy. However, research reveals the opposite: complex internal anatomy, with up to eight different canal configurations[5,6]. These teeth therefore pose a challenge, especially regarding the high occurrence of flattened canals, accessory canals, and isthmuses[1,6].

In addition, studies have reported that dental anatomy is genetically determined, varying according to ethnicity[2,6,7]. However, most of the published studies are based on Caucasian populations, and are therefore not applicable to Brazil, where the population is heterogeneous and miscegenated[8]. Studies of this kind in the Brazilian population could therefore contribute directly to knowledge of dental anatomy, and indirectly to the success of endodontic treatments, particularly for this group of teeth.

Based on the literature, the most probable hypothesis is that there would be extensive variability in the morphology of premolar root canals in the Brazilian population. Therefore, the aim of the present study was to analyze the internal root canal configurations of maxillary and mandibular premolars in a portion of the Brazilian population, establishing the frequency of the different morphological types proposed by Vertucci[5].

## MATERIALS AND METHODS

A total 1,021 CBCT scans performed on male and female patients were analyzed. The scans were obtained from a private oral radiology clinic in Rio de Janeiro. All healthy or coronally restored maxillary and permanent mandibular premolars with fully formed root apices were included. Endodontically treated teeth, teeth with prosthetic restorations and intraradicular retainers, teeth with incomplete root formation, root resorption, root calcification, or images with artifacts that prevented correct evaluation were excluded. The CT scans were performed from January to March 2015 and acquired using the iCAT Classic unit (IMAGING SCIENCES, Hatfield, USA, 0.2mm voxel size, 120kv, 6-cm FOV (field of view), as suggested by other studies. All CBCT scans were performed with the minimum exposure required for adequate image quality. The ALARA (as low as reasonably achievable) protocol was strictly followed.

CBCT scanning indications included assessing bone volume for dental implant planning, diagnosis of dentoalveolar trauma, management of impacted teeth before orthodontic treatment, and treatment planning before nonsurgical and surgical endodontic treatment. This study was carried out after approval by the Research Ethics Committee of the Health Sciences Center of Estacio de Sá University (protocol number: 64659816.3.0000.5284). All patients provided written informed consent to participate. Following data protection of minors, the Institutional Research Ethics Committee does not allow the use of CBCT data from persons younger than 18 years, so only CBCT exams from individuals over 18 years of age were included.

After applying the exclusion criteria, a total 398 CT scans were analyzed using the Dental Slice software version 2.8, for Windows (2014, Bioparts Prototyping Biomedica, Brasília, DF, Brazil). The contrast and brightness of the images were modified when necessary to ensure optimal viewing. The images were evaluated from three planes: cross-sectional, axial and panoramic, using the space between the 1-mm cross-sections (Fig. 1a, 1b and

