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# A Cone-Beam Computed Tomography Study of the Root Canal Morphology of Mandibular First Premolars in an Indian Subpopulation

*Diana John[1], Jayasree S.[2], Ramesh Kumar M.[3], M. Abdul Rahman T.V.[4], Gokulraj R.[5]

[1,2,3,4,5] *Department of Conservative Dentistry & Endodontics, Govt. Dental College, Kozhikode, India*
**Corresponding author: *Diana John[1]*

***Abstract**: Introduction: Successful root canal therapy requires an in-depth knowledge of root canal morphology. The aim of this study was to investigate root canal morphology in mandibular first premolars in an Indian subpopulation using Cone-Beam Computed Tomography (CBCT). Methods: Four hundred extracted mandibular first premolars were selected for the study, based on the inclusion and exclusion criteria. CBCT acquisition of each specimen was done and the root canal morphology was reconstructed three-dimensionally with a semiautomatic threshold-based segmentation approach. The root canal morphology of the mandibular first premolars was classified according to Vertucci's classification. The level of root canal bifurcation, if present, was also noted. Results: The mandibular first premolars showed Vertucci's Types I, II, III, IV, V and VIII. Type I was observed in 315 teeth [78.75%], Type II in 5 teeth [1.25%], Type III in 3 teeth [0.75%], Type IV in 64 teeth [16%], Type V in 11 teeth [2.75%] and Type VIII in 2 teeth [0.5%]. Root canal bifurcation, if present, tended to occur in the middle third (63.16%) or apical third (36.84%). Conclusions: Type I configuration represented the highest percentage (78.75%). There was high incidence of Type IV configuration as compared to Types V, II, III and VIII in the descending order. CBCT is a valuable diagnostic tool in the management of mandibular premolars with complex canal morphology.*

***Keywords:** Cone-beam computed tomography; mandibular first premolar; root canal morphology*

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## I. Introduction

Successful root canal treatment relies on a comprehensive understanding of the morphology of the root canal system. The inability to detect, prepare, or obturate one or more of the root canals is a common cause of failure of endodontic treatment.[1] According to Hoen and Pink, the incidence of missed roots or canals in the teeth that needed retreatment was 42%.[2]Frequently considered an enigma to the endodontist, the mandibular first premolar can generate complicated mechanical problems due to the tortuous nature of the canals dividing at various levels of the root. Mandibular premolars may present the greatest difficulty of all teeth to perform successful endodontic treatment.[3] This fact can be substantiated by the presence of multiple root canals[4], lateral canals, apical deltas and C-shaped canals. In addition, the access cavity in these teeth is relatively small, resulting in reduced visualization. Canal configurations in mandibular premolars may vary significantly with respect to ethnicity[5–7], race[8], and sex[6,9].Previous studies have shown that a high percentage of mandibular first premolars have more than one root canal ranging from 11.53% to 46%. These variations may result in missing root canals in mandibular first premolars that need root canal treatment.[10]

Advanced modes of radiographic imaging and analysis such as spiral computed tomography (SCT), micro-computed tomography (micro-CT) and cone-beam computed tomography (CBCT) have allowed for extensive knowledge of pulp space anatomy in three dimensions and identification of rare aberrations.[11] CBCT uses a cone-shaped beam instead of the fan-shaped one used by regular CT scanners. CBCT scanning can help clinicians view morphologic features from a 3-dimensional perspective. The images are displayed in axial, sagittal, and coronal sections and can reduce the superimposition of surrounding structures.[12]Owing to the variations in root canal anatomy, the mandibular first premolar is quite notorious for its high flare up and failure rates.[13] Though a few studies have been carried out in India, no study on the variation in root canal anatomy of mandibular first premolar has been done in the Malabar subpopulation of India. Hence, the purpose of this study was to determine root canal morphology of mandibular first premolars in Malabar subpopulation using CBCT and to classify the canal morphology according to Vertucci's classification[14] (Fig 1). The level of root canal bifurcation, if present, was also noted.

