# Analysis of the root canal morphology of mandibular premolars using cone-beam computed tomography

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## ABSTRACT

**Introduction:** The success of an endodontic treatment depends primarily on cleaning and shaping of the root canal system. Therefore, the anatomy of the root canal system should be known in detail. However, this anatomy is complex and varies morphologically in different populations. This study evaluated the root canal anatomy of mandibular premolars in a Brazilian population using cone beam CT (CBCT). **Methods:** CBCT axial, coronal and sagittal slices of 426 mandibular premolars were analyzed. Number of roots and canals, as well as Vertucci type, were recorded using a spreadsheet. Associations between sex, number of roots, and Vertucci type were analyzed using a chi-square test ($p<0.05$). **Results:** Of the 426 teeth evaluated, 224 (52.6%) were first premolars and 202 (47.4%), second premolars. Most first premolars (93.3%) and all second premolars had one root. Vertucci types I, II and V were found, and type I was the most frequent. Type V was only found in two-rooted first premolars ($p<0.001$). There were no significant associations between number of root and sex ($p=0.182$). **Conclusion:** Most mandibular premolars had one root and were Vertucci type I, which indicates that there is little anatomic variation of these teeth in the Brazilian population under study. There was no sex predilection for number of roots or Vertucci type.

**Keywords:** Anatomy. Premolar. Root canal obturation.

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## Introduction

The success of endodontic treatments is directly associated with cleaning and shaping of the root canal system (RCS) followed by its three-dimensional obturation to create a good seal.[1] For that purpose, RCS morphology and possible anatomic variations should be well known, as lack of this information may lead to failure in detecting all root canals and in determining which instruments to use. Such failure may result in an endodontic treatment failure.[2,3]

In clinical endodontics, periapical radiography is the most frequent method to study root canal anatomy.[4] However, as it is a two-dimensional imaging method, it may lead to mistakes or limited RCS interpretations.[5,6] Anatomic variations may be suspected only when there are changes in the shape or direction of a root canal, or when the canal is not fully visualized on a radiograph, which suggests the presence of two root canals. In current Dentistry, cone beam CT (CBCT) has been used to diagnose and plan the treatment of selected cases before endodontic treatment.[7] CBCT images provide a three-dimensional view, with no superimposition of anatomic structures, which favors a more precise evaluation of tooth anatomy and root canals.[8]

The anatomy of root canals of mandibular premolars and the morphological differences between first and second premolars have been evaluated in several studies, such as clinical cases, literature reviews and laboratory trials, using clearing techniques, periapical radiographs, clinical microscopic analyses and CBCT.[3,9-14] These studies[3,9-14] revealed variations in the number of roots and type of root canal and apical foramina in mandibular premolars. Such differences may complicate endodontic treatments.

Factors such as age, sex and ethnicity determine anatomic variations of root canals, which have been confirmed by several studies[14-16] that have evaluated premolar morphology in different populations. The RCS may be expected to have great morphological variations in the Brazilian population, as this is one of the most heterogenous populations in the world, with contributions of European, African and Asian ethnic groups.[17] However, no CBCT studies have described the anatomy of mandibular premolars in the Brazilian population.

This study determined the number of roots and the morphology of root canals of mandibular premolars in a Brazilian population using CBCT.

## Material and methods

this study was approved by the Ethics in Research Committee of the institution were it was conducted, under no. 1.840.898. This cross-sectional observational retrospective study analyzed CBCT scans obtained from the database of the Dental Radiology Department of the Federal University of Juiz de Fora.

Of the 426 teeth included in the study, 224 were first premolars and 202, second premolars of a group of 119 patients of both sexes and any age in the region of Zona da Mata Mineira, Brazil. Scans were included if their image quality was good, and if they showed the mandibular region with a fully erupted permanent mandibular premolar. Exclusion criteria were facial trauma, fractures, orthognathic surgeries, maxillofacial lesions and craniofacial anomalies visible on CBCT scans. Teeth were not analyzed if they had endodontic treatments, fractures, root resorptions or intraradicular posts.

Images were acquired using the same scanner (I-Cat®, Imaging Sciences International, Hatfield, PA) and scanning parameters for all patients: 120 kV, 8 mA, 26.9 s, 0.25 mm slice and FOV of at least 7 cm.

All scans included in the study were evaluated using the XoranCat 3.1.62 software (Xoran Technologies, Ann Arbor, MI). Image brightness and contrast were adjusted using a software tool to improve visualization. Moreover, the scanner settings were adjusted to multiplanar (MPR) display mode and 0.25-mm slices without filters. A trained and observer with experience in CBCT image analysis evaluated all images. One week after the first evaluation, 10% of the samples were re-evaluated to confirm method reproducibility.