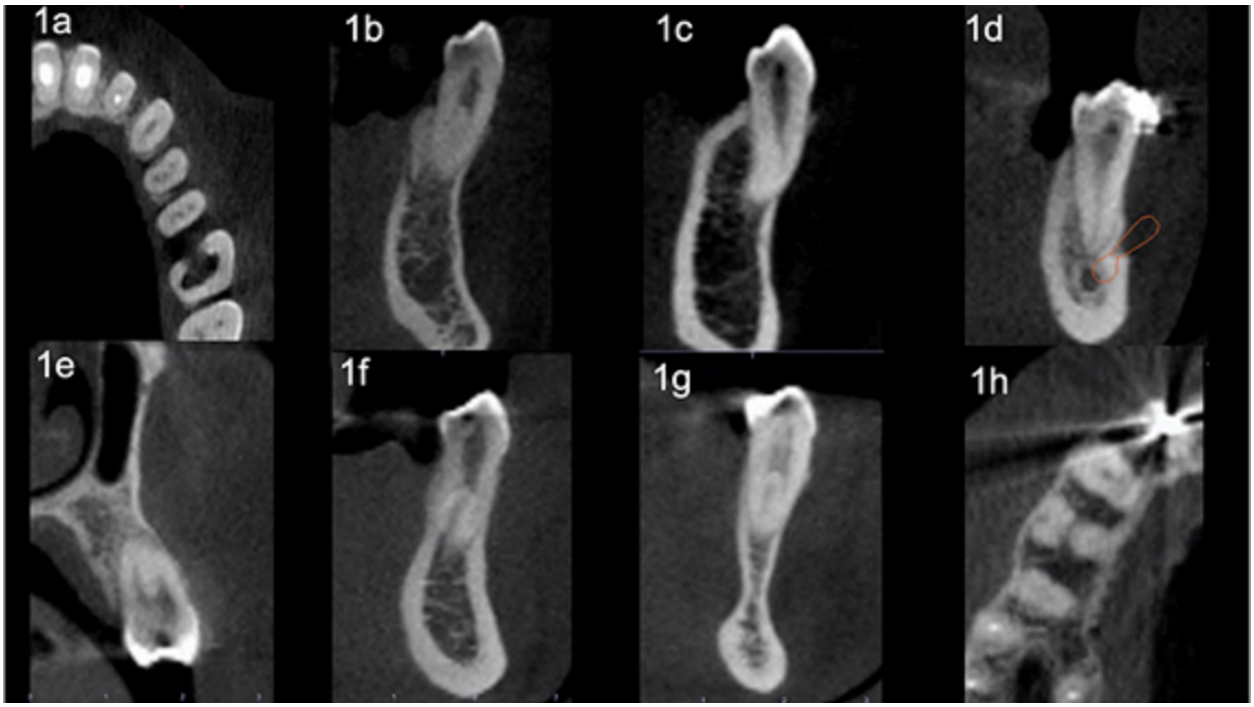


*Fig. 1: Examples of different root canal configurations of maxillary and mandibular premolars. (1a) CBCT axial reconstructions showing different endodontic anatomy. (1b) CBCT sagittal reconstructions of a mandibular premolar showing Vertucci type V classification. (1c) CBCT sagittal reconstructions of a mandibular premolar showing Vertucci type V classification. (1d) CBCT sagittal reconstructions of a mandibular premolar showing Vertucci type I classification. (Red line showing the mandibular canal location). (1e) CBCT sagittal reconstructions of a maxillary premolar showing Vertucci type IV classification. (1f) CBCT sagittal reconstructions of a mandibular premolar showing Vertucci type V classification. (1g) CBCT sagittal reconstructions of a mandibular premolar showing Vertucci Type III classification. (1h) CBCT axial reconstructions of maxillary premolar showing Vertucci type VIII classification.*

1c). They were then classified according to the eight morphological root canal configurations proposed by Vertucci[9].

The analysis was performed independently and randomly by two endodontists, one with a degree in dental radiology. The third examiner, also an endodontist, analyzed and decided the discordant cases.

**Statistical analysis**

All teeth were classified according to their internal anatomy, and the data were recorded on a spreadsheet. The first 300 teeth were used to assess inter-examiner reliability using the Kappa test, which revealed substantial agreement (0.679).

Data were then divided into four dental groups: maxillary first premolars, maxillary second premolars, mandibular first premolars, and mandibular second premolars, and the frequency of each root canal configuration was calculated for each group. Fisher's test was used to verify differences between sexes.

## RESULTS

**Descriptive data**

The study included 398 CT scans, of which 217 were of the maxilla and 226 of the mandibles. The root canal configuration of 1316 premolars were analyzed. Of these, 310 images were of maxillary first premolars and 284 of maxillary second premolars; 407 images were of mandibular first premolars and 315 of mandibular second premolars. There were 501 pairs of contralateral teeth; of these, 443 had the same root canal configuration, and 58 had different root canal configurations.

**Frequency of each root canal configuration**

Table 1 summarizes the frequency of the root canal configuration of each group of premolars. The most frequent canal configuration was Type I (59%) (Fig. 1d), followed by Type IV (23%) (Fig. 1e), Type II (10%), Type V (6%) (Fig. 1b, 1c and 1f), Type III (2%) (Fig. 1g), and Type VIII (Fig. 1h). No teeth were classified as Types VI or VII (Table 1).

**Table 1. Frequency distribution of root canal configurations according to Vertucci's classification (1984)**

| Tooth No | N | I (%) | II (%) | III (%) | IV (%) | V (%) | VI (%) | VII (%) | VIII (%) |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 156 | 5 (3) | 27 (17) | - | 119 (76) | 1 (1) | - | - | 4 (3) |
| 24 | 154 | 6 (4) | 34 (22) | 1 (1) | 110 (71) | - | - | - | 3 (2) |
| 15 | 140 | 59 (42) | 37 (26) | 6 (4) | 35 (25) | 3 (2) | - | - | - |
| 25 | 144 | 75 (52) | 31 (22) | 2 (1) | 35 (24) | 1 (1) | - | - | - |
| 34 | 196 | 159 (81) | - | 6 (3) | - | 30 (15) | - | - | 1 (1) |
| 44 | 211 | 169 (80) | 1 (0) | 4 (2) | - | 36 (17) | - | - | 1 (0) |
| 35 | 162 | 155 (96) | 1 (1) | 1 (1) | - | 5 (3) | - | - | - |
| 45 | 153 | 147 (96) | 1 (1) | - | - | 4 (3) | - | - | 1 (1) |
| **Total** | **1316** | **775 (59)** | **132 (10)** | **20 (2)** | **299 (23)** | **80 (6)** | **0** | **0** | 10 (1) |