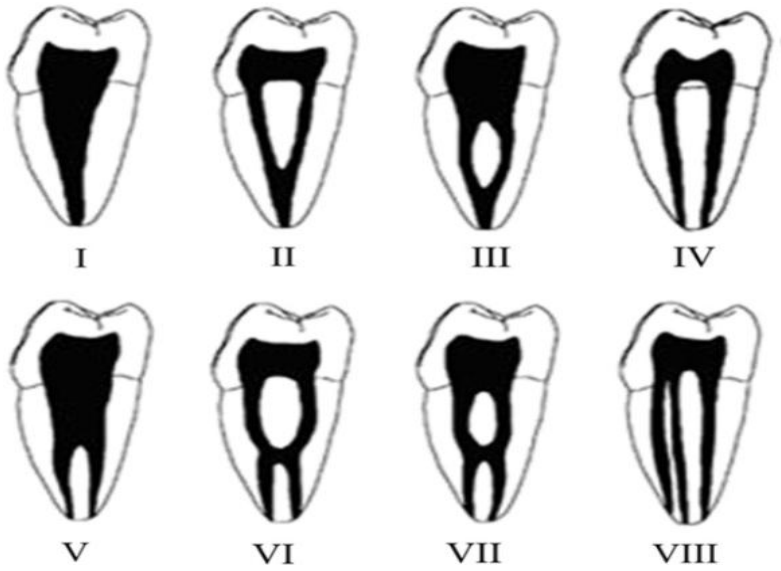


**Figure 1:** The Vertucci classification of root canal configuration

## II. Materials And Methods

**2.3Collection and Arrangement of Teeth in Arch Form**

Extracted mandibular first premolars were collected from the Department of Oral & Maxillofacial Surgery, Government Dental College, Kozhikode, from which 400 were selected for the study, based on the inclusion and exclusion criteria. The study protocol was approved by the Scientific and Ethics Committee of Government Dental College, Kozhikode.

**2.4Inclusion Criteria**

1. Extracted mandibular first premolars collected from Malabar subpopulation, displaying fully formed apices

**2.5 Exclusion Criteria**

1. Grossly carious teeth
2. Root fracture
3. Root resorption
4. Immature apices
5. Endodontically treated teeth
6. Teeth with full coverage restoration

All teeth were placed in 5.25% sodium hypochlorite (Fisher Scientific Qualigens Fine Chemicals, Navi Mumbai, India) for 30 minutes, after which any remaining external tissue or calculus was removed by scaling. Each specimen was then embedded up to the cementoenamel junction in a U –shaped wax block which was moulded to simulate the form of the mandibular jaw. Each wax arch contained 20 teeth. Specimens were placed in close contact to each other to simulate their natural alignment in a dental arch.

## III. CBCT Acquisition

CBCT acquisition of each specimen was done with Planmeca ProMax 3D Mid (Planmeca Oy, Helsinki, Finland). Each wax arch containing the teeth was put in the centre of the cone-beam (field of view, 200×100mm), and after a single rotation, a volume with spatial resolution of 76 μm (isotropic voxel) and contrast resolution of 12 bits was reconstructed. With the data acquired using ProMax 3D, an automatic segmentation procedure was used to reconstruct in 3-D the root canal system. This procedure was the same for each specimen. All scans were performed using 80 kV and 6.3 mA with a 500-ms exposure time.The number of canals, Vertucci's classification of canals and position of canal bifurcation were evaluated by two endodontists and a radiologist. Disagreement in the interpretation was discussed between the examiners until a consensus was reached.

## IV. Statistical Analysis

Raw data were entered into Excel (Microsoft Corporation, Redmond, WA). All analyses were done in an SPSS environment (Version16; SPSS, Inc., Chicago, IL). A descriptive analysis of the data was performed.