The teeth were evaluated beginning with the mandibular first and then second premolar in the right side and then in the left side, following the same sequence. Tooth images on CBCT axial, coronal and sagittal slices were examined to define number of roots and canals, as well as the morphology of the root canal according to Vertucci type (Fig 1).

The number of roots detected on CBCT axial slices was classified using the system described by Pécora et al.[19]

- Single-rooted teeth: teeth with one canal, or two independent canals that seemed to have two roots, but which, in fact, were fused.

- Multi-rooted teeth: teeth with two bifurcated roots, regardless of whether the bifurcation was partial or complete.

Data were then recorded using an Excel 2010 spreadsheet, and then described and analyzed statistically using the IBMM SPSS Statistics 15.0 software (IBM Corp, Armonk, NY). Associations between sex, number of roots and Vertucci type were analyzed using a chi-square test. The confidence interval was set at 95% ($p<0.05$).

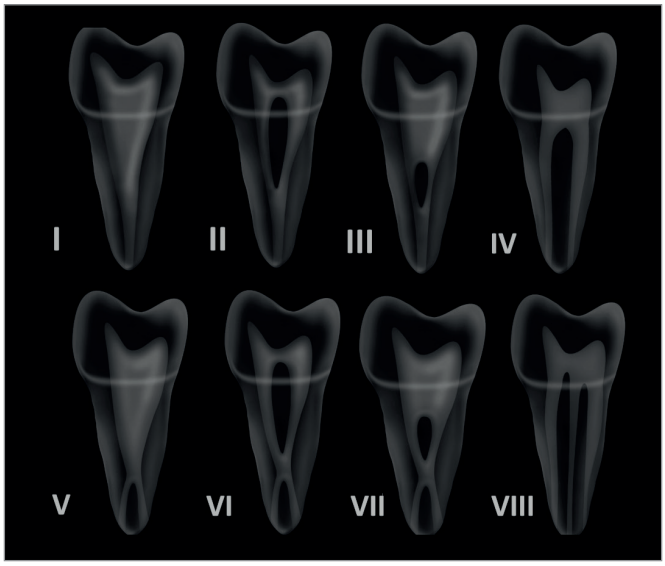


**Figure 1.** Vertucci type according to root canal morphology.

## RESULTS

This study evaluated CBCT scans of 426 teeth (224 first premolars and 202 second premolars) of 119 individuals (76 women) aged 19 to 72 years and whose mean age was 35.8 (±14.8) years.

Table 1 shows the number of roots of first and second premolars according to sex. In the group of first premolars, most (90.4%) of the 83 teeth of male patients had one root, and 9.6%, two. Of the 141 teeth of female patients, 95% had one root and 5%, two. In second premolars, all the teeth (100%) of male and female patients (73 and 129 teeth) had only one root. The chi-square test did not reveal any associations between number of roots and sex when analyzing first and second premolars ($p=0.182$).

Table 2 shows the frequency of number of roots according to tooth position. Of the 224 first premolars, 209 (209 (93.3%) had one root and 15 (6.7%), two. All the 202 second premolars (100%) had one root. There was a significant association between number of roots and tooth position, and only first premolars had two roots ($p<0.01$), with no significant difference between right and left sides.

Table 3 shows the prevalence of types of root canals. The most prevalent in first premolars was type I (93.3%), followed by type V (6.7%). The other types, II, III, IV, VI, VII and VIII, were not found in first premolars. In second premolars, type I was the most prevalent (99.5%). Only 0.5% of all second premolars were type II. There was no association between root canal morphology and sex ($p=0.162$).

There was a statistically significant difference between number of roots and root canal morphological type ($p<0.001$). Vertucci type V was found only in two-rooted premolars (Table 3).

**Table 1.** Prevalence of premolar roots according to sex.

| Tooth | 1 root n(%) | 2 roots n(%) | Total |
|---|---|---|---|
| | 1º PM | | |
| Male | 75 (90,4) | 8 (9,6) | 83 |
| Female | 134 (95) | 7 (5) | 141 |
| Total | 209 (93,3) | 15 (6,7) | 224 |
| | 2º PM | | |
| Male | 73 (100) | 0 (0) | 73 |
| Female | 129 (100) | 0 (0) | 129 |
| Total | 202 (100) | 0 (0) | 202 |

**Table 2.** Number of roots and tooth position.

| Tooth | 1 root n(%) | 2 roots n(%) | Total |
|---|---|---|---|
| | 1º PM | | |
| Left | 104 (92,9) | 8 (7,1) | 112 |
| Right | 105 (93,75) | 7 (6,25) | 112 |
| Total | 209 (93,3) | 15 (6,7) | 224 |
| | 2º PM | | |
| Esquerdo | 102 (100) | 0 (0) | 102 |
| Left | 100 (100) | 0 (0) | 100 |
| Right | 202 (100) | 0 (0) | 202 |