**Table 2. Frequency of distribution of the root canal configurations according to Vertucci's classification according to sex**

| | | Morphological type | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VIII | |
| Sex | F | 506 | 63 | 11 | 149 | 40 | 1 | 770 |
| | M | 269 | 69 | 9 | 150 | 40 | 9 | 546 |
| Total | | 775 | 132 | 20 | 299 | 80 | 10 | 1316 |
| p-value* | | 0.01 | 0.54 | 0.75 | 1.00 | 1.00 | 0.01 | - |

* P-value obtained by Fisher's exact test

Among the maxillary first premolars, the most frequent canal configuration was Type IV (76% were teeth No. 14 and 71% were teeth No. 24). The second most frequent canal configuration was Type II (17% were maxillary right premolars and 22% were mandibular left premolars) (Table 1).

The most frequent maxillary second premolar root configuration was Type I (42% were teeth No. 15 and 52% were teeth No. 25). The second most frequent maxillary right premolar root configuration was Type II (26%), while the most frequent maxillary left premolar root configuration was Type IV (24%) (Table 1).

The most frequent root canal configuration among the mandibular premolars was Type I (teeth No. 34 (81%), teeth No. 44 (80%), teeth No. 35 (96%), and teeth No. 45 (96%) (Table 1).

Upon completing the analyses, the Kappa test was repeated for all teeth evaluated (n = 1316), and the result was higher than the one obtained during the calibration phase (0.692), representing substantial agreement.

Table 2 shows the frequency of distribution of the root canal configurations according to sex. Only Type II and VIII root canal configurations presented a significant difference between sexes (p = 0.001).

## DISCUSSION

The complexity of root canal treatment is directly associated with the number of root canals, bifurcations, anastomoses and isthmuses. Knowing and understanding these possible variations reduces the probability of leaving canals untreated, and increases the success rate of endodontic treatment[4,10,11].

Ethnicity predisposes to root canal variations[2,7], but it is not easy to classify the Brazilian population because of its significant heterogeneity[12]. Few studies in the current literature have analyzed the root canal anatomy from posterior teeth in the Brazilian population, and most of these only evaluated molars[8,12-14]. Studies of premolar anatomy in the Brazilian population are scarce compared to studies in other populations[2,15-17].

The study by Pécora et al.[18] evaluated the morphology of premolars in Brazilian individuals. However, the authors did not use Vertucci's classification[5], and only classified the number of root canals. One of the noteworthy aspects of the present study is that the sample was evaluated independently by two experienced endodontists, and a third examiner resolved conflicting cases. This methodology was the same as the one used in previous studies[2,19].

Nevertheless, in other studies[1, 20], only two examiners evaluated the images, and discussed any conflicting cases until they reached a consensus. There are also studies[4,21] in which only one examiner evaluated the images, increasing the probability of failure.

Although the percentages may vary, the most frequent root canal configuration of maxillary first premolars was Type IV (73.87%), which agrees with many previous studies[4,5,15,20,22,23]. A study in the Turkish population[24] found divergent results, with the most frequent root canal configuration being Type I (62.6%).

In the present study, the most frequent maxillary second premolar root canal configuration was Type I (47.18%), in agreement with other studies[1,4,9,15,23-25]. Among mandibular first and second premolars, the most frequent root canal configuration was Type I, which agrees with studies in other populations[2,4,10,19,21-26]. Similarly to many previous studies[2,4,9,15,19,21,23-26], the present study did not identify any root canals of Type VI and VII configuration. One of the limitations of this study is related to the use of CBCT, which cannot provide images as detailed as can micro-CT[15]. On the other hand, micro-CT cannot be used in in vivo studies. Nonetheless, CBCT has been validated in the literature as a reliable, non-invasive method for evaluating highly complex cases[3]. Further studies are needed to understand the morphology of root canal configuration in the Brazilian population.

## CONCLUSION

It may be concluded that the morphology of the root canal system of premolars in the Brazilian population is as follows: (1) the most frequent root canal configurations found for the maxillary first and second premolars were Type IV and Type I, respectively; (2) a highly significant frequency of Type I configuration was found for the mandibular first and second premolars; and (3) morphology of the root canal system of premolars in the Brazilian population does not differ substantially from other populations (American, Turkish, Iranian, Chinese, Egyptian, Spanish, Arabic, and Portuguese), even though it is a heterogeneous population.

**DECLARATION OF CONFLICTING INTERESTS**

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article

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