## V. Results

**Fig 2**: The mandibular first premolars examined in this study showed Vertucci's Types I, II, III, IV, V and VIII.

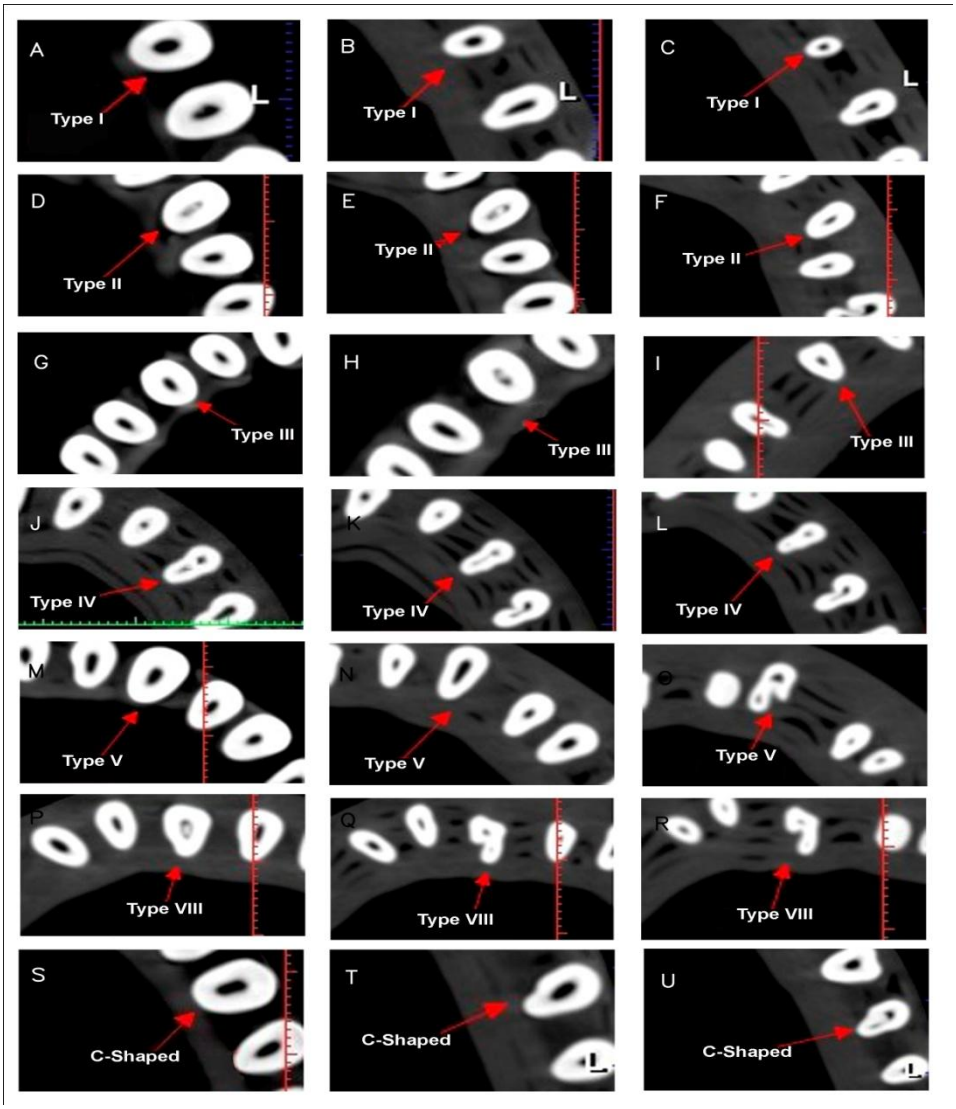


**Figure 2**: The axial planes of CBCT scanning in the coronal, middle, and apical thirds of the root displayed the variation in canal morphology. (Arrows denote the canal morphology.) A–C display type I; D–F display type II; G–I display type III; J–L display type IV; M–O display type V; P–R display type VIII; and S–U display the C-shaped root canal system.

A single root canal was found in 315 teeth (78.75%) and a complicated root canal was confirmed in 85 teeth (21.25%) by CBCT imaging. The frequency distribution of different canal configurations is shown in Table 1.

**Table 1:** Distribution of Root Canal Systems Found in Mandibular First Premolars in the Present Study

| ROOT CANAL CONFIGURATION | NUMBER OF TEETH | PERCENTAGE |
|---|---|---|
| TYPE -I(1) | 315 | 78.75% |
| TYPE -II(2-1) | 5 | 1.25% |
| TYPE -III(1-2-1) | 3 | 0.75% |
| TYPE -IV(2) | 64 | 16% |
| TYPE -V(1-2) | 11 | 2.75% |
| TYPE -VI(2-1-2) | 0 | 0% |
| TYPE -VII(1-2-1-2) | 0 | 0% |
| TYPE -VIII(3) | 2 | 0.5% |

The results indicated that Vertucci's Type I canal configuration represented the highest percentage (78.75%). There was high incidence of Type IV as compared to Types V, II, III and VIII in the descending order. The prevalence of C-shaped canal morphology in mandibular first premolars in this study was 2.25% (*n*=9).The frequency distribution of apical canal orifices is given in Table 2.

**Table 2**: Distribution of Root Canal Systems With Number of Root Canal Orifices At Apex

| **Number of Root Canal Orifices At Apex** | **Percentage** |
|---|---|
| One Canal Orifice | 80.75% |
| Two Canal Orifices | 18.75% |
| Three Canal Orifices | 0.5% |

18.82% of the teeth with complicated canal morphology showed bifurcation, located at 6.3-12.5 mm from the cemento-enamel junction. In particular, the root canal bifurcation tended to occur in the middle third (63.16%) or apical third (36.84%) in bicanal mandibular premolars.