**Table 3.** Prevalence of root canal type.

| | | Morphological type of root canal* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of roots | I | II | III | IV | V | VI | VII | VIII | Total |
| Mandibular first premolar | 1 root | 209 (100) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 209 |
| | 2 roots | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 15 (100) | 0 (0) | 0 (0) | 0 (0) | 15 |
| | Total | 209 (93,3) | 0 (0) | 0 (0) | 0 (0) | 15 (6,7) | 0 (0) | 0 (0) | 0 (0) | 224 |
| Mandibular second premolar | 1 root | 201 (99,5) | 1 (0,5) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 202 |
| | 2 roots | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| | Total | 201 (99,5) | 1 (0,5) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 202 |

* According to Vertucci types.[18]

## Discussion

The anatomic variations of mandibular premolars should always be known to ensure the success of endodontic treatments.[16] These differences may be determined by several factors, such as age, sex and ethnicity. The morphology of the RCS may be expected to vary greatly in the Brazilian population, as this is one of the most heterogenous populations in the world, with contributions of European, African and Asian ethnic groups.[17]

Root canal morphology has been studied using several methods, such as dye penetration, in vitro macroscopy, scanning electron microscopy, contrast medium-enhanced radiography and CT.[18,20,21] However, these techniques can only be used with extracted teeth.

CBCT has been recommended for the evaluation of root canal morphology of patients before and during endodontic treatment, because it is a three-dimensional test with no image superimposition. Moreover, it provides visualization of the RCS on all planes.[14-16] Neelakantan, Subbarao and Subbarao[22] reported that CBCT may detect RCS variations as accurately as staining techniques and CT, and that it is more accurate than periapical radiography. For this reason, this study used CBCT to determine the number of roots and the morphology of root canals of mandibular premolars in a Brazilian population.

In this study, RCS anatomy was classified into eight types, according to the study by Vertucci.[18] Studies including different populations found that anatomic variations of mandibular premolars are very common [15,23,24] (Table 4). Our results showed that most mandibular first premolars had one root and one canal (93.3%), which is in agreement with several studies.[9,11,14,19,23,25,26] However, this result differs from those reported by Lu et al,[25] who found that, in a Chinese population in Taiwan, only 54% of the mandibular first premolars had one canal, whereas 22% had two canals. These differences may be assigned to the selection of the study samples in different populations. All second premolars in our study had only one root, and most had only one canal (99.5%), in agreement with other studies.[14,23,25-28]

Yu et al.[14] and Yang et al.[29] found that, in the Chinese population studied, some premolars had C-shaped canals (1.1% and 1.14%). Our study did not find any C-shaped canals, in agreement with findings reported by other authors.[14,15,23,26]

There was a positive association between number of roots and tooth position, as only first premolars had two roots (6.75%), whereas all second premolars had a single root. These findings corroborate those reported by Estrela et al,[25] who evaluated tooth anatomy in a subpopulation of the Central-West region of Brazil and found that all mandibular second premo-

**Table 4.** Number of roots of mandibular premolars in different studies.

| | Author (year) | Population (sample) | 1 root (%) | 2 roots (%) | 3 roots (%) | C-shaped tooth |
|---|---|---|---|---|---|---|
| 1st premolar | Yu et al.[14] (2012) | Chinese (n=178) | 98,0 | 2,0 | 0,0 | 0,0 |
| | Yang et al.[29] (2013) | Chinese (n=440) | 76,1 | 22,1 | 0,7 | 1,1 |
| | Llena et al.[23] (2014) | Spanish (n=73) | 100,0 | 0,0 | 0,0 | 0,0 |
| | Ok et al.[15] (2014) | Turkish (n=2816) | 93,5 | 6,2 | 0,3 | 0 |
| | Estrela et al.[25] (2015) | Brazilian (n=100) | 99,0 | 1,0 | 0,0 | 0,0 |
| | Goller-Bulut et al.[24] (2015) | Turkish (n=598) | 97,2 | 2,8 | 0,0 | 0,0 |
| | Martins et al.[26] (2016) | Portuguese (n=1054) | 99,8 | 0,2 | 0,0 | 0,0 |
| | This study | Brazilian (n=224) | 93,3 | 6,7 | 0,0 | 0,0 |
| 2nd premolar | Yu et al.[14] (2012) | Chinese (n=178) | 100,0 | 0,0 | 0,0 | 0,0 |
| | Llena et al.[23] (2014) | Spanish (n=53) | 100,0 | 0,0 | 0,0 | 0,0 |
| | Ok et al.[15] (2014) | Turkish (n=2816) | 98,5 | 0,6 | 0,9 | 0,0 |
| | Estrela et al.[25] (2015) | Brazilian (n=100) | 100 | 0,0 | 0,0 | 0,0 |
| | Goller-Bulut et al.[24] (2015) | (n=549) | 99,0 | 1,0 | 0,0 | 0,0 |
| | Martins et al.[26] (2016) | Portuguese (n=833) | 99,9 | 0,1 | 0,0 | 0,0 |
| | This study | Brazilian (n=220) | 100 | 0,0 | 0,0 | 0,0 |

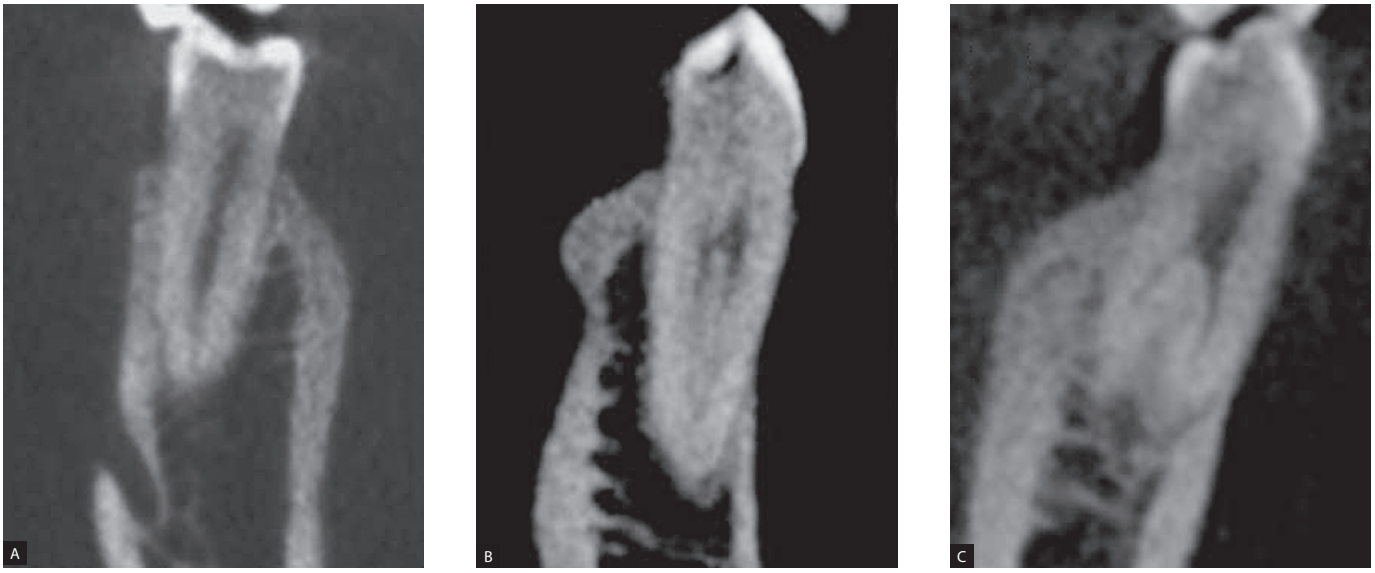


**Figure 2.** Vertucci types found in the study: **A**) type I; **B**) type II; and **C**) type V.

lars had one root. However, other studies did not find any association between number of roots and tooth position.[15,16,29] Ok et al.[15] studied a Turkish population and found that 1.5% of the second premolars had two roots. Shetty et al,[16] in turn, found a second premolar with three roots in an Indian population. This small variation may be explained by ethnic differences between the populations under study. Our study included individuals of a Brazilian subpopulation, whereas the participants in the other studies[14-16,23] were from other countries, such as Turkey, India, China and Spain.

The Vertucci types found in this study were I, II and V (Fig 2). In the literature,[14-16,19] the incidence of only one root canal in first premolars and second premolars ranges from 74% to 93% and 81.5% to 98.8%, results that are similar to those found in this study: first premolars – 93.3%, and second premolars – 99.5%. Type V was the second most common, found only in two-rooted premolars, which corroborates findings reported in several studies[14,15] (Table 3).

There was no sex predilection for number of roots and Vertucci type (p=0.182 and p=0.162), in agreement with the study conducted by Llena et al.[29] However, Ok et al.[15] found that the incidence of single-rooted premolars was greater in men than in women in an Indian population. This disagreement between study findings may be explained by ethnic differences of the populations under study.

This study confirmed the presence of morphological variations in mandibular premolars. Such differences may lead to errors in the attempt to locate root canals. Therefore, when the anatomy of the RCS of mandibular premolars is not clearly defined because of distortions and superimposition of images on periapical radiographs,[30] CBCT should be used to scan the tooth before endodontic treatment. CBCT scanning shows anatomic variations three-dimensionally without any damage to teeth, which ensures greater chances of endodontic treatment success.

## Conclusion

» Most mandibular premolars have a Vertucci type I root.

» All second premolars had only one root in the population under study.

» Vertucci type V was only found in two-rooted first premolars.

» There was no sex predilection for number of roots or type of root canal.

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