## VI. Discussion

Successful root canal therapy consists of meticulous biomechanical preparation and chemical debridement, followed by 3-dimensional (3D) obturation of the root canal system. To ensure these goals, a comprehension of fundamental root canal anatomy is compulsory before performing endodontic therapy.[15]
In our study, majority of the teeth had only a single canal from the pulp chamber to the apex (*n*=315, 78.75%), and 21.25% (*n*=85) had a complicated root canal system from Types II to VIII. This observation is in accordance with the results of previous studies by Iyer *et al.*[16], Velmurugan *et al.*[17] and Yang *et al.*[18]

However, these results are different to those reported in other studies. Lu *et al.*[5] observed that only 54% of mandibular first premolars exhibited a single canal, whereas 22% contained two canals (vs. 18.75% in this study) and 18% had a C-shaped configuration (vs. 2.25% in this study). Jain and Bahuguna[19] reported that Type I canal system was found in only 67.39% (*n*=93) of the teeth studied. The frequency of Type I canal configuration was reported as high as 88.47% in an Iranian population in a study by Khedmat *et al.*[20] and the lowest prevalence was 50% in a Gujarat population in a study by Parekh *et al.*[21] by clearing technique. Several possible reasons may account for the differences. First, the ethnic population in this study was different from that in the other studies. Second, our sample size was larger than that of the other studies. These reasons may result in different frequencies of mandibular first premolars with various canal configurations. In this study, one canal orifice at the apex was found in 80.75% of the mandibular first premolar roots while 18.75% of the teeth had two apical canal orifices. Three canal orifices were found in 0.5% of the teeth. The findings of this study are close to the results of Yoshioka *et al.*[22]

However, these results are different to those reported in other studies. Peiris *et al.* [23] using clearing method reported the lowest frequency of two canal orifices in a Japanese population (1.1%). Lu *et al.*[5] reported the highest frequency of two canal orifices in a Chinese population (46%). The prevalence of C-shaped root canal morphology in mandibular first premolars in this study is 2.25%. C-shaped canals were located at the middle and apical thirds of the canals, and had an oval shape in their coronal thirds. Majority of the C-shaped canals in mandibular first premolars was associated with type V canals. A deep concavity or groove associated with a type V canal could help predict the presence of C-shaped canals. This finding is in agreement with Lu *et al.*[5] who noted that the location of C-shaped morphology in mandibular first premolars is quite different from that of second molars. The C-shaped morphology in mandibular second molars is mostly found coronally and within 3 mm below the cementoenamel junction. Lu *et al.*, in their study, found C-shaped canals in the mandibular first premolars at 3-mm and /or 6-mm level from the apex cross-sections. Coronally, it could be single oval or two canals. Therefore, they concluded that C-shaped canals would be difficult to detect from coronal approach in the first premolar. Using CBCT, Yu *et al.*[24] concluded that the prevalence of C-shaped canals in a western Chinese population was 1.1%. Sandhya *et al.*[25] reported the variation in 2% teeth in an Indian population. However, studies have reported a high incidence of C-shaped canals in Chinese populations ranging from 18 to 24%.[5,26]Using stereomicroscope and photography, Baisden *et al.*[27] reported the existence of C-shaped canals in 14% of mandibular first premolars, associated predominantly with type IV canal systems. Sikri *et al.*[28] indicated that approximately 10% of mandibular first premolars in their study exhibited C-shaped canal.

Root canal bifurcation tended to occur in the middle third (63.16%) or apical third (36.84%) in bicanal mandibular premolars. These findings were seen to be consistent with previous investigations by Liao *et al.*[29]
The introduction of CBCT has undoubtedly widened the sphere of imaging diagnostics. The intricate root canal anatomy of mandibular premolars may be difficult to comprehend in routine intraoral periapical radiographs in

clinical situations. The advantages of CBCT over periapical radiographs have been high resolution, elimination of chemical processing, rapid image acquisition and a number of image processing tools such as magnification.[30] CBCT is well suited for endodontic applications as a complement to conventional radiography since images can be rotated in any spatial plane without superimposition of the anatomic structures. When doubt exists regarding canal variations, or when a change of shape or direction in the middle or apical third of the canal is detected, periapical radiography associated with CBCT can be used to determine or verify the presence and location of canal bifurcation.[24]

## VII. Conclusions

**The following conclusions are drawn while interpreting the results of the present study:**

1. Variations in incidence of single canals versus two or more canals may occur because of ethnic origin or regional background.
2. Type I canal configuration was most common in the mandibular first premolars. (78.75%)
3. A single apical foramen may be found in mandibular first premolar teeth in 4 of 5 cases, but two or more foramina may occur nearly 20% of the time.
4. The mandibular first premolar was prone to bifurcation of canals that tended to occur in the middle or apical third and terminating in multiple apical foramina (in 19.25% of cases)
5. More research is warranted to arrive at definite conclusions regarding the influence of ethnicity, age and gender on the morphology of mandibular first premolars. The use of advanced imaging techniques such as cone-beam computed tomography and micro- computed tomography associated with evaluation of wider populations by using larger study samples will provide a better insight regarding morphology of mandibular first premolars and their inherent variations.

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